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SUSTAINABLE MANUFACTURING

A GUIDE FOR THE PLASTICS INDUSTRY

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British Plastics Federation

Peter Davis OBE, Director-General
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It gives us great pleasure to welcome readers to this extremely handy snapshot of UK expertise in the sustainable manufacture of plastics. The British Plastics Federation has always seen sustainability issues as its heartland and we know how hard won the current sustainability achievements in our industry have been.

We cannot rest on our laurels. Achievements themselves bring new situations, more challenges and yet even higher hurdles to surmount. But the next generation of challenges will be international in scale and will necessitate the sharing of knowledge which this book seeks to encourage. As we write two prominent issues are ideal candidates for this global approach: the challenge of minimising energy use in the face of climate change and the limitations of traditional energy sources; and the problem of avoiding plastics loss to the marine environment.

PETER DAVIS

PHILIP LAW

Planned as a 'first edition' it is the BPF's aim to retain the text as a live document which can be updated, expanded and refined on a regular basis. After all plastics is a fast moving field and I would be disappointed if this book wasn't seriously out of date within two years. Nevertheless allied to the innovative BPF website feature 'Plastipedia' (www.plastipedia.co.uk) - we hope that it will come to be seen as a source of authority on the subject.

Sustainability is a very wide subject and we have tried hard not to focus just on 'ecological sustainability' the minimisation of material usage, design, energy saving, recycling and so on. We must not underestimate the importance of training, safety, employee motivation and communication without which the technologies themselves, described in these pages, would be practically useless.

This book will be launched at a Sustainable Manufacturing Forum organized by the British Plastics Federation at the 'K' exhibition in Dusseldorf on November 1st 2010. We cannot think of a better location to rise to the Sustainable manufacturing challenge. The audience is huge and international. Many of the exhibitors are machinery manufacturers who in their varied technologies are addressing many of the themes outlined in this book, energy efficiency in particular. Let us use the unrivalled networking opportunities offered by 'K' 2010 to debate our future needs and responsibilities as manufacturers and raise the hurdle even higher ourselves without pressure from wider society. Manufacturing in plastics will then truly come of age.

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FOREWORD

UK Trade and Investment

Paul Calver, UK Trade and Investment

UK Trade & Investment (UKTI), a government department that helps UK-based companies succeed in the global economy and assists overseas companies in bringing their high quality investment to the UK, is pleased to be involved with the British Plastics Federation in delivering this progressive sustainable manufacturing initiative.

Advanced engineering enc ompasses all that is great about UK manufacturing. Whether it is in aerospace, automotive, plastics processing, or any other field of engineering, the UK possesses world-class capability in advanced engineering and sustainable manufacturing. UK-based companies are prominent in a wide range of areas including design engineering, advanced materials and manufacturing and are renowned for their innovation and commitment to research and development. The UK has a broad, extensive and expert engineering and manufacturing supply chain that forms the bedrock of UK capability. The UK advanced engineering sector remains highly competitive through product, processes and service innovation.

Globally manufacturing is facing a number of challenges:

Energy costs continue to rise and, in many parts of the world, its availability cannot be assured. The adverse impact on the environment of using fossil fuels to generate an ever increasing demand for energy, is high on the agenda of most governments. In response to this the manufacturing sector is under pressure from governments and non government environmental organisations to reduce power consumption through the use of more energy efficient plant and equipment.

Elimination of waste, be it materials, or other scarce resources, has been a target of UK advanced engineering companies in order to increase enterprise, effectiveness, cost reduction and time to market. However, the effective use of scarce resources and the urgent need to protect our environment has become of paramount importance.

The scarcity of clean water is a real issue and the emissions and waste from manufacturing processes have a real impact on the quality of life for many.

Environmental legislation and regulation has and is being introduced to address these issues, the implementation of which has a significant economic impact on manufacturing processes.

UK companies have recognised these challenges and have implemented strategies and plans to comply with the new legislation with minimum economic impact. Enterprises based in the UK have taken action to improve the operational and environmental performance of their manufacturing operations. They have developed products, services and materials that are more energy efficient, reduce water usage, support recycling and reduce the effect of the complete manufacturing cycle on the environment.

UKTI stands ready to put international manufacturers in contact with UK companies that could work with them to achieve the sustainable manufacturing goal which we are all working towards.

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FOREWORD

Materials KTN

Dr Robert Quarshie, Materials KTN

Knowledge Transfer Networks (KTNs) in the UK provide unique networking opportunities for businesses to meet and network with individuals and organisations, in the UK and internationally. Networking is a well-tested method of finding out what is happening in an organisation, sector, country or even the world. Knowledge Transfer Networks provide businesses, Research and Technology Organisations and academics with the opportunity to network and share mutually beneficial information relating to advances in science and technology.

At the Materials KTN we believe that the individual business people, scientists, engineers, technologists and designers we interact with are the greatest asset in our drive to accelerate industrial innovation in the UK. We therefore ensure that networking activities are more purposeful than purely social groupings. In this era of global competition, organisations must look for ways of generating extra value from their assets. People and information are two critical resources increasingly being recognised as valuable. Knowledge networking is an effective way of combining individuals' knowledge and skills in the pursuit of business and societal objectives. Our networking activities are rich and dynamic during which scientific and technological breakthroughs are shared, further developed and evolved. Many businesses may not make the most of their potential for innovation and often this can be attributed to a lack of awareness and access to the latest technological knowledge and breakthroughs.

Our unique networking activities have been significant in making the necessary connections between various players in the UK economy, helping industry and academia to access scientific and technological knowledge and information central to innovation and market growth. Through our networking activities, we have been successful in:

- **Building a culture of openness of communications** between UK organisations, creating more willingness to share information and knowledge freely.
- **Raising awareness** of the latest technological developments, including emerging regulation of relevance
- **Developing groups of individuals with shared visions and goals**, for example, through our brokering role in bringing people together to develop technology roadmaps to help guide their individual priorities and implementation plans and to seek funding support to collaborate on research or exploit technology.

Over the years, we have created a dynamic two-way channel whereby government is also able to effectively communicate its requirement, such as sustainable manufacturing, innovative public procurement and responsible development, in a timely and well informed manner. Our goal is to drive the flow of people, knowledge and experience between business and the science-base, between businesses and across sectors to accelerate industrial innovations in key areas such as sustainable manufacturing.

We are proud to be partners to the British Plastics Federation in the production of this timely book. There are case studies shown in the book which brings to life some of the KTN's achievements in support of the polymer industry.

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CHAPTER 1

Introduction To Sustainability

Sustainable manufacturing and the UK

By Philip Law, British Plastics Federation

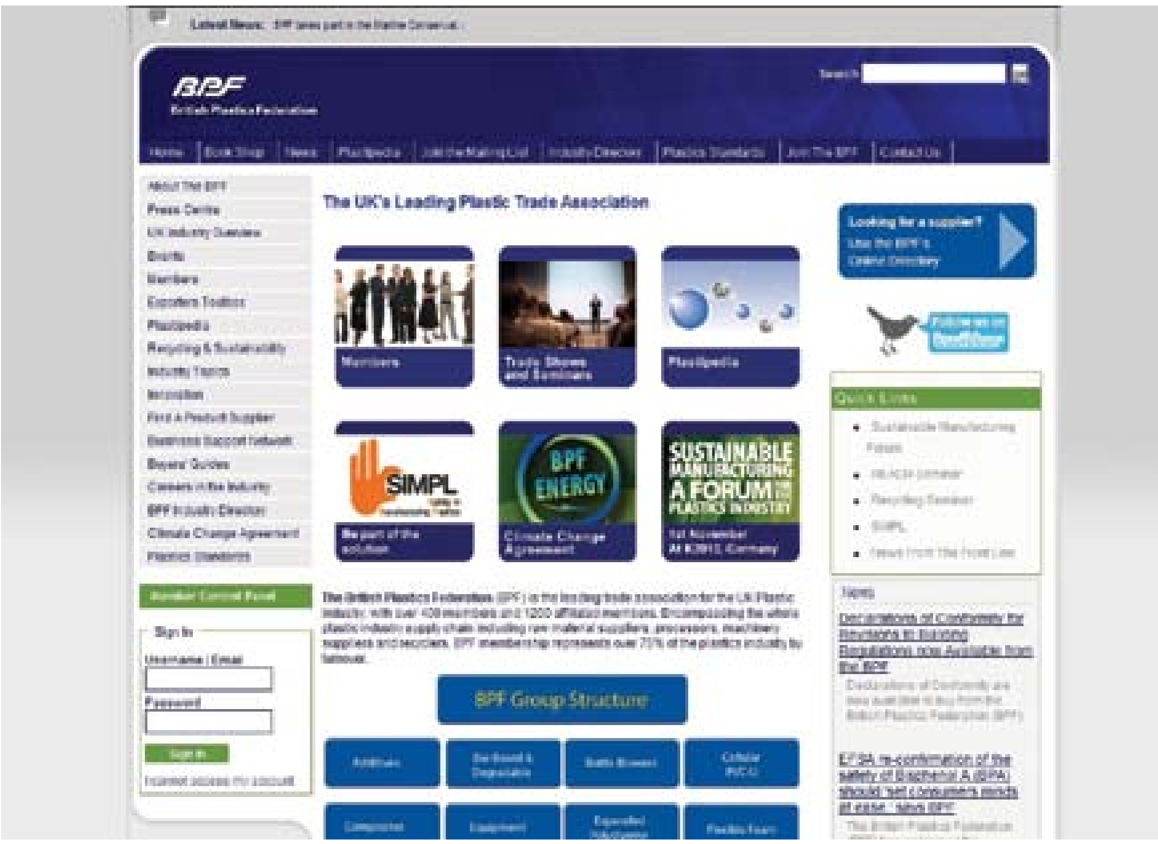
The key point about Sustainability is that it is a journey and not a destination. As a concept it is closely akin to continuous improvement, about changing business for the better and in this the UK has an unparalleled record. Several factors have provided the stimulus :

- Exposure of UK component suppliers to the demands of Japanese Original Equipment Manufacturers in the 1980s and 90s
- Successive cost escalations for energy, raw materials and insurance over the 2000s
- Governmental initiatives such as the Climate Change Levy which provided both a carrot and a stick for manufacturers to attend to energy efficiency.
- The growth of Corporate Social Responsibility as a concept particularly amongst major end users and retailers. Their target-setting on materials usage, wastage, recycling, energy efficiency and other ethical requirements has been translated into product specifications which has to be responded to by designers and manufacturers.
- The 'greening' of Public Sector purchasing particularly in the wake of the Rio Earth Summit of 1992 and the local adaptation of Agenda 21 , an environmental programme for the 21st Century.

UK manufacturers are well ahead on the road to Sustainability and as the industry's trade association, the British Plastics Federation has taken a lead in showing the way. The first port of call for anyone wishing to access the UK's considerable expertise in this field is to consult the BPF website www.bpf.co.uk and in particular its Industry Directory of product and service providers. At the back of this book you will find contact details for many leading suppliers who are members of the British Plastics Federation.

In the first instance the UK is a natural location for the manufacture of plastics. It is just one expression of the country's industrial culture. Resources of coal, then the discovery of oil and natural gas offshore provided the basic feedstocks for manufacturing the raw material. The varied geology of the UK, such as deposits of Calcium Carbonate also provided many additive sources. Additionally regional skills in working with metals, wool and cotton were able to be adapted to plastics and it is no surprise that the key areas for the manufacture of plastics products in the UK today are those very areas where traditional manufactures were strong.

No country understands how sustainability applies to an industrial material like the UK. There is a strong tradition



HOMEPAGE OF THE UK PLASTICS INDUSTRY WWW.BPF.CO.UK of positive dialogue with balanced environmental organisations such as Forum for the Future, the Natural Step and the National Non Food Crops Centre (www.nnfcc.co.uk).

Just to take one example, the UK PVC industry was a pioneer in positively responding to the pressure applied by the environmental movement and the retail sector. Today the UK is amongst the leaders in Europe in the recycling of long-life PVC building products under the industry's pan-European recycling scheme 'Recovinyl' (www.recovinyl.com).

In the evolution of a product, design is the first stage and 'design for sustainability' is emerging as a key theme in the training of the next generation of UK designers. Centres well worth consulting are: The Design Council which has a considerable body of online resources accessible through www.designcouncil.org.uk, Envirowise a UK government funded agency which focuses on resource efficiency has valuable case studies and an Eco-design Indicator featured on its website (http://bit.ly/eco-design).

In terms of actual manufacturing there is enormous support offered by first rate academic institutions. Covering the subject as a whole is Cambridge University's Sustainable Manufacturing Group.: www.ifm.eng.cam.ac.uk/sustainability.

More specifically on the contribution of plastics engineering University expertise in plastics raw materials is exemplified by The University of Loughborough , London Metropolitan University, the Universities of Leeds, Durham and Sheffield and Nanoforce based at Queen Mary College, London University .

For plastics processing technology The Universities of Bradford and Belfast are key. All these institutions are members of the British Plastics Federation's Business Support Network and can be accessed through www.plasticssupport.net. Furthermore they are all listed with contact details at the back of this book.

Additionally much helpful information on materials can be located on the website of the government funded Materials Knowledge Transfer Network (www.materialsktn.net) who collaborated closely with the BPF in compiling this guide.

There is a developing interest in bio-based and degradable plastics in the UK although the actual usage remains small. The centre of expertise in this is the British Plastics Federation's Group of leading manufacturers in the field which is active in setting standards for both products and commercial behaviour in this poorly understood field (http://bit.ly/biogroup). Chapter 7 of this book also treats these materials in some detail.

Plastics Recycling is a great recent success story in the UK. Now over 25% of plastics packaging is being recycled. One third of all EPS packaging manufactured in the UK is now recycled, well over 500 tonnes. The recycling of milk bottles has also been an outstanding development with over 72% of the HDPE containers recycled in 2009. A driving force behind this is the British Plastics Federations Recycling Council (http://bit.ly/BPFRC).

THE WORLD'S FIRST PLASTICS PROFESSIONAL NETWORK WWW.PLASTBOOK.COM

A good source of information is the government's waste Resources Action Plan (WRAP) which can be reached through www.wrap.org.uk. The UK plastics industry is engaging with its stakeholders to identify and overcome the barriers to greater recycling in a programme called the Plastics 2020 Challenge which aims to ultimately see all used plastics diverted from landfill. You can participate in this debate on www.plastics2020challenge.com.

The British Plastics Federation have launched a professional network which brings together over 1000 UK plastics industry networks many of whom have expertise in sustainable manufacturing. You can join this and share your own expertise by logging on to www.plastbook.com

Remember that sustainability is a continuing journey. New issues will continually appear, new solutions will have to be found and new bodies of knowledge created. This is a fast moving field where no-one can afford to stand still.

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What is Sustainable Manufacturing?

By Dr David C. Morgan, University of Cambridge

Sustainable Development and Manufacturing

The industrial system - the collected efforts of manufacturers, businesses and associated infrastructures - has been instrumental at raising the standard of living for many, helping free them from the daily struggle for food and shelter.

This process is ongoing and helping develop economies across the world and changing the way of life of millions of people. Although many positive benefits have been derived from industrialisation there have also been unintended consequences.

The term sustainable development was coined in the 1987 Brundtland report. The report was one of the first documents to collect and articulate the concerns of thinkers from groups involved in environmental and developmental issues as well as reflecting on the benefits of industry has to offer (see Box A).

Box A Brundtland Definition – World Commission on Sustainability

"Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future. Far from requiring the cessation of economic growth, it recognises that the problems of poverty and underdevelopment cannot be solved unless we have a new era of growth in which developing countries play a large role and reap large benefits."

Since then our understanding of the effects of human activity on the planet has improved and extended. Signs of ecological stress are being documented in a number of different areas, with some suggesting that we may be exceeding safe operating conditions in at least three of key planetary environmental systems.

There are those that suggest our social and economic systems are similarly in state of stress, with significant disparity in terms of education, health and poverty across the global population [Millennium Development Goals].

Manufacturing (and industry more generally) is seen as a significant part of the problem. It is the emissions and outputs of factories, and the impacts of products and services produced by industry that contribute to a significant proportion of the environmental stressors observed.

Yet demand for manufactured goods and the services they provide continues unabated, and the clamour for industry as a tool for economic development shows little sign of declining. It therefore follows that whilst manufacturing may be part of the problem – it is necessarily part of the solution.

Defining Sustainable Manufacturing

Given the definition of sustainable development sustainable manufacturing may be considered as manufacturing activity that seeks to meet the needs and aspirations of the present, without compromising the ability to meet those of the future.

Whilst most can agree on the broad principles of such a definition – intergenerational equity and the implicit balance of economic, social and environmental needs of the population, agreeing on actions and implementation is more difficult.

Some authors have sought to provide more specific definitions of sustainable manufacturing, examples are shown below…

"Developing technologies to transform materials without emission of greenhouse gasses, use of non-renewable or toxic materials or generation of waste."

Julian Alwood, University of Cambridge

"The creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities, and consumers and are economically sound."

US Department Of Commerce

"A business practice of the industrial sector, which expands all the company's processes and decisions into the social and natural environments it operates in and affects, with the explicit objective of reducing or eliminating any negative impact, while pursuing the desired level of technological and economic performance."

Silvia Leahu-Aluas, MSME, MBA, Sustainable Manufacturing Consulting

"Sustainable manufacturing can be considered a part of sustainable production related to the transformation of input materials and energy into finished goods for economic trade."

Centre for Integrated Manufacturing Studies, Rochester Institute of Technology

Formal definitions for "sustainable manufacturing" continue to evolve. Many organizations that are involved with sustainable manufacturing and the broader topic of sustainable production are building on the concepts of the Bruntland Commission, Herman Daly, and John Elkington.

For those who consider sustainable manufacturing specifically, there is broad agreement on certain themes e.g. the need to address harmful emissions, our reliance on non-renewable resources and linear flows of materials.

There are however, also differences between the definitions. Are "social" issues the remit of engineers?

Are negative impacts to be minimised or eliminated? There are practical issues also – what to measure, how to measure it, what levels of emissions are harmful, which takes precedence; local issues or global impacts?

Some commentators argue that the concept of continuous and indefinite economic growth on which the wealth of nations is built is flawed given the finite resources to hand. Furthermore there are also those, who suggest that movements towards sustainable manufacturing principles cannot lead to a sustainable future for our planet unless it is accompanied by wider systematic change in our political, social and economic systems (e.g. John Ehrenfeld, Tim Jackson).

Given that field of sustainability still open to widely different interpretations it can be difficult for practitioners to identify their role in developing sustainable manufacturing. This problem is compounded when economic pressures come o bear on companies, which makes taking positive action more difficult.

Changing

Significantly better performance of the companies and factories is possible in many cases without relying on step changes in technology. The aggressive reduction of the impact of specific activities is an essential activity and in an increasingly resource constrained world can yield financial and strategic benefits.

Evidence

Whilst these kinds of activities are important, the impact of the whole system must also be considered. Efficiently manufacturing products that are inefficient in use or waste resources at the end of life consequences is not enough. The full life cycle of effects must be considered if the impact.

This life cycle concept presents a challenge to individual firms trying to move towards sustainability. At a facility level – levers are available that can allow improvements to be made, however even within a firm there are constraints which are dictated by other actors within the system.

Manufacturing is often defined as the act of manipulating physical stuff and transforming it into goods which can then be used, sold or leased. In the context of sustainability a broader definition may be useful.

Considering only production, a limited number of levers are available to address the sustainability of the activity and the artefact. When you consider the wider system a much more complete range of levers become available, even if they require more time and effort to pull.

Constraints may also be imposed by other companies within the supply chain, or by the perceived needs of the end customer. In these cases, effecting change is more difficult because action must be taken across functional and company boundaries, with all the additional difficulties that this implies.

Beyond the confines of the industrial system, there are the considerations of the social political context in which manufacturing operates and ultimately serves. There are factors; economic, political, social and environmental which constrain a firms ability to move towards sustainability.

The landscape is complex and constantly evolving with some consensus at the top level vision of what sustainable development is but much less consensus regarding how to move towards sustainability, and little consensus on what models can effectively deliver it.

With this backdrop taking steps towards sustainability can seem daunting especially in the context of day to day competition and survival. Companies can however can take the initiative by identifying the direct impacts they have on the world around them and applying their existing problem solving skills to addressing them.

They can also work to understand the linkages between other members of their supply network and how they might be used in the future to reduce the total impact of their activity.

- Understand the impact of your operations and products
- Identify the levers you have available to improve them
- Work aggressively to reduce your impact
- Identify the linkages which affect your ability to influence other areas
- Work to support those in your supply chain to help address

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UK advances in sustainable plastics processing

By Dr Matthew Thornton, Materials KTN

In 2007 Lord Sainsbury stated, in his review of UK Government Science and Innovation Policies that:

"In the future it will no longer be necessary to start every report of this kind with the dreary statement that, while the UK has an excellent record of research, we have a poor record of turning discoveries into new products and services.

While we believe that our record of innovation is better than is commonly supposed, we have not yet produced the best possible conditions to stimulate innovation in industry." This statement has challenged Knowledge Transfer Networks to work more effectively with companies and universities to accelerate the rate of exploitation of research. The result is that innovation in the UK is starting to yield increasing commercial benefit, within a climate that now has the infrastructure in place to better support industrial innovation and it is this innovative climate that is key to the UK plastics industry's continued success and growth.

There are a number of ways in which the UK plastics industry can remain innovative; one of most important of these is through becoming more sustainable as an industry in terms of energy consumption, productivity, waste generation and recycling and by using less material in production.

The Materials KTN have worked with a number of companies that are exemplars of best practice in doing just that and here we present five case studies showcasing UK advancements in sustainable plastics processing.

Case Study : Vales Brothers, Walsall, UK

Vale Brothers are a Small to Medium Enterprise (SME) that produces a range of equestrian products, mainly brushes and grooming products. In order to drive their product range forward they saw a need to use plastics to refresh their products through the use of texture and colour.

Through utilising design expertise and rapid prototyping technology Vale Brothers decided that they needed to expand production capability and, with support from the Materials KTN, the company took the research and feasibility studies into full scale production and increased it production output by 300%.

Case Study: Axion Polymers, Manchester, UK

Axion Polymers recycle waste electrical equipment into high grade polymer compounds. However, many of the plastic components of electrical goods are made from ABS which can foam causing voiding to appear in the reprocessed material. Through contact with the Materials KTN the company worked on some proof of concept trials in collaboration with Swansea University. This proof of concept work offered solutions to overcome voids in the recycled products and these solutions have been demonstrated on full-scale process equipment, giving Axion Polymers the capability to recycle more waste ABS.

Case Study: Cinpres Gas Injection, Middlewich, UK

Cinpres Gas Injection set out to solve the problem of solving the problem of reducing energy use for injection moulding by conducting a series of trials in collaboration with the Interdisciplinary Research Centre at the University of Bradford.

It was expected that any potential energy saving would be related to the reduced clamp tonnage required for gas assisted injection moulding (GAIM) along with a reduction in, or elimination of, holding time and pressure.

The trials showed that the internal gas moulded component demonstrated savings of 50% in energy consumption, 47% in cycle time and could yield a part weight reduction of 29%, thus saving time energy and material.

LAWNMOWER MADE OF ABS MATERIAL

Case Study: Valueform Ltd, London, UK

Valueform Ltd contacted the Materials KTN as they were interested in solving the problem of preventing food from rotting. Currently, most active packaging entraps and releases a natural antimicrobial. However, there are concerns over the migration of existing antibacterial compounds into food products, and a legal framework now exists as a result of EU regulation.

Valueform Ltd sought to control microbial food spoilage by coating a polymer with static antibacterial properties that would kill pathogenic bacteria by contact. They hoped to do this by modifying chitosan (produced from waste crustacean shells or fungi) to improve its bacterial killing efficacy. A successful solution would both reduce food waste and the risk to human health.

The research was carried out in collaboration with The BioComposites Centre at the University of Bangor and the Food Science Department at the University of Reading. The preliminary research findings proposed new rules to characterise biopolymers as a raw material for antibacterial coatings, and modified biopolymers were successfully synthesised, with a significant improvement in performance. The research also showed that, although more active against spoilage yeasts, chitosan also inhibits some Gram-negative bacteria.

REPRESENTATION OF A FOOD BACTERIUM

Case Study: Re-worked, London, UK

Re-worked is an industrial design company which, over the past few years, have been developing systems and added value applications for recycled coffee waste. The Materials KTN and the Industrial Affiliate Scheme of the Institute of Materials, Minerals and Mining, helped Re-worked to bring together university based technical support and a private company with expertise in recycled plastics.

Coffee is the second most traded commodity in the world after oil and every month the UK imports 14,000 tons of it. The waste produced from this industry is considerable and often in a pure form, meaning that it can be separated easily for recycling. Re-worked have now developed a way in which the waste coffee grounds can be mixed with post consumer recycled plastic waste to produce the product Çurface (pronounced "surface"), an innovative product made from a combination of recycled coffee grounds and recycled plastic.

The Çurface material can be made into products like tables and chairs; made with waste coffee this innovative material takes the cappuccino experience to a whole new level thanks to a unique recycled plastic sheet product developed by Axion Polymers for Re-worked.

Re-worked commercially launched the 'tactile' material – described as a cross between dark leather and wood – at Ecobuild 2010, the UK's largest green design and building exhibition in London and its debut attracted considerable interest.

Re-worked Director, Adam Fairweather, hopes his idea will catch on, particularly with catering establishments for which it has particular relevance.

Steve Bell, Senior Product Development Supervisor at Axion Polymers, said: "this success opens up possibilities for other 'smelly' applications in recycled plastics. We have the capability to do clever things with recycled materials and we're not aware of anyone else using coffee in this way" he adds: "It certainly gives the polymer a different appeal…. and we were smelling coffee in the factory for two days afterwards".

Summary

All of the five case studies presented here show, in a variety of different ways, examples in which innovative plastics processing can lead to a more sustainable future. It is also important to note that all of the case studies, although very different in application and scope, have something very important in common – they all rely on successful collaboration to succeed and it is more often than not that through successful collaboration and knowledge sharing innovation can thrive.

Through UK government initiatives, like the Materials Knowledge Transfer Network, the UK is now better placed than ever to help UK based companies innovate, grow and succeed in what has become a knowledge based economy.

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There is more to sustainable manufacturing than meets the eye

By Roy Coldwell, PICME

Mention sustainable manufacturing and the chances are that environmental issues, carbon footprints and sourcing of raw materials spring to mind. However there is more to sustainability than this, particularly when we consider it from a waste and efficiency perspective. Sustainability must primarily be financial sustainability. To achieve this every area of the business must be focused on improvement. Those companies that continually review their processes, examine their waste, and take action to eliminate such waste in a sustainable way will be in the best position to survive the continuous threats to the economy. Waste takes many forms and can be reduced in some capacity in all areas. For example you should consider such aspects as raw materials, storage space, duplication of tasks, transportation and overproduction. Is there another way that a task could be performed to save time and effort, would it reduce transportation time if the layout of a production line were changed? Are you buying raw materials at a competitive price? What percentage of your product is 'right first time' – are you having to rework due to defects?

Another form of waste concerns inventory - over stocking hides problems and inefficiency, whilst too little inventory risks losing sales. The most efficient and effective way is to adopt a 'just-in-time' approach. This also avoids batching, which can in itself result in delays and affect continuous flow throughout the manufacturing process.

Lean Principles

Lean principles when applied correctly across the entire business can greatly improve efficiency and sustainability. However, let us consider for a moment physical waste products and specifically waste disposal costs, which are continually rising.

One of the best ways to impart a waste efficient mentality throughout the company is through training. Waste reduction awareness is often targeted at management level because they are the ones looking at the accounts and performance, but the employees nearer the factory floor or in an office based environment might not think in the same way. They do not see all the costs, so business improvement thinking and the concept of sustainability must be embedded in the whole organisation. Indeed, to be sustainable, companies must encourage the total involvement of managers and employees in the adoption of lean processes, or progress will be slow and inefficient. Implementing lean practices is not about redundancy, but about the quest for engaging everyone in the concept of continuous improvement.

Energy Efficient

Of course, being energy efficient is a key factor in operating a business which is sustainable, particularly in the current climate. Again, to achieve maximum energy efficiency, a holistic approach should be taken with representatives from all departments involved. Different departments all impact on a business' energy costs. Purchasing will determine the price paid for energy, production for how it is used, engineering for how it is distributed and used, finance to assign financial resources to achieve energy returns from investments and so on.

Once a suitable team has been gathered together, the next step is to start to define and understand where and how your site consumes energy. This is best achieved by mapping out your energy distribution systems and what is connected to them. During this process it is important to remember that energy distribution systems themselves consume energy.

Mapping Stage

From the mapping stage you will have identified points of energy consumption, but now you need to be able to quantify the amounts. How and why is the energy consumed? What is the pattern of energy usage at these points? This data should be delivered by an on-site metering system, which will ideally measure at ten or five

example, are people present in the factory?), output and any others that might occur. Your mapping exercise will highlight the relevant variables to you. With this modelling and with the mapping, you and your team will now have a 'current state' map of your energy consumption. Along the way you will have learned a lot more about how and why energy is consumed at your site, and you will have the knowledge to begin changing it so that the energy consumption and/or cost of energy per unit of product is reduced. You can target areas of waste energy use to reduce consumption and also generate a future state map of how energy should be used on site.

minute increments.

Add in other relevant data. What are the shift patterns you use? When are production lines or units up-and-running and when are they normally idle? What is the production plan and sales forecast like? All these factors and more are relevant to holistic energy improvement. Remember, it is not how much energy you use, but what you make of it.

In a manufacturing or processing environment, companies can make substantial savings through the monitoring of overall equipment effectiveness (OEE). It is easy to consider the deficiencies of OEE in terms of product loss, and therefore lost sales, but the efficiency of the equipment should also be measured in terms of energy usage – notably availability, quality, performance and yield. You should be looking at how often the equipment is switched on and off (broken equipment still uses energy); whether it is running to its maximum performance at all times – a lower-performing machine still uses the same amount of energy as high performers; and the quality of the products it creates. Partly finished products that are thrown away are a waste of energy. Finally you should be examining whether the process converting the raw material to the finished product is as it should be.

Data Analysis

Once you have gathered your data, the next step is to analyse it. Energy is often mistakenly considered as an 'overhead' by organisations. If we take the time to look at patterns in energy consumption, it soon becomes clear that this is rarely, if ever, the case.

Start to look for relationships between consumption and some other variable. For example, if your factory is heated, try relating energy consumption (electricity, gas or steam) to degree days/week or even degree days/day. Degree days are a way of measuring heating requirement against the outside weather.

Other variables to look at include occupation (for

Energy Cost

It is also worth mentioning that in terms of cost, energy bought during the day is different from energy bought at night; and energy bought at short notice is different from energy bought ahead of time. This is a very complex area, but what I am saying is that the purchasing strategy used for energy (electricity and gas supplies) can have a significant impact on energy cost. Add into the mix other variables such as when particular operations are carried out and energy could preferentially be used when it is cheaper. This could result in an energy cost saving of 10-20%, depending on your contract.

In the current climate every company should be looking inside itself to see what can be done to achieve more with less. Several small improvements can have a large impact on a company's sustainability throughout the coming years. The involvement of multidisciplinary teams, at all levels in the organisation will help to both create the vision of a sustainable future and to create the plan to deliver it.

PICME is a member of the BPF's Business Support Network and has many years of experience helping companies in the polymer and chemical industries improve their performance in a way that it is not only cost effective but is truly sustainable.

If you would like PICME to help your company make lasting improvements to the manufacturing or energy efficiency of your business, then please call Chris Bayliss on 0771 500 8722 or 01926 856634 or e-mail chris.bayliss@picme.org

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The importance of skills for the sustainability of business

By Judith Holcroft, Cogent SSC Ltd

Embedding sustainability into a business is perhaps more challenging than it first may appear – as anyone familiar with the concept will know, it certainly goes far beyond being "green". And it can only be delivered through the skills of employees; without their vital contribution, even those organisations committed to business sustainability, will never get much past a written policy. An organisation may even have any number of initiatives underway – but have failed to look at the sustainability challenge in a more holistic manner.

Before looking at the skills required, it's useful to go back to first principles and attempt to define what we mean by sustainability and then specifically how this can be applied in the context of business sustainability.

The term sustainable development first came to the fore in 1987 when the World Commission on Environment and Development (the Brundtland Commission) produced 'Our Common Future'. Its definition of sustainable development - "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" – is commonly referred to as the classic expression of the term.

Differences in interpretation of sustainable development can arise over differing viewpoints around how each of the three pillars of sustainability – environment, society, and economy – is balanced. The arguments tend to stem from differing views on what is acceptable within business and wider society.

However, for most businesses, operating in a tough economic environment, the need to ensure a healthy bottom line must be the priority – so the balance must make sense commercially; it goes without saying that minimum compliance with regulatory expectations provides the basic license to operate.

So, business sustainability brings with it the additional challenge of increasing profitability and productivity. That's not to say there aren't an array of ethical reasons for reducing the negative impacts of doing business – this is a given. However, the good news is that it's now commonly accepted that pursuing sustainability also makes good business sense. Successful businesses have recognised that by implementing sustainable practices, they can:

- reduce costs
- manage their resources such as water and energy more efficiently
- boost their reputation through environmental good practice and innovation
- be part of supply-chains and markets that demand high standards of sustainability

Plastic Fantastic

The polymer industry has been getting to grips with the sustainability agenda for many years. Innovation abounds – from plastic insulation; lighter weight cars and airplane parts (and thus better fuel utilisation); plastic solar panels and wind turbine blades as well as innovative food packaging …new product development grows more impressive year on year.

The BPF is clear about the contribution of plastics to sustainability: *plastics make an immense contribution to environmental sustainability through their energy saving potential and intrinsic recyclability and energy recovery options.*

The UK's recycled plastics market is buoyant despite tough conditions. A recent WRAP (Waste & Resources Action Programme) report says that demand for food-grade recovered polymers has increased rapidly in the UK, and in some cases, demand is now outstripping supply.

Plastics Europe, the trade association, notes that entire regions in Europe are using renewable energy to meet their energy requirements with innovative solutions made from state of the art plastics.

Embedding sustainability

While the many high profile examples of the industry's sustainability profile, provide an excellent narrative to reflect the industry's commitment, this approach needs to spread its reach to every part of the plastics industry. Not least because of the expectations and demands placed on organisations by their customers and suppliers as well as the commercial advantage it brings. Increasingly, in order to respond to this changing world, organisations need to enhance the skills of employees to increase capability in this critical area.

There are five key components of a skills strategy for sustainable business:

Strategy and reporting: to embed sustainable development into the organisation, it's helpful to think about and document some organisation-wide sustainability principles and measures. This could include a commitment to more efficient resource use including energy efficiency and reducing CO_2 emissions, water consumption, waste, unnecessary travel and so on. From this strategy it will be possible to set out some Key Performance Indicators (KPIs). Even if the company is not ready to report externally, it can start setting targets and sharing the results internally. There are many sources of advice around this, for example, the Department of Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (DEFRA) whose mission is to support a strong and sustainable green economy.

Changing the culture: organisations that have the most success in embedding sustainability tend to communicate the importance of sustainability both explicitly and through the management ethos. Then reinforce this at every opportunity. Principles and progress can be promoted through round-table discussions, employee magazines and team briefings. If it's a Board level issue, it will get taken more seriously – so leadership is critical to making it happen. Once internal communication is underway, the organisation can go public with its commitment, through the website, marketing and so on.

Developing practical skills: it goes without saying that an organisation's most important resource is its employees, whose skills are critical in delivering sustainability. Cogent, the skills council for the polymers industry, in response to the drive towards a low carbon and resource-efficient economy, has developed a suite of small qualifications covering topics such as energy efficiency and waste efficiency. These qualifications are the first nationally accredited qualifications of their type, and are intended to support training for people with responsibility for identifying and implementing efficiency measures for energy, water, waste and transport

Closely linked to this, is the need to introduce business improvement techniques. The National Skills Academy's Productivity and Competitiveness (PAC) Analysis programme is the first of its kind in the Process Industries. It provides a standardised approach for assessing an organisations' improvement needs, as well as access to high quality Business Improvement Technique (BIT) training for manufacturing employers in England. Crucially, reporting and measurement are built in to the process.

All these qualifications are delivered through the National Skills Academy Process Industries Accredited Provider network.

Innovation: this is linked to the development and introduction of higher level skills to develop, for example, technologies which produce materials with lower emissions or which reduce the use of non-renewable or toxic materials. It is here that Higher Education has a critical role to play. The pace of technological change is driving a massive need for workforce development. The Skills Academy is supporting Cogent's development of targeted Technical Foundation Degrees, Higher Apprentices and Technical Masters. Industry has a critical role in developing work-placements and inputting to the curriculum. Work experience can bring fresh ideas into the workplace, as well as nurturing new talent.

Partnerships: working with others through partnerships is a crucial part of sustainable development. It is only through examining supply chains that a product's 'life cycle' can be assessed. This includes raw material production, manufacture, distribution, use, repair and disposal including all the transportation necessary at every stage of the product's 'life'. The sum of all these steps equals the life cycle of the product. There are many tools which ask questions underpinning each life cycle stage, to help product teams think innovatively about sustainability challenges.

It's clear that plastics and associated products have a major role in improving the quality of all our lives through scientific break-throughs and innovation. And of course they also play a vital role, against a backdrop of a world that is growing in population, in supporting ever-increasing demands for basic clean water, for long lasting food, sanitation and energy sources.

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Intelligent Energy Procurement

By Paul Miller, EnergyQuote JHA

It's July 7th 2008 and the world is waking up to a day when Brent oil will hit $147bbl. The US Government have recently introduced sweeping legislation to bail out mortgage facilitators Fannie Mae and Freddie Mac and looking back some may say this peak in oil was the beginning of the end; Lehman Brothers collapse, global recession and near economic catastrophe.

It was an interesting time to be a buyer of power and gas!

Energy Prices

As recently as 2008 there was still a clear index between gas and oil prices; many analysts, traders and buyers monitored the movement in oil as an indicator for gas prices movements. Also at time, Gas fired generation of UK power was around 36% of the total power provision, so if the oil price increased, gas followed suit and power prices were never far behind.

Granted, even if armed with supply and demand fundamentals and all the myriad of technical indicators people use to monitor power and gas movements, history tells us that it's not that simple. However in 2008 the base load power priced breached £90Mwh leaving many energy buyers the unenviable task of informing their businesses that utility contracts were about to double in price. In normal circumstances what would you do? In 2008, few buyers considered the possibility that their budget for utilities could be breached so quickly and now they faced a decision to either lock out the remainder immediately in case things got even worse, or track the market and hope for some price and market correction.

Within the plastics industry, along with many other manufacturing organisations, the bulk of your energy consumption is linked to the cost of manufacturing process and to a degree, the final delivered cost of your product. Any major deviation from a forecast budget position suddenly becomes an issue of profitability and perhaps more critically, impacts the business's ability to remain competitive should others in the industry have secured energy at more favourable rates.

The majority of energy buyers at this point were simply not fully equipped to make an informed purchasing decision and those that were able, either had to report the exposure to the business or ask for authority to buy at record price levels.

The 2008 scenario was just the highlight of what has been a period of major volatility since 2004. The decision making process, the tools and techniques at a buyers disposal and the support available has never been under such scrutiny as it is today.

The key for any business is to understand and manage both the price and volume risk. Energy markets are inherently volatile and like all major business decisions analysing the risk and formulating a strategy is recognised as 'best practice'. A business would not normally invest in a new processing plant or develop a new product without first isolating, considering and understanding any and all identified risk – similarly when you spend hundreds of thousands or even millions on energy why should energy purchasing not follow the same process?

As a buyer when you make a decision to buy all or some of your commodity exposure what drives

Energy Strategy

that decision making process? Is it solely price and the business's budget position? Do you consider operational, market, compliance, credit or other commodity risks? Are you left to justify your decision making process to the board before, during or after the decision has been made? Wouldn't the process be easier, more efficient and commercially viable if the decisions and the price levels to buy are pre-approved by the business?

EnergyQuote JHA has been providing risk based policy and strategy services to global business for over 35 years. These organisations can spend as little as £500k a year to over £500million and include some of the largest brands in the world. The concept is simple; as a business you are unique, the risks you face are unique.

By first identifying the risks and goals associated with commodity buying within your business you can create a formal policy on procurement. This policy sets the framework for all future decisions and from the understanding realised by this policy creation, EQJHA can help identify a purchasing strategy which manages and mitigates the risks and helps achieve your goals.

This process may engage all levels of the business including the energy manager, the buyer, treasury and the board. Only by engaging with key stakeholders in the business do you identify a corporate view on risk appetite, and once this view is quantified the business can put in place the policy and strategy which enables understanding, accountability and defensibility in all future commodity procurement decisions.

Only once a business has this in place, will it be confident that its long term purchasing and risk model is robust enough to navigate through the challenges that awaits the next time oil heads towards $147bbl.

Understanding supplier credit

Credit over the last 24 months has become a fundamental factor for suppliers when pricing and providing supply contracts to any organisation. It is now one of the main factors for suppliers failing to provide prices or to demand strict payment terms. Often a business deems credit as its 'credit worthiness' and considers that because the companies credit score is good they can get a competitively priced supply contract – this is sadly not the case

- **Credit Score/Rating** This helps determine your business's overall credit score and will be recorded against the contracting party. The credit score for the contracting party will be used, not a parent or subsidiary.

  A credit score/rating can be provided / approved several days before a tender event.
- **Credit Insurance** This can determine whether a supplier is prepared to provide insurance on the value of the supply contract you require. More often than not this has nothing to do with your 'Credit Score' and can be left completely at the discretion of the supplier or the insuring party.

Credit insurance can often only be provided/confirmed on the day of execution– sometimes only after a contract has been agreed.

How can I help my business get credit?

The list below represents the key areas a supplier will request/engage in to resolve a credit issue;

- Provide a parent company guarantee
- Provide an upfront security deposit (up to £350 million is believed to be held by the suppliers today)
- Agree to Payment terms of Direct Debit only (often 14 days only)
- In some recently cited cases, payment in full for up to seven months
- Last 12/24month financial accounts
- Director contact (FD) to supplier to discuss options

Under the current financial climate we would recommend all organisations have copies of the last 12/24months accounts ready to support any supplier negotiations.

And if I still cannot get credit?

- The incumbent supplier can roll you onto 'default' or 'out of contract rates' which will typically be up to 50% more than market price until you can secure credit.
- Even remaining with your incumbent supplier will not guarantee a supply contract as they will still have to re-check credit at the point of contract renewal.
- You can speak to the Energy Credit Action Group (ECAG) who are currently engaged with Government to prevent this current situation continuing.

EnergyQuote JHA are the combined force of EnergyQuote and the former John Hall Associates. Two of the pioneers of the UK energy consultancy market came together to form a Global Energy Consultancy service in August 2009, who currently trade in more than £3 billion of energy contracts. EnergyQuote JHA has provided commodity based consultancy services for over 35 years, with over 800 clients spanning the commercial, industrial and public sectors our services cover fixed procurement, portfolio optimization and energy management, flexible trading solutions, global carbon reporting and reduction together with the production of in-depth publications as well as long-term price forecasting. If you're looking for a friendly and approachable energy consultancy which makes complex issues simple, takes a flexible and pragmatic approach to give you a better deal, and can give you all the guidance you need, your search is over.

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Global Trends in Energy Prices

By Ian Parrett, Inenco

Forecasting is a notoriously difficult task. Nils Bohr, the physicist said that "Prediction is very difficult, especially if it's about the future".

If we want to discuss trend in energy prices, it's important to identify which set of prices we mean. Let's take electricity as an example. Generators sell much of what they produce to suppliers in, so called, bilateral deals and only the two parties know the price. Suppliers sell to customers at prices that include the wholesale costs plus transmission costs, overheads and margins. Whilst smaller users will receive a standard tariff, large users will negotiate rates so these too are unknown.

There is another set of prices coming from the open wholesale market. Acting like any other commodity futures exchange, supplies are bought and sold. Suppliers use this market to fine tune volumes for delivery, financial institutions use the market to make profit and some large organisations buy from the market to meet their own needs.

We can only get good visibility of the wholesale market but we have to be aware that it produces a skewed perspective. Outside of the short term the liquidity is low and it's hard to set a realistic price for the long term.

Allowing for these caveats, we'll consider the trends within the wholesale markets for gas and electricity. Gas is often considered as a driver of electricity prices so we will review gas prices first.

The latest forecasts made by National Grid show that the total demand will fall by about 3% across the coming year. This forecast is based on revised assumptions for weather. At the same time the forecasts see that the peak daily demand might rise higher this year reaching over 500 million cubic meters per day (mcm).

For supply the general picture looks comfortable. North Sea production is expected to decline slightly but this is more than made up for by additional volumes from LNG and Norway. The fundamentals of the market suggest that prices should be fairly flat.

There is an outside chance that if deliveries of LNG are low, or flows from Norway are reduced coinciding with sudden peak demand, the system will be put under pressure. This is likely to create spikes in the spot markets but not disrupt the trend.

A quick glance at wholesale gas prices tells a different story. The market touched bottom in August 2009 as the full scope of the recession became apparent. Unlike most other economic indicators though there has been no lengthy trough. The trend in prices is up and has been so

for a year.

Brent Crude prices turned the corner about seven months before gas did and we may be seeing the traditional oil to gas price relationship returning to operation. Oil prices have now reached a plateau and if we see a similar pattern in gas, then it provides good evidence of the linkage.

Over the longer term the situation becomes more complex. A resurgence of global economic activity will push up demand. The strongest growth is likely to be in Asia and with limited local production gas will need to come from Russia, Turkey or as LNG. At the same time if the promise of Shale Gas in the USA is delivered then LNG demand will fall significantly. These factors could balance out to keep prices relatively stable.

The potential problem comes in the form of carbon pricing. As a generation fuel, gas is much less carbon intensive than coal but certainly isn't either zero carbon nor renewable. We can expect to see carbon pricing applied to gas. Whilst renewable generation can in theory replace the gas fired stations, there is no ready alternative for gas as a source of heat. A carbon tax is likely to simply push prices up.

In summary then, gas prices seem likely to rise then plateau in the short term and then be at the mercy of macro-economics in the longer term. In the final analysis carbon reduction measures may have the most significant impact on pricing levels.

Until the recession, the price of wholesale electricity followed gas which in turn followed oil. Whilst the oil to gas linkage seems to been restored the electricity market has continued on its own path. In late 2008 concern about supply margins drove prices into uncharted levels which then crashed as supplies were restored and the recession impacted on the economy. Since then whilst there has been a slow upward trend prices have remained low.

This is good news for businesses seeking supply contracts but is slowing down the development of renewable generation. On a marginal cost basis, because the investment is already sunk, coal and gas plants can produce electricity far more cheaply than new nuclear or renewables. This is what sits behind the renewables obligation and the feed-in-tariff. It's also why large players like EDF are looking for a carbon support price of at least £40 per tonne of carbon to make nuclear build viable.

The issue, however, is that in a time of economic stringency it's hard to justify the level of subsidy we have, let alone look to increase it. Setting a market price for carbon seems to make the most sense, but if market prices should float upwards then the Government will feel less exposed to claims of increasing fuel poverty.

So with electricity it's possible that in the near future wholesale prices will stay flat and only start to rise on the movement of the gas markets. The current share of renewables is so low that although this is far more expensive to produce the price effect has been minimal. With subsidies being handled separately to power exports then in the medium term the carbon costs may be carried by consumers without being fully reflected in wholesale prices.

The big driver of market prices will be availability. There have been significant concerns about the loss of nuclear and coal fired capacity through this decade. With intermittent wind power being the main replacement there are worries that at times of high demand there will be insufficient power to go around. We've already touched on the results of low margins on prices.

The new Industrial Emissions Directive has offered some hope in relation to the coal plants. Instead of having to face shutdown in 2016, their potential working lifespan has been extended to 2023. There is also some discussion of whether the existing nuclear fleet can be coaxed into a few more years of operation.

The key question for medium term availability will be the degree to which carbon reduction will drive our energy mix. If there is a major push towards electric vehicles and heating then the potential for supply shortfall will be massive. There will have to be standby arrangements to use high carbon fuels to balance supply but it's likely that at these times we will see very high wholesale prices.

For both gas and electricity, the short term picture is fairly stable with classic demand and supply models looking to push prices up slowly as the economy recovers. The driver of future prices though is in our own hands as we pursue the policies of carbon emissions reduction. Energy use is the primary driver of emissions and it will be energy prices that will bear the costs.

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CHAPTER 2

Design For Sustainability

Designing products for sustainability

By Jenni Donato, AEA

Introduction

The Bruntland Commission Report defined sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." For a company to grow and secure its growth in the future, it needs to embed sustainability into all its products, services and processes.

Companies have long been looking for a way of quantifying sustainability and as a result Carbon Footprinting or Life-Cycle Analysis (LCA) have become commonplace approaches adopted to identify the impact of a company and its activities in terms of the environment. These are both appropriate as indicators of sustainability and involve calculating the embodied carbon within a product or activity and using this as a metric throughout the entire life-cycle of a product, service or process. The basis of carbon footprinting and LCA stems from the idea of "Life-Cycle Thinking" which is, very simply, just looking at the life-cycle of a product, service or process from raw material extraction, through manufacture and distribution to ultimate disposal (see Figure 1).

For everything that is manufactured, it makes sense to look at sustainability from the very beginning of the process, and thus the concept of eco-design has evolved over time. Eco-design has been around for years, even Dieter Rams, chief designer at Braun in the 60's and 70's included environmental considerations in his 10 principles for good design. It can be described as a simple application of life-cycle thinking from a design perspective, and the benefits of doing so can include cost savings, legislative and regulatory compliance and customer satisfaction (or PR).

If a company wants to design a product with sustainability principles in mind, all it needs to do is to consider its eco-design and its life-cycle impacts and then minimise the biggest environmental impacts identified from this analysis. This is the first step to sustainable design.

Life-cycle diagram

Persil recently looked at the sustainability of its products and its "eco-design" solution was to move the Small and Mighty liquid detergent to a 2x concentrated product. The benefits of this was that it now only takes ½ the water to make it, ½ the packaging volume in which to put it and ½ the number of lorries to deliver it . Simple really.

The Design Process

During product or packaging design, the environmental impact should be considered at every stage in the life-cycle, from the raw material extraction through to the end of the product's life. Designers already do this when considering form or function; for example, a common design question is "how strong does packaging need to be to transport the product safely from the manufacturer to the consumer?". It is therefore only a small step for businesses to start to consider the life-cycle from a wider sustainability point of view.

For example, when manufacturing a mobile phone and looking at the consumer behaviour, we can see that it is often only used for twelve to eighteen months before it is replaced. Therefore, one of its biggest impacts would be disposal (which can be minimized by designing the phone for ease of recyclability), so a mobile phone company might want to examine the amount and mixture of materials from which it is made to help minimize any impacts associated with its dismantling and disposal. During the 'eco-design' process the company would need to consider its manufacturing using as little (and as few) materials as possible. If the phone is compared to the mobile phone charger, the biggest environmental impact of this is almost definitely the amount of energy expended during its usage. It would therefore be sensible to 'eco-design' the phone charger by trying to optimise the energy efficiency during usage.

The Design Council recently estimated that 80% of the cost of a product is set at the design stage, and therefore reducing the environmental impact of any product during the concept design is actually the most beneficial stage at which to make cost savings.

Eco-Design – Tools and Techniques

There are a number of tools and techniques that can be used to design products more sustainably, and the right technique will depend on each company's aims and objectives. For example, if a company is looking to reduce its carbon footprint, then it would make sense to look at "Design for embedded carbon" and review the material selection, or look at "Design for transport efficiency", as the distribution of the product may well cause the biggest production of carbon. However, if a company has set targets for moving to 100% recyclable packaging, then it would need to look at "Design for recyclability" and move towards using mono materials that can easily be separated at point of disposal and recycled in most local authorities' collection streams. Companies need to be careful, however, when transporting packaging or products abroad that the materials can be readily recycled at their destination.

A few of the techniques commonly used for minimizing environmental impact are outlined below.

Packaging eco-design techniques

Design for embedded carbon: Look at the material used in the product or its packaging; for example, using aluminum that is made from 60% recycled content can reduce the product's embedded carbon by up to 90%

Design for recyclability: Consider the recyclability of the materials from which the product or packaging is made. Minimize the different types of materials used and, if possible, move to a single material product. Look at how the materials are fixed together; for example, moving from screws to snap clips reduces the amount of time it takes to dismantle the product and they could also be made from the same material

Design for recycled content: Most modern materials can include high levels of recycled content, for example cardboard boxes, metals and most plastics. An obvious and commonly-used example is the Innocent Drinks bottle, one of the first to be made from 100% recycled PET. By asking suppliers for more recycled content in the materials purchased, costs can often be cut and money can be saved.

Design for bio-degradability or compostability: Does the consumer have the ability to compost? If so, moving to biodegradable packaging (which is suitable for home composting) can minimize the impact of the packaging at the end of its life. However, care must be taken and the company needs to ensure that the packaging really will be composted. The EU Landfill Directive sets demanding targets to reduce the amount of biodegradable municipal waste going to landfill, one of the reasons being this type of material can increase methane and CO_2 production by up to 20 times!

Design for transport efficiency: A series of questions should be asked, can the packaging be designed so that more products fit onto one pallet? Can the packaging be designed to interlock or stack in a different way to allow more products to stack together? Can shelf-ready packaging be introduced, thus eliminating the need for secondary and transit packaging and therefore fitting more products together in one pack?

Product eco-design techniques

Design for concentration: If a product contains water, for example cleaning products, paints, coatings or drinks, can it be concentrated so the consumer can mix it with water at it's destination? This means smaller (and cheaper) packaging, lower transport and storage costs and sometimes a longer lifespan of the product.

Design for longevity: Historically, some companies have been accused of planned obsolescence, which is deliberately planning or designing a product with a limited useful life, so that it will become obsolete or nonfunctional after a certain period to ensure consumers re-purchase products. Most designers are, however, now moving away from inbuilt obsolescence and looking at whether the product can be designed to last longer, for example a kitchen knife with two blades, so that, once the user cannot re-sharpen the first blade satisfactorily, the blade can be swapped and the blunt one sent back to the manufacturer to be professionally sharpened. Another example is that of re-programmable washing machines, so that when a new washing powder is released that allows consumers to wash at a lower temperature, a new programme can be uploaded that sets the temperature to the new level.

Design for energy efficiency: Products that use energy are starting to be covered by new regulations (under the European Energy Using Products Directive) which set out eco-design requirements, mostly to do with energy efficiency in use. Therefore, manufacturers are starting to have to document and reduce the energy used in standby, on and powered-down modes

All of the above can (and should) be considered during the design stage of any product or packaging. A good way to do this is to undertake a workshop, inviting representatives from all the different sections of the business, from marketers, production managers and environmental managers to the senior management to attend and contribute. Brainstorming with these different staff together, looking at product lines as specific examples and building short, medium and long term plans for improvements, quite often identifies projects where low cost / no cost changes can save vast amounts of money. It is worth remembering that no-one knows a company better than its own staff, and as such your initial workshops may be best conducted in-house. External consultants can then add value later in the process, by providing additional advice and expertise and by helping to facilitate further discussions.

Green Consumption

The green consumer market grew by 15% in 2008, whereas the overall figure for the consumer market growth was nearer 1.4%, with estimates on sustainable food up by 14%, sustainable textiles up 71%, green stationery up 49% and even eco-friendly funerals up by 18%, now is the ideal time for companies to grow by producing and marketing more sustainable products.

Conclusions

Terms like eco-design, design for sustainability, carbon footprinting and life-cycle thinking all sound very technical and complex when first looking at the sustainability of a product, service or process. However, all these terms have roughly the same meaning and use similar approaches to identifying potential improvements in the design of "greener" products, packaging and services. In simple terms, they all suggest that the entire life-cycle of the product should be considered when looking at improving any product and this will usually include the added benefit of identifying where costs are highest and where easy financial savings can be made. After all sustainable design must also be about financial performance as well as social and environmental benefits.

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CASE STUDY

Agentdraw – Supporting Young Product Designers

By Luke Parsons, Agentdraw Ltd

Agentdraw Ltd is a company based in the Midlands which offers a complete concept to manufacture service. Created in 1991, Agentdraw has evolved from simply fulfilling injection moulding requirements to now being a fully integrated, design led manufacturing company.

"The injection moulding process is extremely versatile, plastic is a wonderful material which provides product designers and companies with a world of possibilities" says Agentdraw's Managing Director Darren Parsons. "The material is also easily recyclable. Careful consideration during the design phase can ensure that any product has less impact on the environment, a factor we take very seriously."

There are ever increasing developments in material technologies which means that plastics are being used in far more technical roles, reducing weight and increasing functionality of products. Combining this increased component functionality and reduced weight which, in turn, reduces transport , fuel, etc, with a high recyclability, makes plastic products actually very environmentally friendly when compared to other production methods. The truth of the matter is we just need to be better at designing and recycling them.

Here at Agentdraw we try to consider every aspect of a product through its life from manufacture all the way to end of life disposal, or, the recycling of the product. Too often products are designed and manufactured without considering their environmental impact. The simple and often quoted *"form follows function"* statement that many designers use is a philosophy that falls short of what is required in a modern world, where sustainability is becoming more and more important and there is far more to consider than form and function.

Mr Parsons, was asked to take part in the Phillipe Starck Program 'Design for Life', which was purported to highlight the great UK design talent but simply seemed to do the opposite, with the program stating that there had been no decent design talent out of the UK since Sir Terence Conran. When Mr. Parsons interviewed the finalists as part of the competition it was obvious that no consideration had been made to the sustainability of their products, nor was it a criteria of the competition.

Upon Mr. Parsons's return from Paris he decided that Agentdraw should do something to support the young design talent in the UK. He conceived the Agentdraw Young Designer Award which would be used to educate the young designers with a formal design strategy and highlight the creativity in Great Britain.

Each contestant needed to follow the companies design philosophy to design and develop products. Product sustainability is a large part of the requirements of the competition and the contestants were required to demonstrate their considerations and knowledge in this area in order to move forward through the competition stages.

At the beginning of 2010, Agentdraw Ltd began their tour of UK universities to promote their Young Product Designer Competition. The competition was open to all designers under the age of 25, with the aim of finding real design talent In the UK.

The winning competitor would receive the Agentdraw Young Designer Award which would be presented at the prestigious Plastics Industry Awards at the Park Lane Hilton Hotel. This evening would include an expenses paid gala evening and overnight stay in the Park Lane Hilton. At this event the contestants would have the opportunity to show case their designs to the best of the plastics industry and potentially launch their design career.

The main prize is that the winning contestant will have their product prototyped, marketed and possibly manufactured by Agentdraw Ltd, a fantastic and potentially lucrative start to any design career.

The format of the competition comprised of several stages, varying in complexity. The purpose of the competition was not only to find creative ideas but also educate students of the real design processes used for product development.

The first stage required applicants to produce hand renderings of their initial idea on a single sheet of A4 paper. It is an important design skill to have the ability to communicate an idea in its most basic form before too much time is invested in a particular direction or product.

There was an overwhelming response to the first stage of the competition, with some inspiring ideas sent in. The volume of entrants demonstrated an immense amount of design talent in the UK.

The applicants then went through several stages following the Agentdraw design process which has evolved their ideas and also improved their understanding of product development.

The three finalists had products in very different market sectors and all of them had demonstrated a real passion for product design throughout the process.

Dynamic Chair

The Dynamic Chair - A simple moulded chair designed to solve the issue of lower back pain from developing in both children and adults.

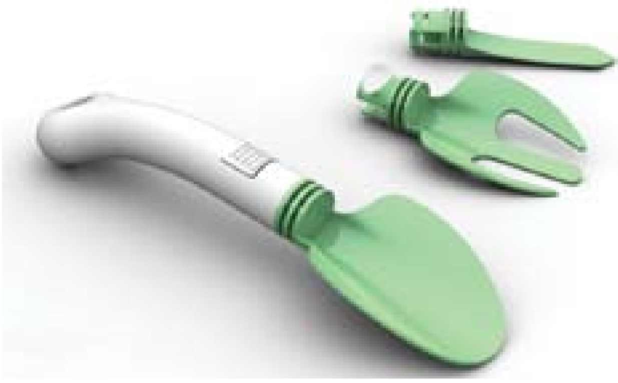
An unstable base provides a full range of motion to keep the back muscles working. The 'rubber' pads at the front ensure it doesn't slide. Its shape has been carefully designed to allow the user to rock forward and thus sit in a healthy position while still allowing the chair to stack for convenient storage.

The space saving, very efficient stacking of the design meant that the product could be transported very efficiently. There were many engineering developments during the design process to reduce material content, reduce cycle times and energy requirements in the manufacturing process. The material choices were also a key consideration as the product required the use of both hard and soft polymers, however, by use of material additives a single polymer solution was possible enabling easier recycling of the product when it reaches end of life.

Vegetool

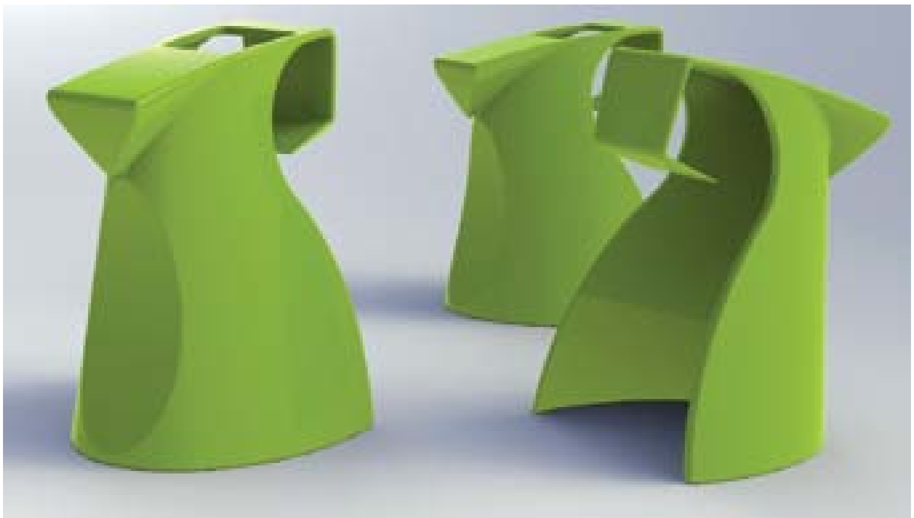
This is a garden multi-tool that uses a single handle to simplify the gardening experience. The design minimizes the material volume used for a tool set and allows easy and comfortable operation of the product, particularly for low dexterity users.

The product is constructed from corn starch based materials as the contestant was very keen to choose materials from a renewable resource. The result is a sustainable solution for design conscious users whilst offering a new level of functionality.



This has been a great opportunity for young designers to get valuable exposure and the opportunity to have their product prototyped, marketed and manufactured.

The 2010 competition was a great success with a high standard of entries which demonstrates the design talent that exists in this country. We look forward to seeing next year's entrants.



Orana

The Orana is a handheld product which works by using a small cutting edge and guide at the front to slice orange peel and on the reverse has another device to remove the tops of bananas.

This contestant decided to use bio-degradable polymer for his product as he wanted to ensure that his product had minimal environmental impact.

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CASE STUDY

VISION A Sustainable solution for egg packaging

By Caroline Eaton, Ovotherm

With more than 40 years industry experience and in response to market demands and extensive customer research Ovotherm successfully launched to the global market the new VISION range for packaging eggs during 2010.

In 2008 packaging from Ovotherm supplied to Tesco received an award for Best Business solution, breakage and wastage had been reduced by over 50%. Based upon these competencies and following Ovotherm's philosophy that clear packaging allows the customer to see what they are buying also with increasing industrial packing operation demand the design of this revolutionary VISION egg packaging made from 100% post consumer recycled PET began. Essentially created for resource efficiency VISION optimises the amount and type of packaging for eggs, the VISION range is designed to be the fittest for purpose and at the same time to be lowest environmentally impacting of all egg packaging types.

VISION 100% RECYCLED EGG BOXES

Key criteria such as lightweighting has always been at the forefront of Ovotherm's innovations and VISION carefully minds environmental responsibility whilst bringing many benefits:

- Made from 100% post-consumer recycled PET (made from recycled bottles using advanced recycling processes to allowing that recycled material is once again suitable for food industry packaging)
- The environmental impact of this packaging is the lowest of all in the market place. The carbon footprint of RPET egg packaging is 15% lower than pulp egg packs
- 100% recyclable - check your local facilities
- VISION is more than 10% lighter than typical traditional fibre packaging for eggs (meaning lower environmental impact as less fuel is required for transport)
- The use of plastics rather than traditional cardboard means that 40% less lorries are on the road delivering packaging and 40% less warehouse space required
- Plastics Egg packaging can significantly reduce the incidence of breakage and wastage by as much at 50%
- Customers can see what they are buying and can inspect the quality of eggs without opening the packaging
- Also, cashiers can inspect quality of eggs without opening packaging – this saves time and is more hygienic
- Due to the innovative New Snaplock - Easy Opening mechanism the box features a more secure closure and ease of access to product
- No fresh water is used in the production of Ovotherm egg packaging
- Energy used in the production of Ovotherm packaging is 100% from renewable sources
- Ovotherm have reduced the energy consumption used in production by 35% within the last 5 years
- By Ovotherm implementing new ultra-hygienic outer-packaging for products a reduction of 57% emissions has been achieved

VISION was successfully launched into UK retail in June 2010.

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CASE STUDY

Upcycle, the new Recycle

By Peter Woodd, IDT Systems Ltd

Everything in our world is created using the natural resources of our world. This, combined with human ingenuity, products are created to address social and economic needs. In the last century it is safe to say that progress has mostly been driven by the needs of commerce without, in most cases, any respect for the environment on the planet earth.

Fortunately there is now considerable awareness and focus on producing products from reused materials. The benefits are immense, not the least of which is that it takes less energy to recycle than to create virgin products.

So "re use" has come into our vocabulary. As has 'upcycle'…yes, there is a process known as 'upcycle'.

VALOX IQ PBT RESIN CHEMICAL ' UPCYCLE' PROCESS

Adding value

Industrial design has moved from function to fashion, purely functional is no longer the only competitive advantage. The consumer is enticed by the appearance of the product and the importance of the brand in representing their personal values, thus extending the brand experience.

We have seen the emergence of expressions like "mass customisation" and "personalisation." Technology has permitted the opportunity for Rapid Manufacturing (RM) processes which are seen by many as the driving force in future product sales. Digital technology has been the most significant and "disruptive force " in the printing industry.

It really is "print on demand "that has created the practical opportunity to personalise products to a customer's design, in a production environment, at a cost that is competitive. It is also instant all that is needed is a 'jpeg' or 'tiff' file and within minutes you have printed and decorated.

It is capable of decorating 3D products with hi res images or colours, an amazing pallet of effects for the CMF / DMF Group. The whole process also consumes less energy in production.

Adding value & taking out cost

As we move forward with innovative upcycled material solutions we need also to look for environmental improvements in the decorative finishing space. In the consumer electronics space the use of solvent based paint has been extensive. Today, companies are looking for alternatives to solvent based paints. There have been strong moves to use water based paints and this is a step in the right direction.

The next step

Alongside the drive to create re-usable polymers has been the drive to take paint out of a process. Upcycled materials can be decorated without paint/coating using tool finishing to deliver a range of exciting surface finishes.

I-SD SYSTEM DECORATED MASK

This process, known as i-SD (In-Surface Decoration), actually allows for digitally printed images to be decorated directly into the surface of the part. Yes, not on the surface, into the surface - up to 200 microns. This provides a variety of additional benefits as it:

- cannot be scratched off
- resists chemicals more effectively have good UV performance without UV topcoat
- needs no intercoat adhesion

The components used in the process are all recyclable and being water based now allow for low cost recyclability of the decorated part.

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CHAPTER 3

Manufacturing Efficiency In Plastics Processing

Using assisted injection moulding (AIM) technologies to reduce cost and improve quality

By James Jenkinson, Cinpres Gas Injection

Description of Basic Assisted Injection Moulding Processes

Full shot moulding: A full shot moulding is filled to at least 100% of mould cavity volume with plastic during the plastic filling stage. Gas is then injected and flows into the component to compensate for the plastic shrinkage. The rate of flow of gas into the component is controlled by the rate of plastic volume shrinkage. The amount of gas flow into the component is limited by the shrinkage of the material. To create a larger gas channel, it is necessary to reduce the amount of plastic we inject, commonly referred to as the Short Shot gas injection process.

Short shot moulding: Short shot mouldings are filled to less than 100% of mould cavity volume with plastic, gas is then injected to complete the filling of the cavity. Once the cavity is filled the gas continues to flow as it packs the plastic. The initial gas flow into the cavity is high and controlled by the resistance of the plastics being displaced towards the unfilled areas. During packing the gas flow into the component is controlled by the rate of the shrinkage of the material as with Full Shot gas injection process. The short shot process has a number of limitations when applied to more complex components. In these situations overflow wells are used.

Advanced Process Options

The Plastic Expulsion Process (PEP): Overflow wells allow the component to be completely filled with plastic and packed with plastic prior to gas injection. Gas is injected displacing the plastic out of the gas channels into specifically designed wells outside the component cavity. This added control over the process produces the best cosmetic surface, controls the size and concentricity of the gas core and guarantees that the gas channels are fully cored with gas.

Internal gas injection cycle times can be further improved by using liquid or gas cooling. The Liquid Cool process injects cooling water through the gas channels, cooling them rapidly. Cooling times can be reduced by up to 50%.

Liquid Cool (LC) Process: The Liquid Cool (LC) process builds on the PEP process to deliver shorter cooling times. Plastic packing can then be used to optimise the surface finish. Gas is injected and after a delay, the path to the overflow is opened. The gas displaces the plastic into the overflow and starts packing the component. After a given delay time, water is injected into the cavity and the gas is released. Water flows through the component under pressure for a given time, before being displaced by gas, injected again from the fixed pin nozzle.

In some cases the size of overflow wells can be reduced or eliminated by pushing the molten plastic from the gas channel back into a hot runner manifold.

TV BASE AFTER EGM: THE "PIANO GLOSS" 'A' SURFACE WITHOUT SIGN OF SINK MARKS, BELIES THE SUBSTANTIAL RIB STRUCTURE ON THE 'B' SURFACE. IN PART, THE RIBS THICKNESS IS RATIO IS 1:1 WITH THE 3.5MM WALL THICKNESS. WITH THE TV BASE MOULDED IN PC/ABS, THE REDUCTION IN CLAMP FORCE AND MOULD DIMENSIONS ALLOWED THE PART TO BE MOVED FROM AN 800 TON INJECTION MOULDING MACHINE ONTO A 500 TON MACHINE, WITH A 19% CYCLE TIME REDUCTION AND AN 8% REDUCTION IN MATERIAL CONTENT.

External Gas Moulding (EGM)

EGM is a low pressure moulding process that uses pressurised nitrogen gas as the packing medium, to complement the injection moulding process. Pressured nitrogen gas is applied from the core side of the moulding to pack the component against the cavity. Gas packing pressure forces any sink to occur on the non visible side of the component. The gas compresses the plastic forcing sink to occur on the non visible side of the component.

EGM allows the designer to break the rules of injection moulding. With conventional moulding, wall section is often determined by the thickness of the ribs on the underside – typically, the rib must be less than 40% of the thickness of the wall section. Reducing the thickness of the wall section or increasing the thickness of the rib would normally result in sinkage on the visible surface.

By contrast, EGM gas pressure packs plastic into the intersection where the sinkage occurs forcing the sink to occur of the underside avoiding sink on the show surface.

This capability gives the part designer much greater flexibility in rib location and dimensions, frequently allowing thinner wall sections – with resulting material savings – without loss in the physical properties of the part.

With certain types of mouldings, it is also possible with EGM to achieve substantial cost savings through

- Reduced clamp force.
- Reduced cycle time.
- Reduced material volume.

Another benefit of EGM is the ability to mould to finer dimensional tolerances and with enhanced surface finish. The shorter plastic packing times and lower pressures lead to reduced moulded-in stress, resulting in reduced distortion.

The above features of the EGM process tend to mean that the cost and design benefits are most significant with larger part weights and flow lengths, where the opportunities for reducing machine size, material and cycle time have a greater impact.

An Automotive Door Pocket as an Example of Combining AIM Processes

Automotive door pockets often incorporate internal gas injection, to allow a thick section lip at the top of the map pocket to be moulded. The Full Shot process can be used but this will severely limit the size of the gas channel.

The PEP process allows the component to be manufactured as an injection moulding with plastic filling and packing. Gas is then injected displacing the hot plastic out of the gas channel into the overflow well. Gas in then used to pack the gas channel as it cools. The size of the gas channel and the shape of the cross section determine the length of the cycle time. If the component is de-moulded too soon the gas channel can continue to cool causing distortion.

Adding liquid cool to achieve further cycle time savings: We can improve on the standard method and achieve faster cycle times by using a liquid or gas cooling process. After the gas has been injected and the gas channel is cored out we can circulate cooled gas or water through the channel enhancing it's rate of cooling. This can dramatically reduce the cooling time of the gas channel, bringing it into line with the cooling time of the surrounding wall section.

EGM, allowing the wall thickness to be reduced whilst keeping ribs and bosses the same: Now we can achieve rapid cooling of the gas channel using liquid cool we can consider reducing the general wall section. As discussed before the thickness of the wall is usually limited by the size of the injection moulding ribs on the back of the component. EMG allows us to break those rules. A small reduction in the wall section produces a significant material saving.

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Optimising plastics material selection

Dr Chris O'Connor, Smithers Rapra

Designing to ensure plastic product reliability is critical due to the increasing importance of product liability claims, environmental concerns, certification in order to become an approved supplier and an awareness of quality costs.

However, despite the advances in manufacturing and design technology, it is a fact that around 70% of plastics fail before their design lifetime, resulting in litigation, expensive recalls, warranty claims, re-tooling and, in an ever competitive market – loss of brand credibility.

So where is the issue? From the 5000 plastic product failures which have been the subject of extensive study at Smithers Rapra we conclude that the problems often arise at the design stage.

Smithers Rapra has classified an extensive catalogue of plastic product failures on the basis of primary failure caused by material/phenomenological factors, as shown in Figure 1 below:

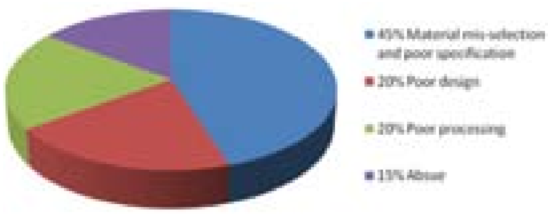

FIGURE 1: MATERIAL OR PHENOMENOLOGICAL CAUSES OF FAILURE.

A further analysis of plastics product failure due to human error is shown in Figure 2 of which 45% are due to mis-selection and poor specification of material.

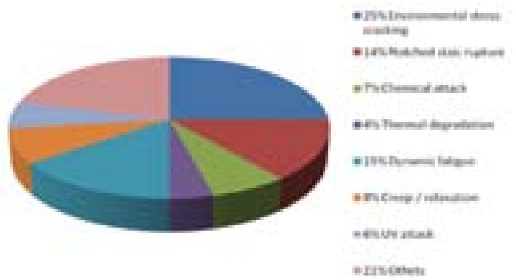

FIGURE 2: HUMAN CAUSES OF PLASTIC PRODUCT FAILURE.

Data compiled clearly demonstrates that all too often, product failure due to poor material selection is the single most common error made by designers or engineers of plastics products. Moreover, our experience indicates that it appears to be caused by a lack of awareness or understanding of the material's properties. This is perhaps not surprising given that there are over 90 generic classes of plastic, which can be broken down into around 1000 sub-generic modifications and finally over 50,000 commercial grades from a host of materials suppliers. The result is a vast array of trade-names, generic nomenclature, and plethora of often incomplete and inconsistent data with insufficient standardisation which can sometimes confuse and frustrate the best plastic expert. The task to sift through this immense volume of data and make comparative judgements can to the inexperienced seem like an impossible task. The situation is further complicated by the competitive and positive marketing of material suppliers, which makes it sometimes difficult to identify material limitations and disadvantages.

Material selection

From the outset of material selection, the basics of polymer structure and properties should be considered.

Polymers are broken down into three main groups – Thermosetting Plastics, Thermoplastic Plastics and Elastomers (rubbers). For the purpose of plastics design, the two basic choices are Thermoset and Thermoplastic.

Thermoplastics have two basic types – amorphous and semi-crystalline plastics.

Amorphous plastics are preferred for applications where transparency, good appearance, high gloss, high dimensional accuracy and stability are preferred. They should not be utilised for applications involving thermal or mechanical stress cycling, high mechanical abuse or contact with a wide range of chemical environments.

Whereas semi-crystalline plastics, as the name suggests, have ordered crystallite structures and are better able to withstand fatigue than amorphous plastics. These plastics are best used where chemical contact, mechanical abuse and resistance to repeated cyclic loading is required.

When considering the design and development of a plastic component the designer must understand that:

- plastics are visco-elastic materials
- plastics have time and temperature dependent properties
- plastics physically and chemically age
- are susceptible to weathering
- are susceptible to chemical attack, stress corrosion cracking (SSC) and environmental stress cracking (ESC)
- plastics will, under the action of a tensile stress, eventually fail
- with Plastic materials the time to failure will diminish as the stress and/or temperatures increases, in the presence of certain environments and under the action of cyclic loading
- the moulding process can result in significant levels of moulded-in (residual) stress
- plastic materials are notch sensitive

- the addition of any form of filler will always have some form of detrimental effect on a plastic material
- reinforced plastic materials are anisotropic

Time, temperature and stress / strain

Visco-plastic materials respond to stress as if they were a combination of elastic solids and viscous fluids. Consequently they exhibit a non-linear stress-strain relationship and their properties depend on the time under load, temperature, environment and the stress or strain level applied. Visco-elastic behaviour can be seen with Silly Putty, a class of silicone polymer marketed as a children's toy. If this material is pulled apart quickly it breaks in a brittle manner. If, however, pulled slowly apart the material behaves in a ductile manner and can be stretched almost indefinitely. Decreasing the temperature of Silly Putty, decreases the stretching rate at which it becomes brittle.

All plastics exhibit creep, consequently design calculations and FEA analysis in order to prove a design are flawed if long term properties such strength and stiffness values are not used. These should be determined through experiments under worst case scenario operating conditions including maximum service temperature, stress levels and the effects of the environment. Unfortunately, many designers too often assume that 'it is just a plastic' and readily use the short-term test data provided by the plastic manufacturers datasheets. The result is many product failures due to visco-elastic induced failure mechanisms.

Designers and engineers must realise that data sheet information is derived from short term tests which do not take into account time, temperature and environment. Test pieces are also simple shapes, which are moulded under ideal conditions. This rarely applies to moulded products. According to short term data plastics may appear to be able to endure strain levels of 200% or more. However, for long-term performance, the window for design strain is massively smaller. Recommended design strains are as follows:

Static stress conditions

- Amorphous plastics ≤ 0.5% strain
- Semi-crystalline plastics ≤ 0.8% strain

Cyclic stress conditions

- Amorphous plastics ≤ 0.3% strain
- Semi-crystalline plastics ≤ 0.5% strain

In order to avoid failure it is imperative that the designer and engineer understand that:

- Plastics will deform under load
- When subjected to static low stress / strain a ductile - brittle transition will occur at some point in time resulting in brittle failure
- Cyclic stressing will result in a ductile / brittle transition resulting in brittle failure at low stress level
- Premature initiation of cracking and embrittlement of a plastic can occur due to the simultaneous action of stress and strain and contact with specific chemical environments (liquid or vapour)

Design failure may also be attributed to reduced safety factors due to cost pressures and the use of plastics is demanding applications taking them to their design limits where on occasion they are exceeded.

Environmental Stress Cracking (ESC)

ESC is the premature initiation of failure and the apparent embrittlement of a polymer under the simultaneous action of stress/strain and the environment. ESC differs from chemical resistance in that chemical resistance testing uses specimens immersed in the chemical for a time period with a measurement of properties before and after exposure (typically these are tensile and impact properties).

However, at no point does the specimen come under any stress except after it has been cleaned ready for test. With ESC, the presence of both a stress and the chemical environment can lead to dramatic effects, mainly catastrophic brittle fracture of even the most toughest of materials.

Amorphous plastics are, in general, more susceptible to ESC than semi-crystalline materials.

Consider service environment and possible synergistic effects

The majority of plastic product failure is due to cumulative effects due to the synergies between creep, fatigue, temperature, chemical species, UV and other environmental factors.

Processing effects

At Smithers Rapra we find that even the best plastic designs with good material selection can fail. The cause is poor processing due to a blatant disregard for established processing procedures and guidelines provided by material manufacturers. The driving force is typically economic drivers to achieve reduced cycle times and higher production yield.

All plastics have limitations

Plastics are tremendously versatile materials, but they have their limitations. For the designer and engineer it is a practical necessity to understand their fundamental nature, limitations and failure modes to reduce the likelihood of product failure. There is at times a fine line between good product design, correct material selection and failure that can be easily crossed if expert knowledge is not used. Attention must be paid to the many variables that can influence plastic properties of which seemingly small differences can have a dramatic affect on plastic and product performance.

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CHAPTER 4

Energy Efficiency In Plastics Processing

How UK technology can improve energy management and efficiency

By Robin Kent, Tangram Technology

Introduction

In trying to achieve the ultimate goal of "Sustainable Manufacturing," energy usage and management is extremely important and the UK is taking a leading role in developing the enabling technologies and techniques to achieve this.

Energy efficiency has traditionally had a low priority in plastics processing due to the relatively low cost of energy compared to other costs such as materials and labour but this has changed dramatically in the past decade. In fact, a completely new set of rules are being applied to the sector and energy efficiency is now a major factor in management, machine purchases and operations.

There are three major drivers for this increased concern with energy use:

Cost: The relatively high cost of energy in the UK and the tax treatment of energy, e.g. the UK Climate Change Levy, both encourage investment in energy efficient technology. The cost of energy in the UK is high compared to many countries and even small reductions in energy use can often easily be financially justified.

Security: The security of energy supplies is no longer assured for most countries and the UK is no exception. It has been widely demonstrated that improving energy efficiency is far more cost effective and easier than finding new sources of supply and increasing generation capacity.

Legislative drivers: Environmental legislation in the UK is well advanced and there is a wide range of environmental legislation forcing companies to reduce carbon emissions to meet government targets, e.g. Carbon Reduction Commitment.

The result of these three drivers is that the UK plastics processing industry is rapidly moving to become a world-leader in energy efficient plastics processing. Although the transition is difficult for some companies, the results in the long-term will be worth it.

Energy management

Benchmarking

UK plastics companies are developing world-leading techniques in monitoring and targeting for plastics processing. Tangram Technology (www.tangram.co.uk) is an acknowledged world-leader in developing simple techniques for monitoring and targeting using easily available information. These techniques use simple internal information to set energy performance targets on a monthly or weekly basis by finding the Performance Characteristic Line (PCL) for the site. This information can also be used for future energy cost budgeting to provide accurate future energy costs when production volumes vary.

Tangram Technology has also developed operating curves for many plastics processes both at the site and at the machine level, e.g. injection moulding, extrusion, rotational moulding and thermoforming. These operating curves can be used to benchmark both sites and machines against comparable sites and machines world-wide.

Measurement

It is no accident that the UK market for monitoring and targeting equipment (to measure, record and analyse energy use) is one of the most advanced and competitive in the world. These systems can be hard-wired or use wireless connections for more flexibility. Specialist UK companies have also developed methods of integrating process equipment such as mixers and blenders into the measurement systems to provide accurate measurement of material throughput, e.g. www.resourcekraft.com.

The UK has a wide choice of competing suppliers and systems but other areas of the world are still only discovering the benefits of this technology. UK companies are therefore well placed to export and develop markets for their innovative technologies.

Reporting

All areas of the world are improving energy efficiency but reporting of progress and achieved energy use reductions is a vital part of the process. The demanding UK requirements for reporting have led to the development of innovative software for the reporting process and more new software tools are being developed to meet this need.

The essential tools for energy management are being developed and used in the UK to establish a framework for experience in this vital area.

Services

Development of the measurement and reporting framework is vital but UK companies are also developing the hardware to reduce energy use in a wide variety of services. Typical work involves the development of low-loss transformers, e.g. www.bowerselec.co.uk, power conditioning and voltage reduction equipment, e.g. www.powerperfector.com and measurement and control equipment compressors, cooling and chilled water, lighting and polymer drying.

Prime processing machinery

It is an undeniable fact that the UK has decreased in importance as a supplier of prime plastics processing machinery but this has been replaced by the rapid development of add-ons and controls for the prime machinery to improve the overall energy efficiency.

This can range from simple insulation for most processes to reduce heating energy use (see Figure 1) and this can be supplied by well established UK suppliers, e.g. www.elmatic.co.uk and www.insulwatt.co.uk.

UK suppliers also at the forefront of developing machine controls for reduced energy use, e.g. www.ccstech.co.uk and much of this technology is unique to the UK. This is not simply the development of controls for the main machinery but also the development of controls for the complete production management system and ancillary equipment, e.g. www.mattec.com.

UK suppliers have also developed economical and simple tools for monitoring the energy use of all types of sites and processing equipment. This type of simple, portable equipment allows processors to 'look inside' their process and to use the information from this to improve energy efficiency, e.g. www.spcmini.com.

Training and surveys

The UK is not only developing the technology but is also actively engaged in training the rest of the world how to reduce energy use in plastics processing. The Carbon Trust (www.carbontrust.co.uk) in the UK has produced a wealth of information and resources for training and information and has also trained and accredited many people on how to carry out energy surveys to identify and implement energy saving opportunities. Tangram Technology (www.tangram.co.uk) is also active in training and surveying plastics processors around the world and has a unique position in this area.

The pressures on the UK plastics processing industry may well be seen as detrimental to the industry but they are driving changes in the industry. The high costs of energy are forcing the plastics processing industry to change their methods of operation and they are becoming leaders in many of the advanced technologies that will be needed around the world in the future.

Energy efficiency is recognised as a vital part of the world-wide drive towards a sustainable future for plastics processing. The UK industry is already providing the tools and techniques to improve energy efficiency and will continue to do so in the future.

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FIGURE 1: PROCESS INSULATION

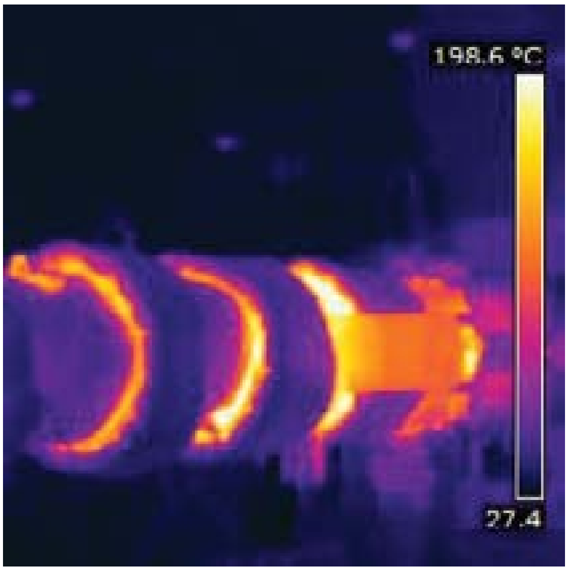
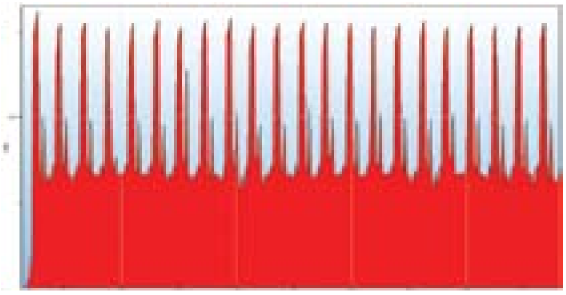


FIGURE 2: ENERGY TRACE FROM INJECTION MOULDING MACHINE USING SPCMINI



CASE STUDY

The polymer processing research centre at Queens University, Belfast

By Mark McCourt & Mark Kearns, Queens University

Research in various aspects of polymers, including their processing, has been carried out in the School of Mechanical & Aerospace Engineering at Queen's University, Belfast (QUB) for over 25 years. During this time substantial investment has been made in establishing and maintaining state of the art processing and analytical facilities.

Building on the long established processing expertise at QUB in rotational moulding and polymer extrusion and extending into the complementary processing technologies of injection moulding, blow moulding and thermoforming, the Polymer Processing Research Centre, PPRC, was established in 1996 with assistance from the local development agency Invest NI (formerly IRTU) to carry out and support leading edge, industrially exploitable, fundamental and applied R&D to demonstrably improve industrial competitiveness.

In 2002 there followed the establishment of the Medical Polymers Research Institute MPRI which provides a forum for collaborative work between Mechanical and Aerospace Engineering and colleagues from Pharmacy concentrating on research in the field of new polymeric materials, products and processes for the medical devices and drug delivery industries.

In addition to working directly with industry in carrying out R&D as well as knowledge and technology transfer programmes and the provision of training courses, staff in the Centre work closely with academic colleagues in the Polymers Research Cluster on a wide range of research programmes.

Not only are short term, direct contract research and development activities undertaken in its two industrial supportive Research Centres, the Polymer Processing Research centre (PPRC) and the Medical Polymers Research Institute (MPRI), there is also a wide range of industrially applicable research being undertaken at QUB in the Polymers Research Cluster in the School of Mechanical and Aerospace Engineering. A total of around 70 people comprising academics, contract technical, support and research staff, together with PhD students, are engaged in polymers research at the University. The work undertaken is broadly follows four principal themes of Polymer Processing, Modelling and Control, Nanomaterials and Medical Biomaterials.

As well as undertaking strategic multidisciplinary research into the processing of materials, the University has a strong reputation in the modelling of and development of high performance polymeric materials. Ongoing investment in processing, analytical and testing facilities means that Queen's is equipped to undertake high quality applied and fundamental research, reflecting the needs of the polymer industry in the UK and abroad.

Within this industrially relevant research portfolio there is an interest in sustainable manufacturing much of which has been or is currently being commercialised. Below are examples of how the PPRC is helping industry across Europe develop novel, new and innovative sustainable manufacturing techniques:

Case Study: Micromelt Project

The Micromelt Project aims were to increase product quality and reduce energy consumption in the rotational moulding process by improving both heating and mould cooling, and are partially funded by the EC Framework programme. Partners in the project included research institutions Pera, Fraunhofer TEG and Queens University Belfast (QUB) as well as trade associations the British Plastics Federation (BPF), The Association of Rotational Moulders of Central Europe (ARM- CE) and the Association

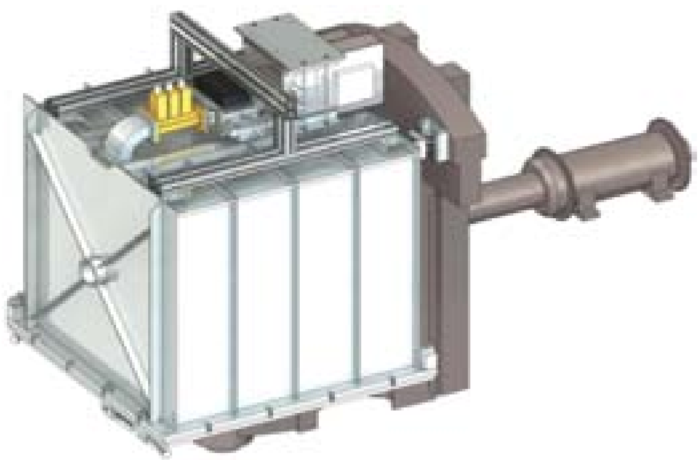


FIGURE 1 – DESIGN OF PROTOTYPE MICROWAVE OVEN ON DROP ARM OF ROTOMOULDING MACHINE

FIGURE 2 – PROTOTYPE MICROWAVE OVEN ON DROP ARM OF ROTOMOULDING MACHINE

of Rotational Moulders of Ireland (ARMI) as well as SMEs in Germany, Sweden, Italy, Ireland and the UK.

The concept was to utilise microwave heating and internal water cooling to reduce energy requirements and cycle times. This leads to significant cost savings.

Traditionally, rotational moulding involves rotation of a mould filled with polymer in an external oven. This process is very energy intensive. It had been shown by computer modelling from Fraunhofer that microwave heating methods as opposed to conventional hot gas heating can greatly reduce processing time. This was confirmed by practical work at Pera on test samples. Suitable test moulds were developed to aid the heating process, and a choice of material for optimal performance made. Following benchmarking of the conventional rotational moulding process by QUB, a prototype rotomoulding tool was designed by Pera which optimises design for efficient microwave transmission. A prototype industrial microwave oven was designed and built by Fraunhofer and positioned on the QUB Ferry Rotomoulding machine – extensive trials indicate that with further optimisation >25 % reduction in cycle times through the use of microwave heating technology is possible as well as an energy cost saving of > 24% due to the high efficiency of the microwave coating.

Work by QUB also made significant progress in improving the cycle time and efficiency of the cooling cycle. A prototype, internal mould, water spray cooling rig has been shown to significantly reduce the cooling stage of a number of test tools. Industrial trials at rotomoulding factories in Germany, England, Ireland and Scotland showed considerable cooling stage cycletime savings. An added benefit was the subsequent reduction in part warpage due to the 'balanced' internal and external mould cooling – improving part quality, reducing scrap and jigging times.

The technology developed during the Micromelt project appears to have serious potential for reducing cycle times and energy costs during a rotational moulding cycle with the potential for >40% reduction in overall cycles times through the use of both technologies.

Case Study: Badana Project

Under the European Union's Seventh Framework Programme, the PPRC at Queens University, Belfast secured a research grant to conduct applied and fundamental research in the field of combining natural banana plant fibre in rotational moulded plastic products.

The 2 year 'Badana' Project began on July 1st 2009 and is a truly pan-European project with the research conducted on behalf of companies in the UK, Spain, Germany, Netherlands and Eastern Europe.

The main objective of the 'Badana' project is to develop and validate novel procedures for the extraction of truly sustainable, natural fibre from waste matter derived from banana cultivation in the EU that does not displace food production. The fibres will be used to develop innovative, sustainable rotationally moulded and injection / press moulded thermoplastic composite products.

Almost 20% of the bananas consumed in Europe are produced in the Canary Islands with around 10 million banana plants are grown annually in Gran Canaria alone. In the past, the banana plant waste was used as a support element for arable plants as well as cattle fodder, basket weaving, etc. Today, however, these vegetable wastes are deposited in ravines where they become decomposition material. An estimated 25,000 tonnes per annum of natural fibre is found in this waste. With this in mind one of the largest Banana plantation cooperatives in the Canary Islands approached the local University to see if it were possible to do something constructive with this waste product. Queens were approached because of their expertise in Rotational Moulding and strong links with a number of Universities in Spain (University of Las Palmas / University of Zaragoza) that are involved in the project.

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Automatic energy monitoring and management of electricity and other resources

By Mike Dorgan, NewFound Energy Limited

Why should you be monitoring your energy use?

All reductions in the use of energy and other resources will improve your company profitability £ for £, but before embarking on steps to change practices and cut waste etc it is essential that precise information confirming how and when energy is used is collected.

Energy and other resource monitoring provides information that enables a user to cut operational costs through improved knowledge and analysis of how a site(s) uses electricity, gas, water and other resources.

For efficient management of resources a comprehensive energy monitoring system will provide the following:

- Automatic energy/resource use data collection
- Early warning of potential overuse
- Identification of possible circuit overloads
- Analysis of usage to highlight waste and inefficient practices/machinery
- Precise cost allocation to user defined cost centres
- Improved area manager accountability
- Confirmation that your supplier has not overcharged you
- The basis for identifying the best new tariff for you

How?

First of all meters for the resource(s) of concern need to be installed. All utility meters are now available with a pulse output and sometimes additional data communication facilities such as MODBUS, network communication and radio/GSM modems. Unlike when tenant billing is required, for electricity sub-metering, it is not necessary to use OFGEM or MID approved meters as lower cost class1 meters are readily available. These meters may have a simple consumption display or may provide more comprehensive information to the user.

To physically read the meter and manually transpose and analyse the information at an intended 'regular' interval is far from efficient and not guaranteed to be sufficiently accurate to gain full benefit. This method will also not bring the power of precise defined usage information as will be available from an automatic monitoring system.

It is also essential that meters are installed in the most appropriate and useful locations. To determine these locations requires considered analysis of the purposes to which the information gathered will be put and the benefits possible from the efforts applied.

Where?

If electricity alone is the initial concern, and it is not certain precisely which areas should be monitored, the use of a temporary portable electricity meter will provide a valuable insight into the pattern and level of use of the circuit monitored. With this kind of equipment it is also sometimes possible to obtain information relating to the state of the electricity network.

Data collected can be analysed, usually with software supplied with the system, to indicate areas where action will bring an improvement in energy use and remove waste, bad practices and potential overload or phase imbalance problems.

Using this information the best locations for permanent meter installation can easily be determined as a forerunner to installing an automatic energy monitoring and/or control system.

The approach of using a temporary portable meter is also possible with respect to water where non-invasive meters are available. Unfortunately it is not as easy with gas, compressed air and other resources such as fuel oil where, to measure use, it is necessary to cut into the flow line.

After initial surveys the path to follow depends on the site requirements and how the measured usage information is to be collected from the meters. Historically the use of pulsing meters with loggers has, and can continue to be, the backbone of data collection. With site-wide and multi-site network systems this approach can easily cover many locations without the need to use radio or modems.

When necessary wireless technology can be utilised but it should not always be the first route to be considered.

Some electricity meters are now available that provide more than just energy usage information. These meters can also give information on current, voltages, peak values on various parameters, and in some cases harmonics etc. The meters tend to have, if not as standard, an option for MODBUS or other forms of communication including the possibility of the data stored being collected over a network. These meters are individually more expensive than the standard kWh meter with a pulse output. They can, however, in some instances, form the basis of a system for a site (or sites) with widespread metering point locations that may prove no more expensive than a system based on the use of data loggers. Some of the meters are supplied without software so that the user(s) can create their own reporting capability; others have software available that includes all the facilities of an effective energy monitoring system.

From current available energy monitoring systems the data collected should be readily available to any interested party on the site that has access to a networked PC. This is equally relevant to 'in-house' systems and hosted packages. Most 'in-house' systems will have a 'real-time' element that will assist in live efforts to control usage. A system with quick response will show the success or otherwise of improved practices and decisions made by line managers in their efforts to operate more efficiently.

Visual and audible alarms will assist in control actions and, if required, systems are available that can be packaged to include fully automatic control of loads to prevent excessive energy use on a demand or load basis. This helps protect against tariff excess charges and overload failures where use levels can exceed supply capacity provision.

Reporting facilities will be available that will provide precise information on levels and patterns of use plus costs attributable to product production runs even when very complex electricity tariffs are involved. These reporting facilities will enable the user to

- validate utility bills for accuracy and provide internal billing capability for cost centres
- display period by period data over a user selected date range for a number of sites or cost centres for comparison purposes
- compare the consumptions of similar production areas and 'identical' machinery to identify the most efficient plant to use
- identify peak demand levels with times so that causes can be determined and removed
- show consumption trends over user selected date ranges
- analyse real usage against target levels
- determine potential supply capacity and power factor problems
- confirm the benefits of installing more energy efficient equipment and highlight further areas for making savings
- identify the need for maintenance due to increased levels of energy use
- confirm compliance or otherwise with statutory obligations

Those users requiring automatic report production can utilise those facilities provided for this capability. Many *am&t* systems can interface with other software packages including site manufacturing control packages used by large energy users. So in addition to enabling wider energy control by using the system this 'spreads the word' around the company to assist in promoting better energy management by all the personnel on site.

Furthermore those 'too busy' to manage their daily energy use by analysing usage against production and using their specialised site knowledge can opt for hosted systems where pre-determined report analysis results are made available on the internet via a secure web-site.

In other words there is the system out there for everyone.

Can you afford not to find your system? Remember, every wasted kWh of energy or litre of water etc is part of those £ that should be in the profit line of your company.

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Energy management: A Basic Guide

By Robin Kent, Tangram Technology

Energy management – why worry?

Energy management is a fundamental to sustainable manufacturing and yet many companies have no clear idea of where to start in the measurement and management of energy. Indeed, few companies have carried out even the most basic actions to reduce their energy consumption. Yet this is one of the easiest actions that they can take to improve sustainability, to reduce costs and to improve competitiveness.

A variable cost

The plastics processing industry regards energy as a fixed and uncontrollable overhead cost but this is untrue. Energy is a variable and controllable cost and most processors can reduce energy usage by up to 30% and increase profits by up to 30% through simple management, maintenance and investment actions.

Energy use in plastics processing is a combination of two components:

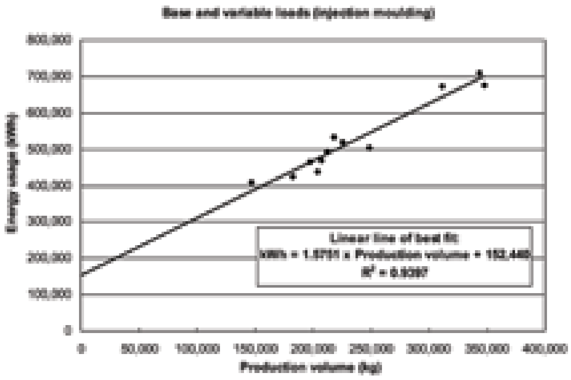
Total energy use =
Base Load + Process Load

The base load is the fixed element of energy use, it is incurred irrespective of whether production is taking place or not and it does not change as output changes. This is the load used for heating, lighting, air leaks from compressors and pumps operating when there is no production at all.

The process load is the variable element of energy use and for most plastics processes it varies directly with the production volume. This is the load used to actually run injection moulding machines, extruders or other process machinery.

The base and process loads can be easily found using available information: Record the energy usage (in kWh) and the related production volumes (in kg) for at least 12 weekly or monthly periods. Plot these using a scatter chart and find the equation of the best-fit line for the data. The best-fit line is the Performance Characteristic Line (PCL) and a typical result for most processes will be as shown in Figure 1:

FIGURE 1: A PERFORMANCE CHARACTERISTIC LINE FOR AN INJECTION MOULDING SITE



The equation of the line of best fit for this data is:

kWh = 1.5751 x Production volume + 152,440
R2 = 0.9397

The good R2 value (0.9397) indicates that the data set is relatively consistent with the line of best fit - not all data is this good.

The equation of the best-fit line can be used to separate the base and process loads:

- The base load (in kWh) is the intersection of the best-fit line with the vertical axis. The example site has a base load of 152,440 kWh/month. This is nearly 30% of the site energy use and is primarily due to operating machinery or services with no productive output. Reducing the base load is possible without affecting operations in any way and is extremely profitable.
- The process load (in kWh/kg) is the slope of the best-fit line. This is the average energy used to process each kilogramme of plastic and shows the processing efficiency of the site. The example site has a process load of 1.5751 kWh/kg.

The PCL shows that energy use varies directly with production volume and can be used to assess a site's energy performance. Simply feed the production volume into the equation for the PCL and the result is the predicted energy usage for the given production volume. For the site shown in Figure 1, if the production volume is 200,000 kg, then the predicted energy use will be:

kWh = 1.5751 x 200,000 + 152,440 = 467,460 kWh

Production accountability for energy use is possible by comparing the predicted and actual energy use for the actual monthly production volume. The simple PCL approach provides a vital tool that can be used to set targets and assess performance of any plastics processing site based on a historical performance. The PCL can also be used to forecast a site's future energy use based on the sales forecast. Simply translate the sales forecast into monthly production volumes and use the PCL to predict the energy use and cost by month.

The PCL gives plastics processing site vital information on where to start looking for energy usage and cost reductions. Sites can:

- Reduce the base load to reduce the fixed costs – this mainly involves switching something off and is a sure way to make savings because the energy used is not production related. Some examples are: idling machines with no production, compressors running with no production etc.

- Reduce the process load to reduce the variable costs – this involves improving production efficiency and is something we should always to trying to do.

Where are we using energy?

Understanding where a site is using energy is fundamental to managing usage. For most plastics processing sites the approximate energy use distribution is as shown in Figure 2:

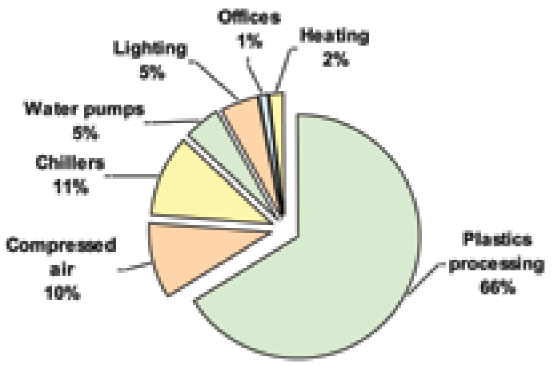


FIGURE 2: APPROXIMATE ENERGY DISTRIBUTION IN PLASTICS PROCESSING

Before starting work, sites need to establish where they are using energy and one of the best tools is an 'energy map' of the site. A typical site energy map is shown in Figure 3 shows where the site is using energy and how much is being used in each area. This can be used to target the high usage areas, e.g. it is rarely worthwhile worrying about lighting – the usage is small and it is better to concentrate on bigger usage areas for bigger gains.

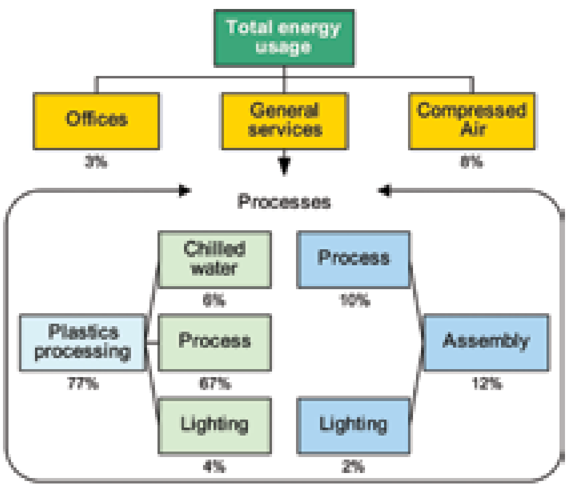


FIGURE 3: A TYPICAL SITE ENERGY MAP

What can we do to reduce energy usage?

Management and measurement

Energy management is the same as the management of any other resource. If you are not managing it then it is managing you and measurement is fundamental. Measurement leads to management: but only if it is on the real management agenda.

TIP Make someone responsible and give them targets.

TIP Report the results widely, it shows that you care.

TIP Get the whole company involved by showing the results and rewarding performance.

TIP Use the data from the PCL to set targets for performance.

Maintenance

Machine selection and operation

Maintenance is not simply the maintenance of the machinery. It is a whole range of activities that do not require significant investment and yet can have a remarkable effect on energy usage and costs. Maintenance is about how the site is operated.

TIP Using large machines for small products always wastes energy. Check that all jobs are on the appropriate machine.

TIP Optimized machine settings reduce energy use. Get machines set right, record the settings and don't change them unless absolutely necessary.

Machines use energy even when idling and this can be anything from 52% and 97.5% of the full energy consumption. An idling machine is not 'free'. Idle periods of greater than 45 minutes may make it cheaper to switch off and restart. Find the minimum stand-by settings and establish setting sheets so that operators always leave machines in this condition when not producing.

TIP Develop and use effective start-up, stand-by and close-down sheets to formalize machine settings and operations.

TIP Stop supplying services, e.g. compressed air and cooling water to idle machines and tooling.

Services

For any service, the best approach is to 'minimize the demand and then optimize the supply'.

TIP Up to 40% of the compressed air generated at sites is lost through leaks. The 'ssssss' noise that can be heard at most sites is profits leaking away.

TIP A simple survey, with leaks tagged and repaired as soon as possible, can greatly reduce leakage. The only tools needed are a good sense of hearing, some soapy water and a brush.

TIP Stop the using compressed air for ventilation, cooling or conveying material or products – any other method is cheaper.

TIP Check that compressed air is not being generated at a higher pressure than required.

TIP Check that cooling water is at the maximum temperature and minimum quality.

TIP Check that cooling water is efficiently treated and distributed.

TIP Set downstream handling systems to operate 'on-demand' – link the controls to the machine operation.

Investment

The cost of the energy used during the lifetime of almost any piece of capital equipment will be more than the initial purchase cost and the initial purchase cost or payback should not dominate the decision-making process. Instead focus on the 'whole life' cost of the investment and look at the long term cash flow to find the product with the greatest benefit. Improved energy efficient technology now makes it possible to re-equip a factory for permanently lower operating costs.

Typical projects have paybacks from under 4 years and often as low as 9 months. Investment in energy efficiency projects can significantly improve profits.

TIP Make 'energy efficiency assessment' an essential part of the capital expenditure approval process. No assessment of operational energy use = No capital expenditure approval.

TIP Get proof of the energy efficiency of equipment and check that it is applicable to your project and needs.

TIP Be prepared to pay slightly more for energy efficient products but be prepared to reap the benefits over the life of the equipment.

TIP Look for projects where the rules can be changed and make energy saving automatic.

The real secret

The real secret is not in the technical aspects – it is in the management attitude. A desire to reduce costs through good energy management and an effective implementation and monitoring programme will always produce the results and the commercial benefits.

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CHAPTER 5

Ancillary Equipment For Energy Efficiency

Microscale Polymer Processing – advanced software tools and potential applications

By Dr. Suneel Kunamaneni, University of Leeds

Introduction

The Polymer IRC (Interdisciplinary Research Centre) at the Universities of Leeds, Sheffield, Durham and Bradford in conjunction with the Universities of Cambridge and Oxford has, over the last 10 years, successfully run a world-leading project, the "Microscale Polymer Processing" consortium (μPP).

The aim of μPP was to develop an understanding of how molecular parameters affect the processing of industrial polymers. This was achieved by the unique idea of synthesising small quantities of polymers with known molecular parameters in sufficient quantities of a few grams, to allow them to be processed using specially designed rigs. Ultimately, the aim was to follow the processing path of well characterised polymers from synthesis, through processing and property evaluation, combined with the parallel development of a mathematical and computational modelling protocol. Please visit www.mupp2.com for more details.

In spite of the increased sophistication of polymeric materials, now designed with many molecular parameters in mind, the choice of resin is still more an art than a science. Requirements often specify no more than the "melt flow index", a number which can have little or no relevance to the actual process performance of the plastic. The missing information is the set of rules that connect the molecular structure of a polymer to its process performance in a predictive way, expressed in terms that SME converters can handle. This leads to huge wastage in down-time, poor supply-chain and consequent lack of competitiveness. There is therefore a huge opportunity to supply this sector with latest tools based on new physics generated within the μPP consortium.

The many potential benefits of these tools include:

- Precise choice of plastics grade and processing parameter's using latest scientific tools will yield savings in overall production cost and energy (less waste).
- Establish the importance of batch to batch variation from the polymer supplier.
- Considerable reduction in time-to-market.
- Improved processing translates into improved product quality.
- Increased knowledge assurance and awareness of Polymer science among SMEs thus stimulating better judgement.
- Enable the companies to secure niche markets.

In the following sections we describe some of these tools.

FlowSolve – theory in application

FlowSolve is an advanced Computational Fluid Dynamics (CFD) software, developed at the University of Leeds, for the analysis of polymer processing and hosts a library of molecular polymer melt models. FlowSolve is capable of visually predicting process features of plastic melts that depend on their specific molecular structure.

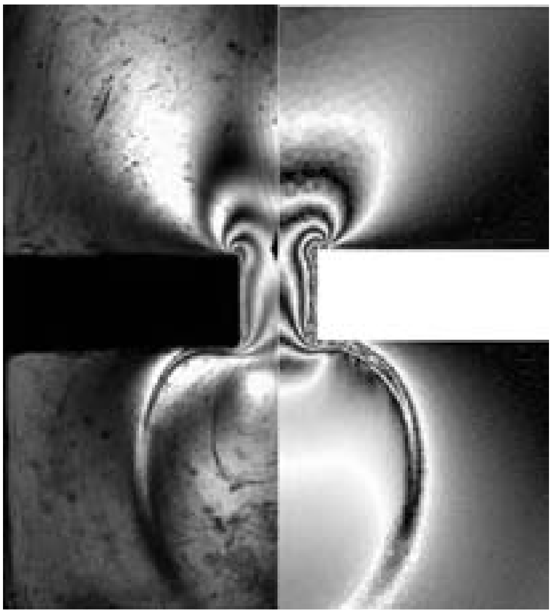


FIGURE 1: FLOW OF A POLYETHYLENE MELT THROUGH A CONSTRICTION: PREDICTED (RIGHT) AND MEASURED (LEFT); THE FRINGES INDICATE QUANTITATIVE LEVELS OF STRESS IN THE FLUID.

There exists a fundamental lack of quantitative and qualitative knowledge with regards to the relationships between machine design, total process operation and polymer flow. This knowledge gap has been identified as a major barrier to the advancement of polymer processing. FlowSolve will significantly strengthen the knowledge-base available to the polymer industries, enabling the realisation of new and optimised materials with enhanced properties and functionality, greater process efficiency and energy reductions.

REPTATE – analysing rheology made easy

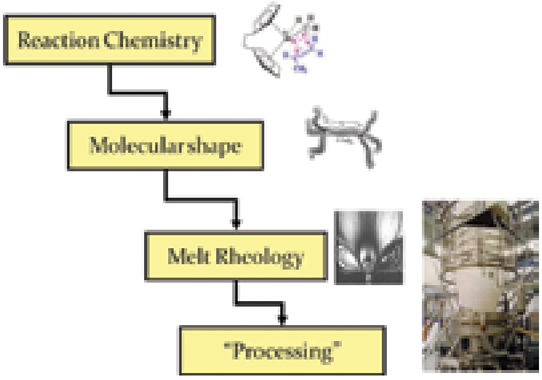
Rheology, which is the study of fluid flow, is a fundamental tool in polymer research and is a central science that can be applied successfully to material systems as seemingly dissimilar as tomato ketchup and paints, and the use of rheometric instrumentation in development and quality control is well established in the plastics industry. As a comprehensive materials and process design tool, however, the traditional rheometer is of limited use.

We have therefore developed the REPTATE (Rheology of Entangled Polymers, Toolkit for Analysis of Theory and Experiments) software which is uniquely suited to understand the molecular structure of polymers using advanced physics based theories. It has potential applications in understanding batch to batch variability, reducing operator variability, increasing efficiency and designing new polymers for a given target application. The main idea of REPTATE is to create a platform which makes comparing theory and experiment much easier than ever before, in order to fast track development of new materials and optimize existing production processes. Please visit www.reptate.com for further details.

BoB and REACT – nothing is impossible

The processing properties of plastics are governed by the reaction chemistry used to make the material. The reaction chemistry controls the structure (branching) of polymer chains. Understanding the links between the chemistry and final properties is key to designing tailored polymer materials.

We have used this idea to develop the Branch on Branch (BoB) software tool. This prescription has been used successfully for modeling the properties of both conventional LDPEs and metallocene catalyzed polyethylene. A separately developed reaction chemistry software REACT is used to produce the input for the BoB tool. Product development with this tool can help move metallocene polymers from specialty applications focus into the arena of commodity markets and applications. In making this move, economic considerations and manufacturing efficiencies become important drivers of technology development. For further information on BoB, please visit http://sourceforge.net/projects/bob-rheology/. Both BoB and REACT are also embedded in the REPTATE platform, albeit with few less features.



Conclusions

The microscale polymer processing project has radically transformed understanding of polymer rheology and processing, from a phenomenological based approach to that based on physics, which is both descriptive and predictive. We have used the science to create novel polymers, both unfilled and filled, that extends the range of processability, into areas previously unobtainable and expect these developments to grow in the future.

The software tools enable connecting in-house process knowledge (knowing how to make molecular systems) with application properties (knowing which molecular systems have certain properties). These tools can give plastics producers and processors a competitive edge that is essential in today's environment.

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Improving performance with manufacturing execution & intelligence systems

By Andrew Jewell, Mattec Ltd (Solarsoft)

Supervisors and Managers require a clear view of manufacturing performance. Plant Managers needs answers to questions like: which machines are idle, who is waiting for materials, when will that job finish, what is the current yield?

In the board-room, the questions may be different: which plant achieves the highest productivity and why?

But the challenge is shared - how to achieve:

- Better Overall Equipment Efficiency (Improve OEE)
- Improved yield through reduced defects and scrap
- More accurate scheduling and delivery forecasting
- Efficient schedules for preventive maintenance

From Top Floor to Shop Floor Manufacturing Execution Systems (MES) and Enterprise Manufacturing Intelligence (EMI) deliver unprecedented clarity and insight into manufacturing performance at plant level and across the entire enterprise.

ENTERPRISE RESOURCE MANAGEMENT

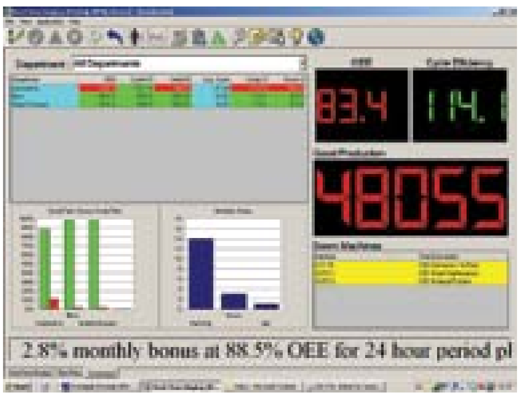
Ready-to-run configurations are available for:

- Consumer packaged goods
- Food & beverage manufacturing
- Industrial applications
- Metal stamping and die-casting
- Pharmaceutical & medical manufacturing
- Plastics and rubber injection molding, extrusion & blow molding

Key Benefits of Manufacturing Execution and Intelligence technology is designed to support manufacturing performance improvement initiatives.

The system allows companies to:

- Access clear, easy-to-understand analytics and reports that show OEE, downtime, waste and other important key performance indicators
- Collect and analyse data across multiple plants, production machines/lines and asset types
- Increase productivity, unlock capacity and reduce inventory and labour costs
- Reduce scrap, waste and rework with up-to-the minute monitoring of process conditions
- Resolve issues before they arise with real-time alerts and notifications
- Exchange data with other factory floor and enterprise systems
- Model and test manufacturing scenarios to prioritize actions
- Create improvement strategies by region, product family and/or asset type
- Assess the accuracy of planning rates used in ERP, supply chain and scheduling systems
- Eliminate idle lines and backlogs by improving planning rates
- Optimize plant loading with real-time drag and drop scheduling software



MATTEC REAL-TIME MANUFACTURING/SHOP-FLOOR PERFORMANCE REPORTING

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CHAPTER 6

Increasing The Use Of Recyclate In Plastics Products

Understanding the plastics recycling industry's value chain

By Keith Freegard, Axion Recycling Ltd

How do you add value by recycling plastics? Where in the process is most value added to the product? And who appreciates the real value of the material?

The act of 'RECYCLING' is a complex process which starts with the disposal of waste items and ends with the re-use of a value-added material to deliver a set of customer benefits.

The full recovery process from the point of waste-creation to eventual re-use as part of a new product, can involve a large number of collection, sorting and separation stages. Often, several complex processing and conversion operations take place and the recovered material passes through several changes of ownership before returning to a new-life with a consumer. Each successive owner of the material will be driven to either minimize the cost of waste disposal or to maximize the net profit of re-processing during their temporary ownership phase as part of the complete recycling loop.

The same plastic item, which changes from being a *'waste problem = cost'* to the end-of-life disposer, has be 're-born' as a *'product = value'* when fully recycled and re-used. The skill for the recycler is to be aware of how to preserve the embedded value in the material as it moves through the whole, complex process.

'User Value = perceived benefits'

A marketing manager in the recycling sector needs to know how to add more value by increasing the number of customer benefits associated with the use of the supplied polymer material. Therefore adding value to a polymer implies an ability to understand the exact needs of the customers (N.B. – there ARE more than one) and at what point in the downstream value chain the 'real customer' is positioned.

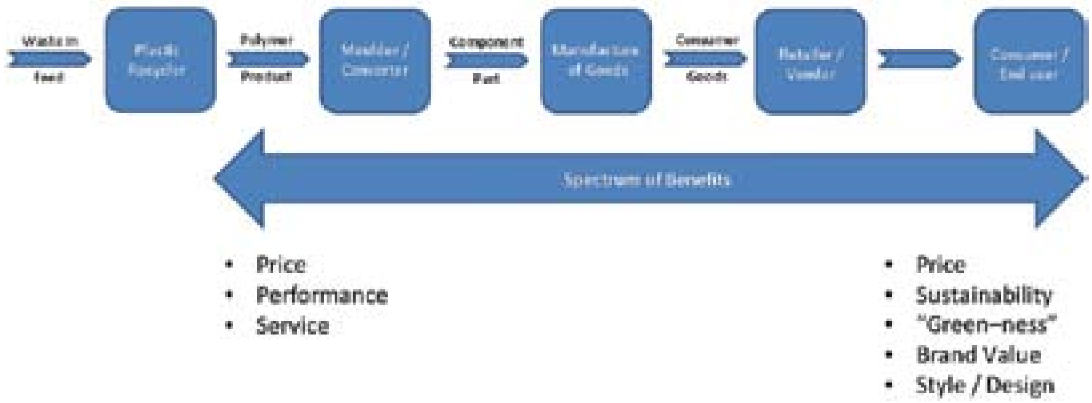
Example

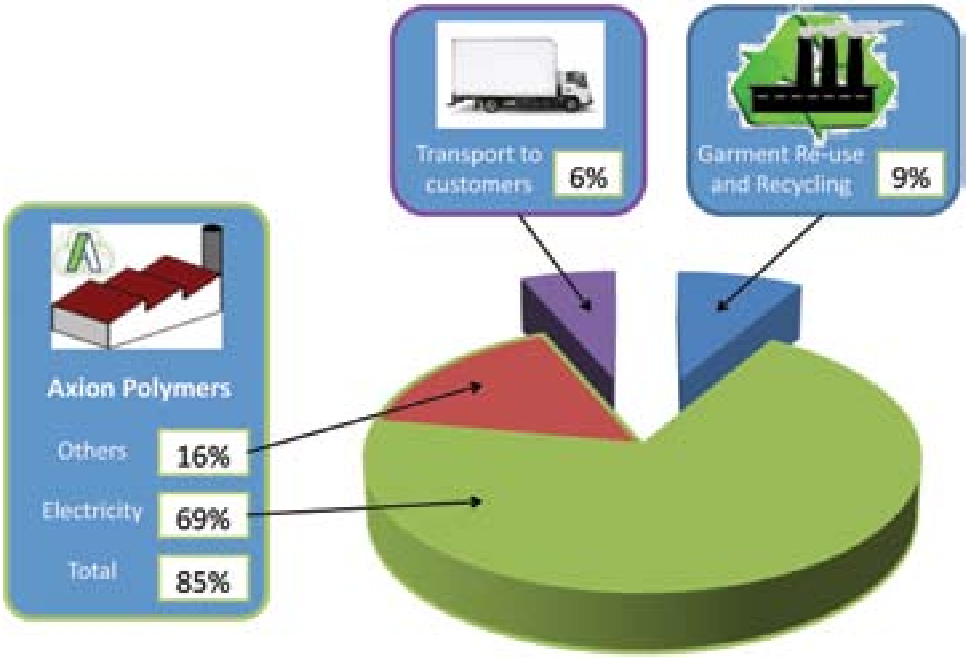
When selling resin compound direct to a moulder of a component for electrical goods, the plastic buyer at the moulding company simply wants a good quality polymer which meets the technical specification and at the lowest possible price per moulded part.

However the part is only being made to meet the demands of the electrical goods manufacturer, who will use the part in a final assembly, and the electrical goods are then sold onto a retailer and eventually an end-user – maybe a householder or a business consumer.

Only at the final purchasing point (retailer-to-consumer) are ALL of the attributes of the product evaluated against the end-user customer's list of important benefits – this list might include, brand-name, functionality, artistic style and design, energy consumption, reliability AND – as an increasing part of the 'overall purchasing decision' – environmental impact of the item – or 'greenness'! (In today's highly competitive marketplace it is a 'given' that the customer will be faced with several choices of branded goods which are almost equal on a price versus functionality comparison; so it is the evaluation of the above list of perceived benefits which swing the final choice of product.)

This makes life for the plastic recycler difficult: at the first sales transaction, the polymer product has to 'win' on a simple price and technical performance comparison (being made by the plastics buyer and





manufacturer's equipment designer), BUT also there is a more complex sales and marketing job to be done to carry the perceived benefits of the product's unique history and environmental credentials all the way down the value chain to the eventual purchaser of the item in a retail environment.

The secret of success in this competitive arena is to realise the importance of the upstream supply chain into the recycling factory and to organise the flow of materials so that the value-adding attributes of the waste feed-stocks are not lost in the re-processing stage.

In order to carry forwards the aspects of the upstream supply chain through the recycling and conversion processes and make sure that they are being noticed and valued by the end-users (i.e. OEMS, retailers and consumers) – the recycler must set up fully traceable inward supply streams with clearly defined segregation between different groups of feedstocks.

For example, at Axion Polymers we produce each of our primary polymer grades from exactly the same type of waste feedstock. So grade *'Axpoly® PS01 – high-impact polystyrene'* is only made from recycled refrigerator plastics collected under the WEEE processing system. Keeping this firm and fixed link between the origin of the waste feedstock and the individual grade adds-value to the polymer we produce. Customers like to know 'where has it come from' and being able to guarantee this in a fully traceable manner for every batch we produce is perceived as important to the downstream users. Statements such as *'Washing machine with parts made from recycled fridge plastics'* OR *'This flat-screen monitor has been made with plastics recycled from end-of-life TVs'* convey a simple-to-understand model of sustainable product manufacturing to the end-user and have a kind-of 'green-logic' which makes sense to the man on the street.

Once the principle of keeping the inward raw material waste streams well-defined and segregated has been established and 'built-into' the company's operating model, other benefits start to appear. For example, it is then relatively straight forward to evaluate the carbon impact of the raw material supply chain and the processing stages for each of the Axpoly grades, because the structure of the inward supply chain is very similar across the defined set of suppliers in the WEEE treatment sector. Carbon Footprinting techniques can be used in parallel across the different suppliers to label each of the Axpoly grades with a fixed and audited carbon impact figure. This new 'carbon currency' is beginning to be understood and utilised by retailers as a useful way to evidence and display the sustainable value of products onto consumer goods at the point of purchasing.

At Axion Polymers we have successfully combined these end-user perceived values into our 'Axpoly®' brand-name which carries forward the inbuilt attributes of quality, reliability, low-carbon and traceable origin of the material down the value chain to the person who gains most benefit from those 'brand-values'. Our ultimate success is measured when the marketing manager in a large OEM tells his equipment designer to specify the Axpoly® brand and the moulder's plastic buyer is left with no choice but to 'call Axion!'

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Increase the use of recyclate in end products without reduction in quality, and with improvements in production efficiency

By Kerry Bodin, Triton Technology Ltd

Recycling environments can mean several things to different organisations;

If we first consider a production line where articles are being extruded or injection moulded there will always be a certain amount of waste material. If the original material used is a virgin grade of known quality, the assumption is that this waste will be the same and can be used with little or no risk in the same process or bagged off and sold on as a known polymer. This may or may not be true. Contamination can occur if more than one type of polymer is present in the factory and polymers are also thermally labile and may or may not have degradation that could affect the final properties of the articles being produced.

Consider also a second situation in a recycling company - many tons of mixed polymers will be present. Mechanical sorting using a variety of techniques can sort out a considerable portion of the material. Waste can be from domestic or industrial sources e.g. bulk waste from polymer converters which should have some known providence. Unfortunately, the quality in reality can be highly suspect unless substantial comprehensive testing is undertaken. Even the most sophisticated separation technologies will always fail to completely isolate all the different polymers. There are also many grades of each polymer type and these certainly are not easily sorted.

Generally before using and after sorting, all these materials are subjected to regrind and sold on with an indication of type and quality. The most common indication used, though not necessarily the only one is the melt flow index (MFI) value. This may or may not be adequate. In essence, a single point in the rheological profile of the polymer in question is used to indicate its quality. This is not a characterisation and will not profile the overall properties of the regrind material. Further more, this cannot provide a safe comparison against a virgin material.

As mentioned earlier, a more comprehensive testing regime is required to characterise these materials sensibly and provide an assessment for use. Traditionally, these tests would in most cases be uneconomic and unsustainable for any operation in the recycling chain. The common approach for providing a more comprehensive characterisation of polymers uses thermal analysis techniques. Two in particular are very good at providing comprehensive thermo mechanical profiles of polymers. These are Dynamic Mechanical Analysis (DMA) and Differential Scanning Calorimetry (DSC). Unfortunately, these are expensive, time consuming and require careful evaluation of the results by a skilled scientist. Additionally, no statistical assessment of product quality is achieved using these instruments.

A new product, the identiPol QA, produced by Triton Technology Limited, strives to solve many of these issues outlined above. In essence, a device has been produced that can profile the thermo mechanical properties as found on a DMA and DSC in one small and at a substantially lower package cost. Typically the unit is set up to take small samples of the material. A test sample is prepared in the unit and run rapidly, especially in comparison to the traditional equipment. This only takes 10 to 15 minutes in total, including the cool cycle, preparing the unit ready to run another test.

The first stage of evaluating the quality of an unknown material is to teach the unit what the thermo mechanical profiles typically look like. The user does not normally see these or indeed need to, but they can be accessed if required via a management programme.

The user will typically need to 'feed' the unit with at least 10 to 20 samples of the material being assessed before a reasonable Quality Index Score (QIS) can be produced. The user should understand that the all polymeric material varies to some extent therefore the more material run the better the evaluation.

After the learning set of a minimum number of samples have been run, the device starts to output QIS scores. The learning set produces an envelope of acceptable values for subsequent tests. If these fall in the envelope, they would normally be added until a substantial data set is reached. In order to reduce the risk of missing a low level drift in the material, a maximum number of samples in the training set is fixed as well as a minimum. This is typically 50. If an unknown material falls below the minimum envelope threshold, further samples must always be run to check if the material is definitely different or not. If low results continue to be produced, the thermo mechanical profiles can be examined by the manager or the data can be forwarded back to Triton for comment.

It should be understood that it requires the identiPol QA to be installed as part of a general quality regime. Other relevant tests should also be considered. For example, the MFI value is still a useful indicator of processibility. The testing of materials passing through an organisation should be at an appropriate level to reveal a true statistical evaluation of the quality of materials being used or produced.

The unit has additional tools that can be used to compare data sets, grades or even polymer types. In addition to the QIS score, a report is available showing the Glass Transition (Tg) and Melting Point (Tm), where applicable. These can aid confirmation of polymer identity and show whether the material is an amorphous or semi crystalline polymer.

This new technology designed and developed by Triton is not generally affected by fillers or colourant. It checks material via the materials' thermo-mechanical properties, so even glass filled nylon with up to 60% filler will be correctly identified as nylon material. Also, carbon black and other colourant have no major effect on the thermo mechanical properties and therefore do not prevent the ability of the unit to identify the material as would be the case with Infa Red. It should be pointed out that a virgin material and one with filler and / or colours may almost certainly have different thermo mechanical properties and the unit will detect these if they are significant. Indeed, this may well be highly relevant for operator.

Used as indicated above, the identiPol QA can fill a major gap in many operations where polymers are either being produced or used. It has particular high relevance for assessing recycled materials.

The device works with virtually any thermoplastic and can be operated by non scientific staff with ease. The capital cost and ongoing consumable costs are very low compared to traditional thermal analytical technologies and additionally provides extensive statistical comparisons of complex scientific information. This is essential for Quality Assurance purposes.

Appropriate use of this device can also prevent misuse of material, inadvertent loading of hoppers, extruders etc. with incorrect material and the consequent cost savings of emptying and cleaning out of plant.

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The effective reuse and applications for mixed plastic waste

By Kevin Ross, Impact Solutions

Introduction

We use plastic every day of our lives, at work and at home, and much of it has a very short life cycle. The question of what we do with end of life plastic is of growing importance due to environmental concerns and in some parts the developed world, the escalating costs of disposal (often the result of deliberate government policy). So, given these commercial and other pressures why is all plastic not recycled?

The Challenge

The two most significant stumbling blocks are material variability and the costs associated with identifying and separating waste plastics into recognisable grade ranges. The more knowledge you have about the material you intend to recycle the easier it is to put into valuable second use applications.

Plastics are highly engineered products manufactured in sophisticated and highly controlled manufacturing operations to meet clear specifications which correlate to a well defined set of physical properties. These properties are chosen to fit specific end-use applications and set the manufacturing specifications.

For example, polyethylene is produced using numerous different technologies in a wide range of densities and molecular weights. The resulting materials are designed to suit thousands of specific applications, ranging from assorted films, blown/rotationally/injection moulded bottles, sealing caps, oil tanks, specialised gas & potable water pipe grades through to Ultra High Molecular Weight Polyethylene (UHMWPE) often used in biomedical applications. This already diverse supply chain is further complicated via blending, the use of additives (colour, UV protection etc.) and fillers. Furthermore, end users can also add their own functional additives and may use two or more very different plastics in a product. (e.g. composite films)

As a result, single plastics with known properties and additives are the easiest to reuse, assuming they can be collected and reprocessed cost effectively. However, in many cases it is not cost effective to collect waste plastics due to low volumes and material diversity. Technically it is possible to separate most mixed plastics into recognisable streams, but commercially this is currently only economically feasible for higher value plastics. (e.g. PET or the HDPE used in bottles)

Effective recycling therefore is dependent upon knowing the property range of the materials you separate, having an efficient collection infrastructure that can consistently gather the desired products and a method of reprocessing the waste plastic that produces a product suitable for re-use.

There are two extremes on the recycling continuum; at one end of the scale is the factory which reprocesses its own off-spec products, and at the other end of the scale is material such as the plastic blend found in domestic black bag waste which can contain large numbers of different polymers which are often contaminated. Variability and the investment cost of separation equipment are key reasons why only 25% of domestic plastic waste and 40% of bottles are recycled.

The Impact Solution

Impact Solutions has been working on developing applications for diverse and varying blends of plastics, and is also evaluating novel low cost plastic separation technologies based upon density separation.
Impact Solutions believes if this technology can be commercialised it could significantly increase the volume of available recycled plastic.

Most currently available recovered plastic streams will almost certainly be a mixture of different polymers, different grades, and different colours. This is especially true of plastics in domestic waste streams. Currently the market for lower value mixed plastic is limited with much being exported to low labour cost economies where manual separation of higher value fractions is feasible, and where residues can be used in other applications such as fuels. There are however applications being developed to utilise lower grade mixed plastics some examples being:

Powder Impression Moulding (PIM): A process where low value and even highly diverse plastic blends can potentially be used to create a range of moulded items. This process is now being successfully used in the production of hoarding panels by the UK's 2K Manufacturing.

Encapsulation: Using the recycled plastic as a "former" which is then encapsulated by a thin layer of higher value plastic. This enables the product to have the appearance and much of the performance of the higher value encapsulated plastic.

Fibre Plastic Composites (FPC): Have experienced significant growth since the early 1990's in the US and have been successfully developed for niche applications in Europe. Composites can contain a wide range of both plastics fibres from high value PET with carbon nano-tubes to low value wood and other waste cellulosic fibres combined with mixed polyolefins.

Impact are actively developing FPC formulations and applications for low value plastic blends and using these in combination with low value, difficult to recycle waste fibres. Our goal is to produce low cost FPC, initially for low tech outdoor applications including decking and fencing. We are also targeting development of formulations suitable for wood replacement in internal applications such as skirting and other non-structural uses.

Historically the key barrier to the successful introduction of FPC's in Europe has been their high costs due to the use of either virgin polymer or single grade highest value recyclates. Impact Solution's recent work in this area has focussed upon the low value plastic obtained via a mass treatment of un-segregated domestic black bag waste. We have successfully combined various fractions of this waste stream with a range of low value fibres including MDF, wet strengthened paper waste and even waste carpet trimmings. The work has seen Impact produce FPC's which have the required physical properties for our chosen applications. If our scale-up efforts are successful these will be produced at significantly lower cost than current FPC's. This work is being supported by the Scottish Government and current effort is focused on better defining a clear processing window and producing pilot scale quantities of selected formulations.

IMAGE 1: UNSORTED BLACK BAG PLASTIC WASTE POST MASS TREATMENT

The use of low cost waste steams as plastic additives and fillers is another area of active investigation for Impact. The addition of filler usually results in a reduction in polymer cost due to substitution. In particular, Impact has examined the performance of a low value and readily available powder waste that behaves similarly to higher value talc fillers. This material has proven to be easily incorporated and processed, and commercial scale trials will commence in the near future.

The Future

Many technologies exist which facilitate the separation of mixed waste plastic into fractions of various purities and values, but the economic argument for using these on the majority of low value mixed plastics is still very far from proven. However, it is Impact's view that current developments in large scale, more efficient processes for handling un-segregated waste will change both these economics and step-change the availability of consistent plastic waste.

Surely the key challenge for us all is to view ALL plastic waste as a valuable resource and to develop techniques and processes that convert these materials into ever higher value products.

Impact is at the forefront of this activity, and is proud to be involved in efforts to maximise the reuse of this valuable resource.

IMAGE 2: BLACK BAG WASTE PLASTIC POST SORTING

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Recycling of Engineering Polymers

By Oana Ghita and Mike Sloan, Exeter University

Established in 1997, Exeter Advanced Technologies (X-AT) is a team of industry focused multi skilled technical researchers based within the College of Engineering Mathematics and Physical Sciences at the University of Exeter. As a self funding organisation, X-AT specialises in applying its expertise to industrially focused grant funded research projects and commercial consultancy services. Its core expertise is in materials selection and characterisation and across its 19 current research projects, in which knowledge is applied to enhance the sustainability of materials and manufacture.

One approach to sustainable manufacturing is to recycle materials.

The European (FP7) funded project EURECOMP aims to develop a novel, eco-friendly, and closed-loop route for recycling thermoset composites through solvolysis. It gathers partners from various fields of activity including universities, research centres, and industrial companies (from materials producers to end users).

The water-based solvolysis process (Figure 1) separates composites into different components, such as fillers, fibres and matrix compounds, under specific temperatures and pressures for reuse in new applications. The recyclates, (thermosetting resin and reinforcing fibres), are subsequently investigated in order to optimise the process and the quality of the products.

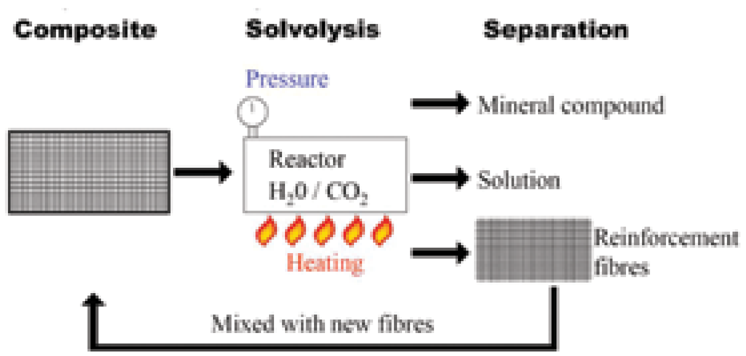

FIGURE 1. SCHEMATIC DIAGRAM OF THE SOLVOLYSIS PROCESS

The technology is expected to solve the problems of recycling thermoset composites and overcome the drawbacks of other recycling techniques. Because solvolysis depolymerises the chemical bonds in thermoset resin, it enables the organic components of the composites to be reused. Furthermore, in comparison to mechanical granulation processes, solvolysis can maintain the length of the recovered reinforcing fibres so that they can be reused for specific industrial and technical applications.

Building upon the success of the Technology Strategy Board (TSB) funded recycling project RECCOMP (Recycling of thermoset composites for automotive applications), the team at X-AT contribute to EURECOMP by mechanical characterisation of the recyclate fibres obtained from the solvolysis process. Advanced fibre micro-testing facilities at X-AT are used to facilitate the investigation of single fibre mechanical properties (e.g. tensile and interfacial properties). In the past, it has been shown that the mechanical performance of recyclate fibres is strongly affected by recycling processes such as pyrolysis and mechanical granulation. To minimise degradation of fibre strength, EURECOMP will carefully optimise the solvolysis process through a detailed investigation of its various parameters and the products recovered.

The project explores not only the fundamentals of solvolysis but also the practical implementation of the technology. In addition, the project collates information regarding the implications of solvolysis for upstream and downstream markets, economic efficiency, and life cycle assessment.

Building on the recycling theme of EURECOMP, the second approach taken by the team at Exeter is to reduce the waste of current manufacturing processes illustrated by the TSB funded CAPSCRAP project. Working with ten UK based polymer companies the team at Exeter aims to minimize and recycle the waste generated from injection moulding in-house. For the past two years, X-AT has helped partner companies Robinson Plastic Packaging and ALGRAM to clean the containments from their waste stream using novel separation techniques and convert it to a high value recylate stream. Much of this waste is caused by variability in the supply of raw materials and an inability to monitor their charaterastics online (i.e. whlist being processed). The project is developing a methodology to prevent scrap from being generated at source by close monitoring of the polymer melt during injection moulding. This is achieved by employing an in-line monitoring system developed at Exeter in conjunction with Colormatrix Europe Ltd. (the project leader). The system uses two optical fibre probes that continuously monitor material as it flows through the injection nozzle. In this way, real-time spectroscopic information on the condition of the liquid polymer can be collected during the injection process. This offers a solution to materials related problems by providing additional process control based on the real-time condition of the material itself, rather than operator judgement. Other consortium partners Boots plc., Becton Dickinson, Data Plastics, AAVF, and the British Plastics Federation are excited by the possibility of monitoring polymer properties such as mositure content and material degradation in this way. The team at X-AT are working with individual partners to design tailored solutions for each company (i.e. to exploit the in-line monitoring system in a manner that best suits their needs). It is estimated that 63% of the UK plastics sector could potentially benefit commercially from CAP-SCRAP technology.

In addition to recycling and reducing waste, researchers at X-AT are applying their skills to boost sustainability from the very first stages of manufacture. By replacing synthetic materials with sustainable ones, and reducing the net energy input into manufacture, the TSB funded ECOBRAKE project is developing novel brake pads for mass rail transit applications.

Figure 2 shows a pair of rail brake pads, with a 50 pence coin for scale. Four of these pads are used on each disc.

FIGURE 2: A UIC200 BRAKE PAD FOR RAIL PASSENGER VEHICLES

A conventional brake pad is a complex composite of more than 10 ingredients, bound together by a synthetic resin (bakelite). Material formulations are developed empirically and manufactured into brake pads using technologies based around asbestos fibres, which have subsequently been replaced with aramid. In a conventional brake pad, neither the resin (its greatest single component), or the fibres (its most expensive component) are sustainably sourced. The manufacturing process is also incredibly energy intensive. The ECOBRAKE project is developing a new method of manufacture that requires considerably less energy and makes use of environmentally sustainable materials. Synthetic phenol-formaldehyde resins have been replaced with ones derived from Cashew Nut Shell Liquid (CNSL), and aramid fibres have been (partially) replaced with hemp.

Found in the husk of the cashew nut shell, raw CNSL is a viscous substance that contains a variety of naturally occurring phenolic compounds. It accounts for

18 – 27% of the raw nut weight and, since the shells are a waste product of the food industry, is in cheap and plentiful supply. After extraction, the major component (~60%) of CNSL is 'cardanol', which can be used to synthesise phenolic resins.

In the new manufacturing process, aramid can be completely replaced by hemp fibres – grown and extracted in the UK by Hemp Technology Ltd. Hence, there is potential to extend this technology to produce a host of eco-friendly structural composites at a fraction of the energy consumed using current processes.

Developing the friction materials using novel fibres, resins and a new manufacturing process requires a detailed understanding of the raw materials. Samples are analysed throughout the research to characterise their mechanical and thermal behaviour so that the manufacturing process may be tailored to optimise their performance.

Tested on a full-scale rail simulation inertia dynamometer, brake pads made with hemp fibres and CNSL-based resin exhibit significantly better wear performance than the current market material. Supplementing the hemp fibres with a certain proportion of aramid enhances this performance by up to 40% and results in a brake pad that contains a significant proportion of sustainably sourced, lower cost materials and is produced by a manufacturing process that is quicker, cheaper, more reliable and uses less energy.

Sustainability is a core part of the material research taking place at the University of Exeter, for further details please contact Exeter Advanced Technologies.

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CASE STUDY

The world's first 100% recycled PVC window

By John Warren, Epwin Group

The first ever commercial installation of PVC-U windows manufactured from 98 per cent recycled content was completed by the Epwin Group, a UK based extruder and window fabricator, last year marking the beginning of a new era in PVC-U building product sustainability.

The PVC-U window industry continues to encourage recycling and the public acceptance of recycled products. Having promoted and pushed PVC-U sustainability, launching a wide range of recycled component products, it has taken a significant stride forward, manufacturing and completing a commercial window installation using profile made from virtually 100 per cent recycled material.

The recycled profile, a first for the sector, was extruded by Epwin Group systems company, Profile 22, which along with its sister company Dekura UK, has long been at the forefront of innovation and sustainability in the UK PVC-U window and building technology.

The product is laminated to ensure colour consistency and achieves a total recycled content of 98 per cent. Manufactured and installed in a social housing project in Manchester, England, the installation, which was a true closed loop process, is a first for the window industry and the social housing sector, claiming the Best Product category at the UK National Recycling Awards 2009.

"Although we had had the technology to produce a high recycled content product for more than seven years, it was the first time that the commercial climate had been right to deliver it. It was a first for us, first for the industry and has proved an effective tool in showing external audiences just how far the PVC-U building products industry has moved forward", says David Wrigley, managing director, Epwin Group Extrusions Division.

The Dekura service is unique in the UK, able to offer a post-consumer end of life recycling service with full cycle traceability on all of the material that it collects. This allows social housing providers and contractors to follow old material through the recycling process, providing demonstrable and auditable trail that can be used to support the site waste management planning process.

Wrigley argues that it's the downstream activity that is now the Group's greatest focus. "Whatever business might want to claim about its commitments to the environment, ultimately the economics need also to be sustainable.

"For that reason we see downstream integration as of paramount importance because that's where we and the industry achieve added value. As a consequence, our efforts as a Group are focussed on designing products that deliver dual commercial and environmental benefits.

"These are products that can be manufactured more efficiently, that perform better in life and which can be recycled more easily as one life cycle finishes and the next begins."

Based on figures from Recovinyl the carbon footprint of the profile extruded in the Manchester project was just six per cent of that of virgin material. And even after the application of a thin white wood grain foil – applied to ensure colour uniformity and weather performance – it still delivered a significant CO_2 savings.

In a similar vein Swish Building Products – also an Epwin Group business – has launched a new recycled rainwater system. Bringing thousands of tons of end of life material back into use the rainwater and guttering system is manufactured from 84 per cent recycled material which produces 70 per cent less CO_2 than would be created in manufacture from virgin material.

"But it's not necessarily the headline products that are delivering the biggest financial wins or changes" says Wrigley. "Industry is only going to buy-in to sustainability if it makes commercial sense to do so."

He continues: "Our composite recycled PVC reinforcement from Profile 22 is a case in point, illustrating how efficiency and sustainability, not just environmentally but financially, must combine in product development.

"It replaces steel or aluminium reinforcements in the window manufacturing across the whole range of profiles.

On the face of it appears a fairly simplistic concept - a simple window reinforcement - but what it represents and the efficiency that it delivers, both in manufacturing and the use phase, make it such an important product for the industry.

"Raw material prices, whether steel, aluminium or oil for that matter are increasing. In tapping into a comparatively abundant material – waste PVC-U – we're able to insulate ourselves and our customers from the bigger price increases that will be inevitable in the future".

Wrigley concludes: "On a very fundamental level, the recycling of PVC-U is absolutely necessary if we as an industry are going to meet regulatory requirements and to stave off challenges from other competitor material suppliers.

"Significant progress has been made – not just by us but by our colleagues in other PVC-U systems companies. We have the processes and technical innovations and we have the products, we must now ensure that the sustainability benefits of PVC and recycling are understood and demanded by our customers and the world in general."

*David Wrigley is managing director for the Epwin Group's extrusions division and founder member of PVC-U sustainability campaign, PVCaware.org and committee member of the British Plastics Federation.

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98 per cent recycled window – a UK first

Windows with a 98 per cent recycled content, were installed in properties managed by Manchester ALMO, Northwards Housing in March 2009.

Having previously recovered almost 70 tonnes of waste material from a tower block managed by the ALMO, Dekura supplied recovered and reprocessed material to Profile 22 which re-extruded the material. The new windows were manufactured from fully recycled material other than for a thin virgin foiled 'skin', added to ensure colour uniformity.

The project marks a first for UK social housing but also a significant stride forward in PVC-U sustainability winning Best Recycled Product category at the National Recycling Awards 2009.

The Epwin Group – an overview

With unparalleled experience in the supply of low maintenance PVC-U products to the home improvement, social and new build markets, Epwin Group companies are at the forefront of innovation in PVC-U building technology.

Founded in 1976 by group chairman Jim Rawson the Epwin Group has grown from a modest business start-up to boast more than 30 separate brands. With 1.2 million sq ft of production and warehousing facilities, the group today employs more than 2,000 people across the UK with an annual turnover in excess of £188million at its last published accounts.

CHAPTER 7

Biobased And Degradable Plastics

The Case for Bio-based Plastics

By Dr John R Williams, NNFCC

Introduction

Bio-based polymers have been used in many applications for thousands of years, and there was resurgence in the development of artificial bio-based plastics from the mid 19th century until the early 1940's. The main reason for the lack of commercial production was the discovery of crude oil and its large-scale use for plastics since the late 1940's.

It is now often taken for granted that plastics are made from fossil derived oil. The rising cost of oil, regulation and mounting concern over climate change has necessitated a move towards renewable sources of polymer feedstock.

Production of plastics from plant products and biomass offers the potential to replace non-renewable materials derived from petroleum with renewable resources, resulting in reliable supply, jobs in rural communities, sustainable production, lower greenhouse gas emissions, and competitive prices.

The increasing pressure on fossil derived resources because of concerns over climate change and supply security has led to an increase over the past two decades in the developments and industrial scale-up of bio-based plastics.

Bio-based plastics

The early stage developments were improvements in starch and cellulose derived materials but over the last 5 years there has been a huge expansion in the portfolio of products available. Examples include PLA from lactic acid, PHA's from fermentation platforms and polyethylene from bioethanol.

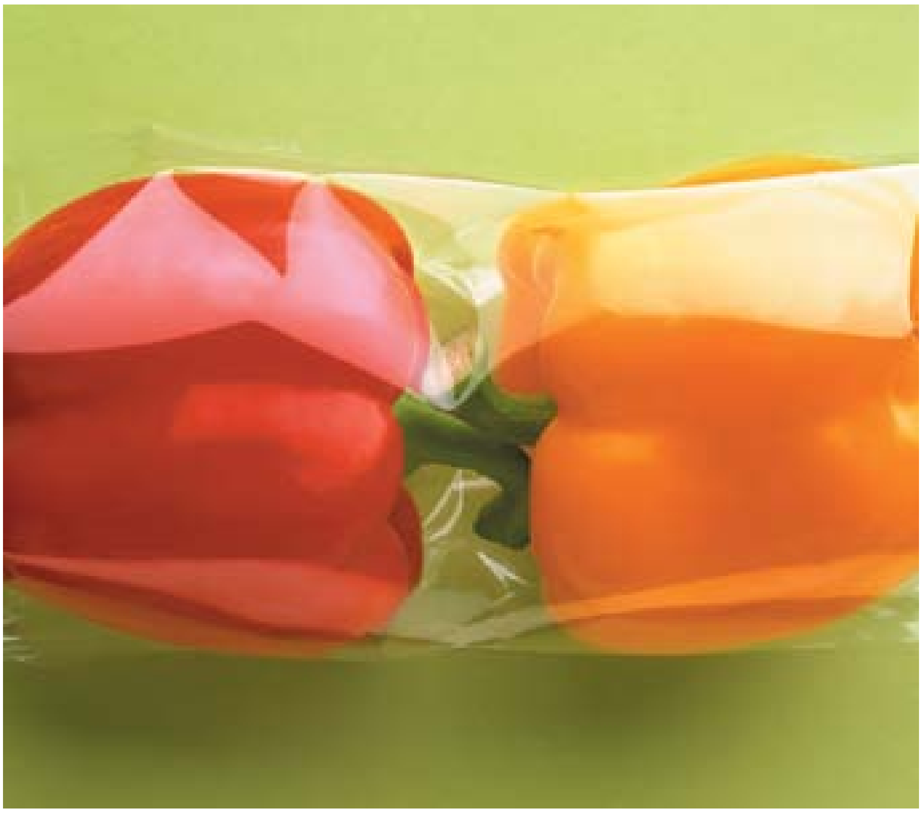
Moreover, recent technology breakthroughs have made substantial improvements to the properties of bio-based plastics enabling their expansion into the mainstream market. In many cases it is only the current relatively small scale of production which prevents wider uptake.

Polymers derived from renewable resources offer the opportunity to benefit society and the environment by reducing demands on fossil resources. Sugars, oils and other compounds in renewable feed-stocks can be converted into platform chemicals and polymers using conversion processes similar to those employed by the petrochemical industry today. Recent reports have identified several building block chemicals produced from sugars via biological or chemical conversions. These building block chemicals together with starch derived directly from plants enable the synthesis of biopolymers. The use of biomass-derived chemicals represents an area with extensive potential for the development of renewable feedstock-based technology platforms. Improvements and innovations to existing biological and chemical processing of cellulose, sugars and starches, often made possible through advances in catalysis, will provide the opportunity for the production of high-value chemicals and polymers from biomass and reduce reliance on petrochemical-derived products.

Bio-based plastics compete with petrochemical-based equivalents, the production of which has been optimized over the last decades. Optimization of these production methods according to green or sustainable chemistry principles may still significantly reduce costs, waste production, energy and raw materials use for petroleum-based polymers. However, many chemical processes are mature and have little room for optimization, while biotechnological processes are in their infancy; there is great potential for streamlining and improved process integration. In petrochemical refineries, the raw materials cost are critical as processing costs have gradually decreased, more products are developed, and less waste is produced.

White biotechnology provides new routes to renewable polymers; biomass can be converted to glucose, fatty acids, or other small compounds, either as the main product or as a waste stream from other production processes. These small compounds serve to produce plastics by microbial fermentation or chemical polymerization. For example, poly-βhydroxyalkanoates,

PET PLASTIC BOTTLES MADE PARTIALLY FROM PLANTS



PLA FILM - SOURCE TREOFAN

The continuing market development of renewable plastics gives far more opportunities to close the loop from raw material to end of life disposal than is possible with fossil derived materials. It should also not be forgotten that reuse and recycle equally applies to renewable plastics as it does to fossil derived polymers, it is just a question of scale.

biocellulose, xanthan, silk, and polythioesters, can be produced by fermentation processes, while polylactic acid (PLA), poly-caprolactone, and other (partially renewable) polyesters such as Sorona (Dupont), and Bionolle (Showa) are produced using chemical polymerization of substrates that are at least in part produced by bacterial fermentation. It is likely that these processes will be part of future biorefineries, which are now in a very early stage of development, with the exception of starch and paper mills. This implies that in biorefineries, the processing costs still determine the economic viability of bio-products. As biorefineries mature, the focus will also shift to the cost of producing the raw materials.

The cheapest and easiest to handle biopolymer is starch. Due to its abundance and low price it has found numerous applications in the non-food sector, which includes its use in renewable plastics. The current rise of the oil and natural gas prices is reflected in the plastics market, and is making renewable plastics more competitive.

As a consequence of the development of new markets energy consumption and waste production are increasing at a fast rate. Emerging countries are requiring more and more fossil resources whilst the developed countries are hesitant in introducing energy saving programmes and controlling the release of greenhouse gases. The amount of goods produced and packed is also growing, making waste disposal a big issue. These problems represent a powerful driving force stimulating the growth of renewable plastics.

Summary

An industry that produced just 200,000 tons in 2006 and is set to grow to about five million tons by 2015, bioplastics is fast gaining prominence, observes the Germany-based Helmut Kaiser Consultancy. Currently, bioplastics production is concentrated in the U.S., Europe and Japan, with the largest market being Western Europe, which accounts for about 40% of the world's demand for bioplastics. This region covers approximately 10% to 15% of the total plastics market and has recorded a fast-paced growth of about 8% to 10% per year. But a report by the market research group Freedonia, estimates that there will be a paradigm shift by 2013 when Asia will become the world leader in bioplastics production, clocking an annual growth rate of 39.1%. In the next decade, the global bioplastics market share is expected to jump up to 25% to 30%.

The renewable polymers market will increase rapidly in the next 10-20 years as the fossil feedstock costs rise and the drive for carbon savings is established. Research and the enhancement/refinement of industrial scale-up processes will introduce a wider array of products into the marketplace at competitive prices. The feedstock for these renewable polymers will be either directly (crop) or indirectly (biomass) derived from agriculture.

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Additive masterbatches to promote degradability in plastics

By Andrew Barclay, Wells Plastics Ltd

Additives to promote degradability in polymers are not a new concept, but have been in the technological arena for at least 30 years following pioneering work in the field by, for example, Scott G. ,Griffin G, Gilead D., and Albertsson A.

Currently available commercial products consist of polymeric based masterbatches containing a pro-oxidant (salts of transition metals) and reaction rate modifiers (generally but not exclusively antioxidants).

These commercial products are added to polymer feedstocks at levels between 1 and 3% by the polymer converter to impart the controlled oxobiodegradable characteristic to the polymeric product being manufactured.

These additives are predominately used in the polyolefin film market for a wide variety of packaging and agricultural mulch applications, but there are other applications in the sheet, closures and bottle industries.

Myths

Many myths surround the technology, generally attributable to misunderstandings regarding the science behind it. These include :

- The products contain toxic heavy metals / are unsafe / are dangerous
- Film and other plastics products manufactured using oxobiodegradable additives merely fragment into plastic particles that remain in the environment with no further change.
- Biodegradation (mineralisation) does not occur.

These can all be shown to be unfounded once the technology is better understood.

Technology

Initial Polymer Breakdown

The high molecular weight of commercial grades of polymers render them too hydrophobic and, therefore, very resistant to direct microbial attack.

It is been well known for many years that the presence of certain metal ions in polymers such as polyethylene and polypropylene can effect and accelerate their degradation.

In the presence of oxygen the metal ions catalyse oxidative chain scission of the polymer, causing a serial reduction in polymer molecular weight which ultimately results in acute embrittlement and microfragmentation (see Figure 1).

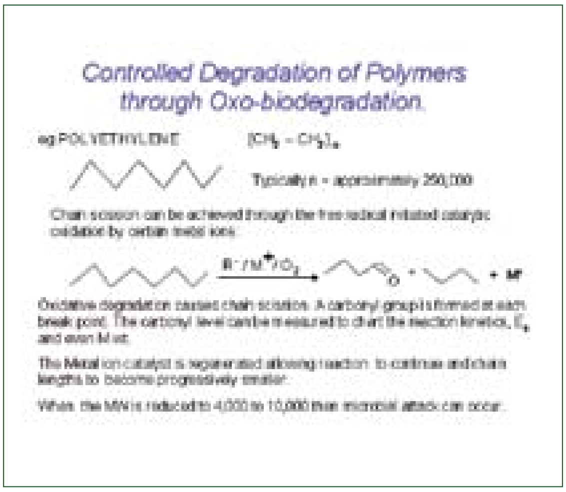

FIGURE 1: BREAKDOWN SCHEMATIC

When the polymer molecular weight is sufficiently reduced it becomes available for microbial attack which further breaks down the polymer into carbon dioxide, water and biomass.

A reduction of the polymer chain length from its initial value of around 250,000 to a value between 4,000 and 10,000 increases its intrinsic microbial accessibility and enables subsequent biodigestion.

This complete process is known as oxobiodegradation.

Technology

A convenient method of measuring the degree of initial breakdown is through Infra-Red spectroscopy (FTIR).

As oxo-degradation causes the formation of a carbonyl group at the point of every scission then the measurement of the onset and level of carbonyl group development in the test sample is a direct measure of its induced degradation by the metal ion pro-degradant. This "carbonyl Index" can be used to ascertain the rate of breakdown of the polymer (see Figure 2).

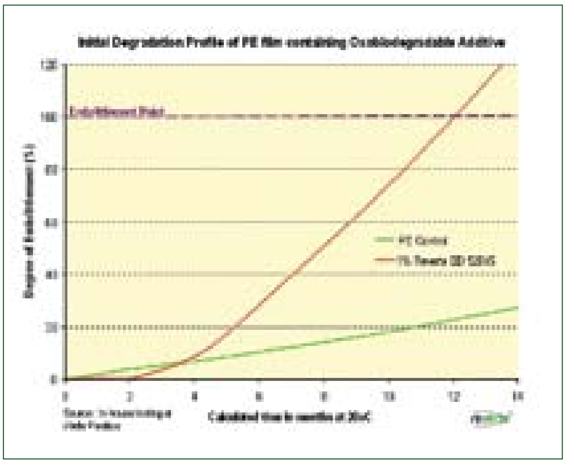

FIGURE 2: TYPICAL FILM BREAKDOWN

Another convenient and accurate method is the measurement of the polymer's molecular weight.

Attempts to directly measure specific physical properties such as Elongation or Tensile Strength are generally ineffective as the polymer breaks down too rapidly to enable such testing.

Carbonyl Group Development

It can be seen from Figure 2 that, following a "dwell time" wherein no breakdown reaction commences, the film containing oxobiodegradable additive has rapidly proceeded to a point of embrittlement (≤5% elongation).

This accelerated testing was performed at 50°C (chosen to be a "reasonable" temperature to give a balance between an accelerated timescale and real-life values) in a heat / UV ageing cabinet and Arrhenius principles then used to estimate the performance at 20°C.

Comparison with the control not containing any oxobiodegradable additive shows that the treated film has a dwell time equivalent to around 4 months at 20°C followed by an induced embrittlement point around 8 months later.

Oxobiodegradable technology enables the reaction profile to be adjusted to fit particular technical requirements such as shelf life, subsequent product lifetime and general fit-for-purpose attributes.

Molecular Weight reduction

Determination of the polymer sample's molecular weight during the initial breakdown period clearly demonstrates that chain scission is occurring.

In the example shown in Figure 3 a rapid fall in molecular weight was measured during ageing at 50°C in a heat/UV ageing cabinet.

In fact the film sample's weight average molecular weight was reduced from its initial value of 170,000 to below 5,000 during the ageing period.

It should be borne in mind that the molecular weight reduction is not the result of a simple chain scission resulting in lower molecular weight polyethylene, but that at every point of scission a carbonyl entity is formed.

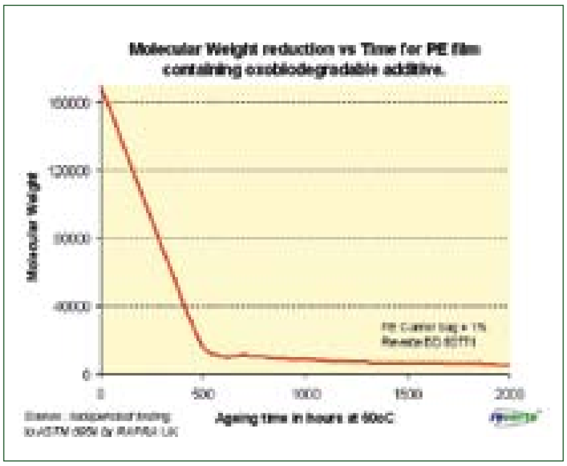

FIGURE 3: MOLECULAR WEIGHT REDUCTION

This effectively changes the simple hydrocarbon that is polyethylene into compounds such as short to medium chain carboxylic acids which are far more hydrophilic and readily biodegraded.

Biodegradation

The subsequent biodegradation (often referred to as mineralisation) of pre-oxidised polyolefin has been studied many times, sometimes with specific microbial strains, under general composting conditions and within aqueous conditions.

These studies, and many others, have demonstrated the ultimate mineralisation of preoxidised polyolefins.

A specific result, obtained from polyethylene agricultural mulch film may be found in Figure 4.

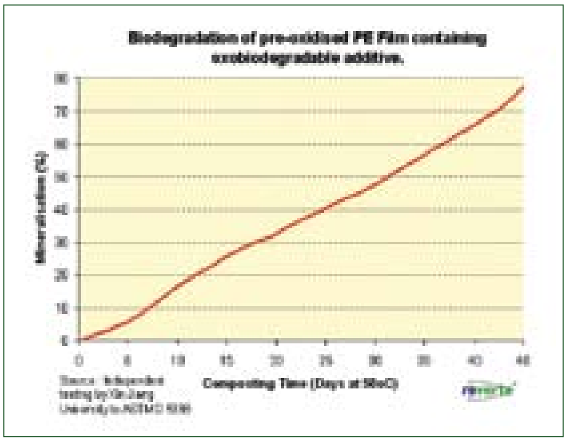

FIGURE 4: MINERALISATION DATA

It can be seen that when the pre-oxidised film was tested according to ASTM D 5338 (an aerobic biodegradation test method) the biodegradation was very rapid, with over 77% of the carbon in the polymer being converted to CO_2 within 45 days.

This is an extreme result caused by the thinness of the film and the activity of the specific oxobiodegradable (OBD) formulation utilised and generally OBD products are not recommended for composting applications as their biodegradation rate would normally be much slower, especially in film thicknesses and types used in packaging products.

Notwithstanding this, it is evident from this independent testing that very fast mineralisation rates can be achieved with OBD additives.

Food Contact Suitability

The major suppliers of OBD additives all claim food contact suitability and specific compliance with the European Directive 94/62/EC pertaining to the presence of toxic heavy metals and the American equivalent, CONEG.

Major food contact specification bodies include the European Community (through EC directive 2002/72/EC and its subsequent amendments), Canada (through their Food Inspection Agency / Bureau of Chemical Safety) and, in America, the FDA (through their positive listings and "Chapter" suitability).

Individual OBD additive suppliers can be approached for independent verification of their products' suitability for food use and their absence of proscribed heavy metals.

In addition, studies have been performed that have confirmed that there is no bio-accumulation of products or possible by-products from oxobiodegradable film use in agriculture, which should give confidence in their suitability for these and other purposes.

All of these data give confidence in the suitability of oxobiodegradable additives for food use and their general lack of toxicological contra-indications.

Examples of Use

- **Carrier Bags** Supermarket check-out bags are an important application for oxobiodegradable additives. Some countries and country regions have legislated for the use of OBD additives in carrier bags, eg UAE, Mexico and Argentina, amongst others.

  It can be seen that OBD additives are used throughout the world for this application and their use is growing.
- **Agricultural Mulch Film** OBD film has been used in many different crop types including tobacco, maize, potatoes and peanuts. At a slower rate the film will be completely bio-digested,eventually producing CO_2, H_2O and Biomass. (see Figure 4)
- **Bubble wrap** Bubble wrap and other similar forms of packaging are often used as short term, one-trip packaging and so are ideal for oxobiodegradable applications.
- **Food Netting** Fruit netting is an application that requires much longer product lifetimes and so the oxobiodegradable additive must be formulated accordingly.
- **Food Bags** Produce bags containing OBD additive are used in supermarkets. Food contact suitability is important in this application.

Summary

Oxobiodegradable additives are not a new concept but have been refined over the years to give better control over the kinetics of the reaction and to therefore increase the broad suitability of these additives for use in a large variety of applications.

The "myths" regarding toxicity, mere fragmentation into smaller plastic shards and no subsequent biodegradation can be seen to be ill-founded from the data and references contained within this report.

In fact, using reasonable accelerated ageing conditions, oxobiodegradable films have been shown to undergo controlled oxidation resulting in serial chain scission giving a rapid reduction in molecular weight, embrittlement and micro-fragmentation of the original product and the inherent denaturing of the polymer to oxidative by-products.

The oxidised by-products can be seen to have undergone biodegradation to ASTM 5338 and, in the example given, to have achieved >77% mineralisation within 45 days.

OBD products are not recommended for applications that require a composting property to meet such composting specifications as EN 13432, but they do have a strong market niche in many significant areas such as check-out bags, food packaging, agricultural films and many other sectors.

Oxobiodegradable additives have become an important product of choice in a broad variety of plastics products and their continuing growth is a testament to their proven efficacy in the right applications.

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CHAPTER 8

Guide to UK Companies

Additive Suppliers

	Blowing Agents	Biodegradable Additives	Catalysts and Hardeners	Fillers and Reinforcements	Flame Retardants	Inorganic Pigments	Inorganic Pigments - TiO2	Lubricants	Impact Modifiers / Process Aids	Stabilisers - Heat	Stabilisers - Antioxidants	Stabilisers - Primary	Stabilisers - Secondary	Stabilisers - UV Light	Organic Colourants	Plasticisers	Pre-matched Colorants	Antistatics	Adhesives	Surface Coatings
Addmaster (UK) Ltd	✓			✓	✓					✓	✓	✓	✓	✓				✓		
Americhem Ltd	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		
Astropol Ltd	✓						✓							✓	✓		✓			
Baerlocher UK Ltd	✓							✓	✓	✓								✓		
BASF					✓	✓					✓	✓	✓	✓	✓	✓	✓	✓		✓
Bayer Materials Science																			✓	✓
Chemson Ltd	✓			✓				✓	✓	✓	✓	✓	✓	✓						
Chemtura Manufacturing UK					✓				✓	✓										
Colloids	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓		
ColorMatrix	✓	✓				✓	✓		✓		✓			✓	✓		✓	✓		
Croda Europe Ltd								✓	✓					✓		✓		✓		
DOW Chemical Company		✓						✓	✓	✓										
Eastman Company UK Ltd																✓				
eChem Ltd								✓		✓						✓		✓		
ExxonMobil Chemical Ltd								✓												
Gabriel-Chemie UK Ltd	✓	✓			✓	✓					✓	✓	✓	✓	✓		✓	✓		
Hubron International Ltd				✓											✓					
IKA UK Ltd										✓	✓									
Kronos Ltd							✓													
Minelco Specialities Ltd				✓	✓															
Mitsui & Co. UK plc	✓				✓	✓			✓		✓	✓	✓	✓					✓	
Omya UK Ltd	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓
RaKeM Ltd			✓	✓	✓	✓					✓			✓	✓					✓
Reagens Ltd	✓							✓	✓	✓	✓	✓	✓	✓						
Silberline Ltd						✓														
Wells Plastics Ltd	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓				✓		
West & Senior Ltd	✓				✓	✓	✓								✓	✓	✓			✓

Masterbatch and Technical Compounds Suppliers

	Form			Polymer Systems								Colours							
	Pellet	Liquid	Powder	Polyethylene	Polypropylene	Styrenics	PET	Vinyl	PC	PA	Universal	Black	White	Pantone Colours	RAL Colours	Standard Range	Custom Matched	Effect Colours	Colour/additive combinations
ADDMASTER (UK)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								
AMERICHEM EUROPE	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
A SCHULMAN INC	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BEGG & CO	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
COLLOIDS	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
COLORMATRIX		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
COLOURTONE MASTERBATCH	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GABRIEL-CHEMIE UK	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
HUBRON (INTERNATIONAL)	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓							
PMB	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PRISMA COLOUR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SILVERGATE PLASTICS	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SPECTRA MASTERBATCH	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	Additives			Service*												Markets				
	United Kingdom	Other EU Countries	World Wide	Processing Aids	Flame Retardants	UV Stabilisers	Antistatic Agents	Anti Block	Laser Additives	Blowing Agents	Nucleating Agent	Anti Fogging	Antimicrobial	Bio-Degradable	Others	Colour Match Lead Time	Additive Enquiry Lead Time	Order Lead Time Custom Products	Minimum Despatch Time Ex-Stock	Min Stock Order Quantity in Kg
ADDMASTER (UK)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	□	1	5	1	1
AMERICHEM EUROPE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1	3	3	1	50
A SCHULMAN INC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5	1	10	1	25
BEGG & CO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1	2	2	1	3
COLLOIDS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	2	2	5-7	1	25
COLORMATRIX	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1	1	1	1	1
COLOURTONE MASTERBATCH	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	1	1	2	1	1
GABRIEL-CHEMIE UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	1	3	3	1	5
HUBRON (INTERNATIONAL)	✓	✓	✓													□	□	5	1	1250
PMB	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2	2	5	1	25
PRISMA COLOUR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	1	1	1	1	1
SILVERGATE PLASTICS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	1	1	1	1	1
SPECTRA MASTERBATCH	✓	✓	✓	✓		✓	✓		✓			✓	✓	✓	✓	1	1	3	1	1
WELLS PLASTICS	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	□	3	10	0	25

* service time (in days)

Polymer Distributors and Compounders

	Polycarbonates				PBT				Nylons				Acetals				Acrylics				ABS				SAN				PS				SBS			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
4PLAS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓			✓	✓	✓	✓						✓					
ALBIS	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓						✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓				
ALPHAGARY																																		✓	✓	
ASHLAND PLASTICS	✓	✓	✓		✓	✓			✓	✓			✓				✓		✓		✓	✓	✓		✓		✓		✓				✓	✓	✓	
AZELIS PLASTICS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓		✓		✓	✓	✓		✓	
BIESTERFELD PETROPLAS	✓	✓			✓	✓			✓	✓			✓	✓			✓	✓			✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	
DISTRUPOL	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓	
HARDIE POLYMERS	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓		✓		✓	✓	✓		✓	
HELLYAR PLASTICS																					✓		✓		✓		✓		✓		✓					
LUXUS			✓	✓						✓	✓	✓											✓	✓						✓	✓					
PERRITE	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓					
PLASTRIBUTION	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓	✓		✓	✓	✓		✓		✓		✓			
RESINEX	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
SUMIKA POLYMER COMPOUNDS																									✓	✓	✓	✓								
TEKNOR APEX					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓																	✓			✓	✓	
ULTRAPOLYMERS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

	PP				HDPE				LDPE				EVA				PVC				TPE				TPU			
	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
4PLAS	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓							✓		✓	✓	✓		✓	✓	✓	
ALBIS	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓										✓	✓	✓		✓	✓	✓	
ALPHAGARY		✓												✓	✓		✓	✓	✓			✓	✓			✓	✓	
ASHLAND PLASTICS	✓	✓	✓		✓				✓				✓				✓		✓		✓	✓	✓		✓			
AZELIS PLASTICS	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓									✓		✓		✓		✓	
BIESTERFELD PETROPLAS	✓	✓	✓	✓	✓			✓	✓			✓	✓								✓	✓	✓	✓	✓			
DISTRUPOL	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓	
HARDIE POLYMERS	✓	✓	✓	✓	✓		✓	✓	✓			✓	✓				✓		✓	✓	✓				✓			
HELLYAR PLASTICS	✓	✓	✓		✓		✓		✓		✓		✓		✓													
LUXUS	✓	✓	✓		✓	✓	✓		✓	✓	✓											✓	✓					
PERRITE	✓	✓	✓		✓	✓	✓		✓	✓	✓																	
PLASTRIBUTION	✓	✓	✓		✓				✓				✓								✓		✓		✓		✓	
RESINEX	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	✓	✓	✓	
SUMIKA POLYMER COMPOUNDS	✓	✓	✓	✓	✓	✓	✓	✓													✓		✓		✓		✓	
TEKNOR APEX		✓	✓															✓	✓			✓	✓			✓	✓	
ULTRAPOLYMERS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓								✓	✓	✓	✓	✓	✓	✓	

Common Abbreviations

PBT	Polybutylene Terephthalate
ABS	Acrylonitrile-Butadiene Styrene
PS	Polystyrene
SBS	Styrene Butadiene Styrene
PP	Polypropylene
HDPE	High Density Polyethylene
LDPE	Low Density Polyethylene
EVA	Ethylene Vinyl Acetate
PVC	Polyvinyl Chloride
TPE	Thermoplastic Elastomer
TPU	Thermoplastics Polyurethane

Key

A	Natural Polymer
B	Filled Compound
C	Customer Compound
D	Reprocessed

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MINELCO Ltd
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Moulders

Type of Moulder

Company	Injection Moulder	Blow Moulder	Compression Moulder	Transfer Moulder	Rotary	Gas Assisted I.M.	Thermoforming	Rotational Moulding	Insert Loaded
AAC Plastics Group Ltd	✓						✓		
Aeroplas	✓								
Agentdraw Ltd	✓								
A K Industries Ltd	✓			✓		✓			✓
Algram Group Ltd	✓						✓		
Avalon Plastics Ltd	✓		✓						
Bemis Ltd	✓								
Big Bear Plastic Products Ltd							✓		
Birkbys Plastics Ltd	✓					✓			
BNL (UK) Ltd	✓								
Bolton Plastic Components Ltd	✓	✓							✓
Broanmain Limited	✓		✓	✓					✓
Calsonic Kansei (UK)	✓								
Carclo Technical Plastics Ltd	✓								
Champion Mouldings Ltd	✓	✓							
CJ Tool and Mouldings Ltd	✓								
Contico Europe Ltd	✓								
Daniels Healthcare Ltd	✓								
Data Plastics Ltd	✓								
Denroy	✓								
Desch Plantpak Ltd	✓						✓		
Dubois LTD	✓								
Eaton Automotive	✓	✓				✓			✓
Flambeau Europlast Ltd	✓	✓							
FL Plastics Ltd	✓	✓							
Forteq UK	✓								
Frontier Plastics Ltd	✓								
Hallam Plastics Ltd	✓					✓			✓
Harold Fisher Plastics						✓			
HM Prison Service	✓								
Homelux Nemplas Ltd	✓								
Hozelock Ltd	✓	✓							
Husqvarna Ltd	✓								
Intier Automotive Interiors Ltd	✓								
John McGavigan Ltd	✓								
JSP Ltd	✓	✓	✓					✓	
Labone Castleside	✓								
Lettergold Plastics Ltd	✓								

Market Sectors

Company	Transport	Building	Business Equipment	Electronics/Comms	Agriculture/Horticulture	Mechanical Goods	Packaging	Healthcare	Waste Management	Housewares	Design / Mnfr Bearings	Other
AAC Plastics Group Ltd	✓	✓					✓		✓			✓
Aeroplas							✓			✓		
Agentdraw Ltd		✓		✓		✓	✓	✓		✓		
A K Industries Ltd	✓	✓	✓	✓				✓		✓		✓
Algram Group Ltd	✓	✓	✓					✓				
Avalon Plastics Ltd												
Bemis Ltd		✓								✓		✓
Big Bear Plastic Products Ltd	✓				✓							✓
Birkbys Plastics Ltd	✓											
BNL (UK) Ltd			✓	✓		✓		✓			✓	
Bolton Plastic Components Ltd	✓	✓	✓		✓	✓	✓	✓	✓			✓
Broanmain Limited	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Calsonic Kansei (UK)	✓											
Carclo Technical Plastics Ltd	✓							✓				
Champion Mouldings Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
CJ Tool and Mouldings Ltd	✓	✓				✓				✓		
Contico Europe Ltd							✓					✓
Daniels Healthcare Ltd								✓				
Data Plastics Ltd	✓	✓	✓	✓		✓	✓	✓		✓		✓
Denroy	✓	✓		✓				✓		✓		
Desch Plantpak Ltd					✓		✓					
Dubois LTD				✓				✓				✓
Eaton Automotive	✓											
Flambeau Europlast Ltd	✓	✓			✓		✓	✓		✓		✓
FL Plastics Ltd							✓	✓		✓		
Forteq UK	✓	✓	✓	✓		✓	✓	✓				
Frontier Plastics Ltd								✓	✓			
Hallam Plastics Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Harold Fisher Plastics		✓	✓	✓		✓	✓			✓		✓
HM Prison Service		✓		✓						✓		
Homelux Nemplas Ltd	✓	✓								✓		
Hozelock Ltd					✓							
Husqvarna Ltd					✓							
Intier Automotive Interiors Ltd	✓											
John McGavigan Ltd	✓			✓								
JSP Ltd	✓	✓			✓			✓				
Labone Castleside	✓											
Lettergold Plastics Ltd		✓					✓	✓				

Services

Company	Clean Room	Tool Design	Tool Manufacture	Spray Painting	Rapid Proto. facilities	Pad Printing	Silkscree n Printing	Coating	In-Mould labelling	Assembly	Machining	High Frequency Welding	Ultrasonic welding	Metalized Plastics	Other
AAC Plastics Group Ltd		✓				✓				✓	✓		✓		✓
Aeroplas			✓			✓	✓			✓					
Agentdraw Ltd		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
A K Industries Ltd	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	
Algram Group Ltd	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓		
Avalon Plastics Ltd															
Bemis Ltd									✓						
Big Bear Plastic Products Ltd	✓	✓				✓				✓		✓	✓		✓
Birkbys Plastics Ltd		✓		✓	✓	✓			✓	✓	✓	✓	✓		
BNL (UK) Ltd		✓	✓							✓	✓		✓	✓	
Bolton Plastic Components Ltd		✓	✓					✓		✓	✓		✓		✓
Broanmain Limited		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
Calsonic Kansei (UK)	✓			✓		✓				✓	✓	✓	✓		
Carclo Technical Plastics Ltd	✓	✓	✓				✓	✓	✓	✓	✓			✓	✓
Champion Mouldings Ltd		✓			✓				✓	✓	✓			✓	
CJ Tool and Mouldings Ltd		✓	✓							✓	✓				
Contico Europe Ltd			✓						✓						
Daniels Healthcare Ltd															
Data Plastics Ltd	✓	✓	✓			✓				✓	✓		✓		✓
Denroy		✓	✓	✓	✓	✓	✓			✓			✓		
Desch Plantpak Ltd															
Dubois LTD		✓				✓			✓		✓				
Eaton Automotive		✓				✓				✓	✓	✓	✓		
Flambeau Europlast Ltd		✓				✓	✓		✓	✓	✓		✓		
FL Plastics Ltd		✓	✓												
Forteq UK	✓	✓	✓		✓		✓			✓		✓	✓		
Frontier Plastics Ltd		✓	✓			✓			✓	✓	✓	✓	✓		✓
Hallam Plastics Ltd		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		
Harold Fisher Plastics		✓	✓			✓				✓			✓		
HM Prison Service															
Homelux Nemplas Ltd															
Hozelock Ltd		✓				✓	✓			✓	✓	✓	✓		
Husqvarna Ltd		✓	✓		✓	✓				✓			✓		
Intier Automotive Interiors Ltd				✓				✓		✓					✓
John McGavigan Ltd						✓	✓			✓					✓
JSP Ltd															
Labone Castleside				✓	✓			✓		✓					
Lettergold Plastics Ltd	✓	✓	✓							✓					

Materials Proccessed

Company	PS	SAN	ABS	LLDPE	LPDE	HDPE	PP	Rigid PVC	Flexible PVC	PA	Acrylic	TPE	PC	EVA	PEEK	PET	PBT	Other
AAC Plastics Group Ltd	✓	✓	✓		✓	✓	✓								✓			✓
Aeroplas	✓	✓	✓				✓					✓						
Agentdraw Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	
A K Industries Ltd	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓			✓
Algram Group Ltd	✓		✓	✓	✓	✓			✓			✓	✓	✓	✓	✓	✓	
Avalon Plastics Ltd							✓											
Bemis Ltd							✓											
Big Bear Plastic Products Ltd			✓			✓	✓				✓							✓
Birkbys Plastics Ltd	✓	✓	✓			✓				✓		✓			✓	✓		
BNL (UK) Ltd			✓			✓	✓			✓			✓		✓		✓	✓
Bolton Plastic Components Ltd					✓	✓	✓			✓		✓						✓
Broanmain Limited	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
Calsonic Kansei (UK)			✓				✓											✓
Carclo Technical Plastics Ltd							✓				✓							
Champion Mouldings Ltd	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	
CJ Tool and Mouldings Ltd	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓				
Contico Europe Ltd							✓											
Daniels Healthcare Ltd							✓											
Data Plastics Ltd	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓		
Denroy	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓	✓	✓		
Desch Plantpak Ltd	✓						✓											
Dubois LTD							✓								✓			✓
Eaton Automotive			✓				✓			✓		✓				✓	✓	✓
Flambeau Europlast Ltd	✓	✓	✓		✓	✓	✓	✓		✓		✓	✓			✓		
FL Plastics Ltd					✓	✓	✓	✓				✓		✓		✓		
Forteq UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Frontier Plastics Ltd							✓											✓
Hallam Plastics Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Harold Fisher Plastics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓	✓	
HM Prison Service	✓		✓		✓	✓	✓			✓		✓	✓					
Homelux Nemplas Ltd			✓				✓											
Hozelock Ltd			✓		✓	✓	✓	✓	✓			✓	✓				✓	✓
Husqvarna Ltd			✓	✓	✓	✓	✓	✓	✓			✓	✓			✓		
Intier Automotive Interiors Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
John McGavigan Ltd			✓				✓	✓					✓					✓
JSP Ltd			✓	✓	✓	✓	✓		✓	✓								
Labone Castleside			✓				✓				✓				✓			
Lettergold Plastics Ltd	✓		✓	✓	✓	✓	✓			✓		✓	✓					

Machine capacity

Company	Minimum Shot Size (g)	Maximum Shot Size (g)	Minimum Machine Locking force (tonnes)	Maximum Machine Locking force (Tonnes)
AAC Plastics Group Ltd				500
Aeroplas	6	500	50	450
Agentdraw Ltd	1	2000	100	400
A K Industries Ltd	0.01	1200	6	450
Algram Group Ltd	8	1777	50	500
Avalon Plastics Ltd				
Bemis Ltd	100	4500	400	1000
Big Bear Plastic Products Ltd				
Birkbys Plastics Ltd	700	7000	25	2000
BNL (UK) Ltd	0.1	320	12	175
Bolton Plastic Components Ltd	50	10000	5	350
Broanmain Limited	1	1000	10	250
Calsonic Kansei (UK)	25	5000	220	2300
Carclo Technical Plastics Ltd	1	7000	50	250
Champion Mouldings Ltd	20	4200	50	720
CJ Tool and Mouldings Ltd		640		300
Contico Europe Ltd	50	6000	250	1500
Daniels Healthcare Ltd	131	2084	50	570
Data Plastics Ltd			7	250
Denroy	5	3000	20	750
Desch Plantpak Ltd	49	709	80	350
Dubois LTD	2	290	125	500
Eaton Automotive	22	5000	20	900
Flambeau Europlast Ltd	10	4000	50	800
FL Plastics Ltd		35		32
Forteq UK		2000	50	450
Frontier Plastics Ltd	4	710	65	520
Hallam Plastics Ltd	15	15000	150	1000
Harold Fisher Plastics	5	3500	60	720
HM Prison Service	109	4300	40	850
Homelux Nemplas Ltd				
Hozelock Ltd	2	5000	22	800
Husqvarna Ltd	5	50	75	1000
Intier Automotive Interiors Ltd	25	5400	130	4000
John McGavigan Ltd				
JSP Ltd	50	7000	16	1500
Labone Castleside				
Lettergold Plastics Ltd	1	350	60	135

Company	Type of Moulder: Injection Moulder	Blow Moulder	Compression Moulder	Transfer Moulder	Rotary	Gas Assisited I.M.	Thermoforming	Rotational Moulding	Insert Loaded
Lettergold Plastics Ltd	✓								
L H Plastics Ltd	✓								
LINPAC Group Ltd	✓								
McKechnie Plastic Components	✓								
McLaren Plastics Ltd	✓								
Measom Freer Ltd	✓	✓							
Mecaplast Peterlee Ltd	✓								
Melba Products Ltd	✓								
Mollertech UK Ltd	✓								
Moss Plastic Parts Ltd	✓								
Numatic International Ltd	✓							✓	
Oxford Plastics Systems Ltd	✓		✓					✓	
Peak Plastics Ltd	✓								
Piolax Manufacturing	✓								
Plastic Omnium Automotive Ltd	✓								
Powell Plastics Ltd (Dyro Holdings)	✓								
Rge Engineering Co	✓								
Richard Sankey & Son Ltd	✓				✓				
Ricoh (UK) Products Ltd	✓	✓							
RPC Containers	✓	✓		✓		✓	✓		
R-Tek Ltd	✓								
Sherwood Plastic Products Ltd	✓								
Silkjet Plastics Ltd	✓								✓
SMR Automotive Mirrors UK Ltd	✓					✓			
Spectra Packaging Solutions Ltd		✓							
SPS (EU) Ltd	✓								
Sterilin Ltd	✓	✓							
Stewart Plastics Ltd	✓							✓	
Strata Products Ltd	✓	✓							
Taylor Engineering & Plastics Ltd	✓					✓			
Technical Mouldings Ltd	✓								
Tex Plastic Products Ltd	✓								
Tex Industrial Plastics Ltd	✓								
Thumbs Up (Bury) Ltd	✓								
TS UK Ltd	✓								
UPG Plastics Ltd	✓								
Weltonhurst Ltd		✓							
W H Smith & Sons (Tools) Ltd	✓					✓			✓

Company	Market Sectors: Transport	Building	Business Equipment	Electronics/Comms	Agriculture/Horticulture	Mechanical Goods	Packaging	Healthcare	Waste Management	Housewares	Design / Mnfr Bearings	Other
Lettergold Plastics Ltd		✓					✓	✓				
L H Plastics Ltd				✓								
LINPAC Group Ltd	✓			✓			✓					
McKechnie Plastic Components	✓	✓		✓			✓	✓				
McLaren Plastics Ltd		✓	✓	✓		✓	✓					
Measom Freer Ltd				✓	✓		✓	✓				
Mecaplast Peterlee Ltd	✓											
Melba Products Ltd												✓
Mollertech UK Ltd	✓											
Moss Plastic Parts Ltd	✓	✓		✓				✓		✓		
Numatic International Ltd						✓				✓		✓
Oxford Plastics Systems Ltd		✓			✓							
Peak Plastics Ltd	✓	✓										
Piolax Manufacturing	✓											
Plastic Omnium Automotive Ltd	✓											
Powell Plastics Ltd (Dyro Holdings)							✓			✓		✓
Rge Engineering Co			✓	✓				✓		✓		✓
Richard Sankey & Son Ltd					✓		✓		✓			
Ricoh (UK) Products Ltd			✓				✓					
RPC Containers					✓		✓	✓	✓	✓		✓
R-Tek Ltd	✓											
Sherwood Plastic Products Ltd							✓					
Silkjet Plastics Ltd	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓
SMR Automotive Mirrors UK Ltd	✓											
Spectra Packaging Solutions Ltd							✓	✓		✓		✓
SPS (EU) Ltd			✓									✓
Sterilin Ltd							✓	✓				
Stewart Plastics Ltd					✓		✓			✓		
Strata Products Ltd					✓					✓		✓
Taylor Engineering & Plastics Ltd	✓	✓	✓	✓			✓	✓				✓
Technical Mouldings Ltd	✓	✓	✓	✓				✓		✓		
Tex Plastic Products Ltd	✓	✓	✓	✓		✓	✓	✓		✓		✓
Tex Industrial Plastics Ltd	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Thumbs Up (Bury) Ltd										✓		✓
TS UK Ltd										✓		
UPG Plastics Ltd	✓		✓	✓			✓	✓				
Weltonhurst Ltd	✓	✓	✓				✓	✓		✓		
W H Smith & Sons (Tools) Ltd	✓	✓	✓	✓		✓						

Company	Services: Clean Room	Tool Design	Tool Manufacture	Spray Painting	Rapid Proto. facilities	Pad Printing	Silkscree n Printing	Coating	In-Mould labelling	Assembly	Machining	High Frequency Welding	Ultrasonic welding	Metalized Plastics	Other
Lettergold Plastics Ltd	✓	✓	✓							✓					
L H Plastics Ltd				✓		✓				✓			✓		
LINPAC Group Ltd						✓				✓		✓			
McKechnie Plastic Components		✓	✓	✓	✓	✓	✓			✓	✓		✓		
McLaren Plastics Ltd										✓	✓				
Measom Freer Ltd		✓	✓				✓								
Mecaplast Peterlee Ltd					✓					✓		✓	✓		
Melba Products Ltd		✓						✓							
Mollertech UK Ltd								✓		✓	✓	✓	✓		
Moss Plastic Parts Ltd		✓	✓			✓	✓			✓					✓
Numatic International Ltd			✓	✓	✓	✓				✓					
Oxford Plastics Systems Ltd				✓				✓		✓					✓
Peak Plastics Ltd		✓	✓							✓					
Piolax Manufacturing		✓								✓					
Plastic Omnium Automotive Ltd				✓						✓		✓	✓		
Powell Plastics Ltd (Dyro Holdings)		✓				✓									✓
Rge Engineering Co		✓	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓
Richard Sankey & Son Ltd															
Ricoh (UK) Products Ltd		✓	✓	✓						✓	✓		✓		
RPC Containers	✓	✓				✓	✓		✓	✓			✓		✓
R-Tek Ltd										✓	✓	✓	✓		✓
Sherwood Plastic Products Ltd										✓			✓		
Silkjet Plastics Ltd		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
SMR Automotive Mirrors UK Ltd				✓						✓			✓	✓	
Spectra Packaging Solutions Ltd		✓	✓				✓							✓	
SPS (EU) Ltd															
Sterilin Ltd	✓	✓	✓				✓			✓			✓		
Stewart Plastics Ltd															
Strata Products Ltd										✓			✓		
Taylor Engineering & Plastics Ltd		✓	✓	✓		✓		✓		✓	✓				
Technical Mouldings Ltd		✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	
Tex Plastic Products Ltd	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	
Tex Industrial Plastics Ltd		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Thumbs Up (Bury) Ltd									✓						✓
TS UK Ltd										✓					
UPG Plastics Ltd	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓		
Weltonhurst Ltd		✓		✓	✓	✓	✓			✓	✓		✓		
W H Smith & Sons (Tools) Ltd		✓	✓	✓		✓	✓			✓	✓	✓	✓		

Company	Materials Proccessed: PS	SAN	ABS	LLDPE	LPDE	HDPE	PP	Rigid PVC	Flexible PVC	PA	Acrylic	TPE	PC	EVA	PEEK	PET	PBT	Other
Lettergold Plastics Ltd	✓		✓	✓	✓	✓	✓			✓		✓	✓					
L H Plastics Ltd	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓		✓		
LINPAC Group Ltd	✓		✓	✓	✓	✓			✓									
McKechnie Plastic Components	✓	✓	✓		✓		✓			✓	✓	✓	✓					
McLaren Plastics Ltd	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓				
Measom Freer Ltd	✓	✓	✓		✓	✓	✓	✓		✓						✓		
Mecaplast Peterlee Ltd			✓		✓	✓	✓				✓			✓				
Melba Products Ltd								✓	✓									
Mollertech UK Ltd							✓											
Moss Plastic Parts Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				✓
Numatic International Ltd			✓			✓	✓					✓						
Oxford Plastics Systems Ltd			✓	✓	✓				✓									
Peak Plastics Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓									
Piolax Manufacturing			✓		✓	✓	✓		✓	✓		✓					✓	✓
Plastic Omnium Automotive Ltd			✓				✓			✓								
Powell Plastics Ltd (Dyro Holdings)							✓									✓		
Rge Engineering Co	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓			✓	✓
Richard Sankey & Son Ltd	✓			✓		✓	✓											
Ricoh (UK) Products Ltd	✓		✓		✓	✓	✓						✓			✓		
RPC Containers	✓		✓	✓	✓	✓	✓	✓	✓		✓			✓		✓		✓
R-Tek Ltd			✓				✓											
Sherwood Plastic Products Ltd					✓	✓				✓								
Silkjet Plastics Ltd	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓
SMR Automotive Mirrors UK Ltd			✓				✓			✓	✓	✓					✓	✓
Spectra Packaging Solutions Ltd						✓			✓							✓		
SPS (EU) Ltd																		
Sterilin Ltd	✓				✓	✓	✓					✓						
Stewart Plastics Ltd	✓	✓					✓											
Strata Products Ltd						✓	✓											
Taylor Engineering & Plastics Ltd	✓	✓	✓	✓	✓	✓	✓			✓			✓				✓	
Technical Mouldings Ltd	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Tex Plastic Products Ltd	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tex Industrial Plastics Ltd	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	
Thumbs Up (Bury) Ltd				✓	✓	✓	✓					✓						✓
TS UK Ltd							✓											
UPG Plastics Ltd	✓	✓	✓			✓	✓			✓	✓	✓	✓		✓		✓	
Weltonhurst Ltd					✓	✓	✓							✓				
W H Smith & Sons (Tools) Ltd	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	

Company	Minimum Shot Size (g)	Maximum Shot Size (g)	Minimum Machine Locking force (tonnes)	Maximum Machine Locking force (Tonnes)
Lettergold Plastics Ltd	1	350	60	135
L H Plastics Ltd	0.2	2000	1	480
LINPAC Group Ltd		2800	800	2200
McKechnie Plastic Components	0.1	8000	40	1500
McLaren Plastics Ltd	1	700	25	270
Measom Freer Ltd	0.1	300	50	150
Mecaplast Peterlee Ltd	5	2800	80	2000
Melba Products Ltd				
Mollertech UK Ltd				2000
Moss Plastic Parts Ltd				
Numatic International Ltd	3	12500	40	1400
Oxford Plastics Systems Ltd	10	25000	50	1200
Peak Plastics Ltd	4	800	60	300
Piolax Manufacturing	6	320	5	250
Plastic Omnium Automotive Ltd				
Powell Plastics Ltd (Dyro Holdings)			100	2700
Rge Engineering Co			40	1500
Richard Sankey & Son Ltd	4	9500	80	3150
Ricoh (UK) Products Ltd	1	2550	9	800
RPC Containers				
R-Tek Ltd	1	1600	150	2000
Sherwood Plastic Products Ltd			20	80
Silkjet Plastics Ltd	0.5	6500	22	1000
SMR Automotive Mirrors UK Ltd	30	600	25	460
Spectra Packaging Solutions Ltd				
SPS (EU) Ltd				
Sterilin Ltd			30	200
Stewart Plastics Ltd				
Strata Products Ltd			60	1000
Taylor Engineering & Plastics Ltd	0.05	24000	35	1600
Technical Mouldings Ltd	0.1	1700	15	300
Tex Plastic Products Ltd	0.01	2200	6	500
Tex Industrial Plastics Ltd	27	6107	22	1000
Thumbs Up (Bury) Ltd				
TS UK Ltd	100	1800	240	700
UPG Plastics Ltd	0.5	3500	40	1000
Weltonhurst Ltd	150	2200		
W H Smith & Sons (Tools) Ltd	1	5000	25	1500

MOULDERS

AAC Plastics Group Ltd
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Fax: +44(0)1484 710 613
www.aacplasticsgroup.co.uk
info@aacplasticsgroup.co.uk

Aeroplas (UK) Ltd
Tel: +44(0)121 522 3000| Fax: +44(0)121 522 3333
www.aeroplas.net
sales@aeroplas.net

AgentDraw Ltd
Tel: +44(0)116 284 1386
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www.agentdraw.co.uk
info@agentdraw.co.uk

A K Industries Ltd
Tel: +44(0)1432 375 100
Fax: +44(0)1432 263 532
www.aki.co.uk| sales@aki.co.uk

Algram Group Ltd
Tel: +44(0)1752 342 388
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Avalon Plastics Ltd
Tel: +44(0)870 389 1998
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www.| keithb@avalonplastics.co.uk

Bemis Ltd
Tel: +44(0)1282 438 717
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Big Bear Plastic Products Ltd
Tel: +44(0)1905 792500
Fax: +44(0)1905 792501
www.big-bear.co.uk
bbsales@big-bear.co.uk

Birkbys Plastics Ltd
Tel: +44(0)1924 414 200
Fax: +44(0)1924 400051
www.birkbys.co.uk
marketing@birkbys.co.uk

BNL (UK) Ltd
Tel: +44 (0)1423 799200
Fax: +44(0)1423 862 259
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enquiries@bnl-bearings.com

Bolton Plastic Components Ltd
Tel: +44(0)1204 526 241
Fax: +44(0)1204 521 958
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Broanmain Limited
Tel: +44(0)1306 885 888
Fax: +44(0)1306 885 889
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info@broanmain.co.uk

Calsonic Kansei (UK)
Tel: +44(0)191 417 0084
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www.ckeurope.com

Robert.endacott@ckeurope.com
Carclo Technical Plastics Ltd
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Champion Mouldings Ltd
Tel: +44(0)161 723 3574
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CJ Tool & Mouldings Ltd
Tel: +44(0)1384 378 866 www.
cjtoolandmouldings.co.uk
info@cjtoolandmouldings.co.uk

Contico Europe Ltd
Tel: +44(0)1209 203 340
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quality@contico.co.uk

Daniels Healthcare Ltd
Tel: +44(0)1865 371 841
Fax: +44(0)1865 309 579
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Data Plastics Ltd
Tel: +44(0)1993 700 777
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Denroy Plastics Ltd
Tel: +44(0)289 147 4822
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Desch Plantpak Ltd
Tel: +44(0)1621 745 500
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Dubois Ltd
Tel: +44(0)1536 263 653
Fax: +44(0)1536 274 899
www.amaray.com
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Eaton Automotive Operations Ltd
Tel: +44(0)1384 424 911
www.eaton.com
CarlBowater@eaton.com

Flambeau Europlast Ltd
Tel: +44(0)1843 854 000
Fax: +44(0)1843 854 010
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F L Plastics LTD
Tel: +44(0)1603 418 989
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forteq (UK) Ltd
Tel: +44(0)1484 424 384
Fax: +44(0)1484 535 053
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forteq.uk@forteq-group.com

Frontier Plastics Ltd
Tel: +44(0) 1495 235 800
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Hallam Plastics Ltd
Tel: +44(0)1773 531 151
Fax: +44(0)1773 533 267
www.hallamplastics.co.uk
enquiries@hallamplastics.co.uk

Harold Fisher Plastics Ltd
Tel: +44(0)1484 854321
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www.fisherplastics.co.uk
jeff.monks@fisherplastics.co.uk

HM Prison Service
Tel: +44(0)300 047 6822
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abdul.majid@noms.gsi.gov.uk

Homelux Nenplas Ltd
Tel: +44(0)1335 347 300
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enquiries@homeluxnenplas.com

Hozelock Ltd
Tel: +44(0)121 313 4242
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www.hozelock.com
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Husqvarna (UK) Ltd
Tel: +44(0) 1325 302 302
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Intier Automotive Interiors Ltd
Tel: +44(0)1926 468 800
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John McGavigan Ltd
Tel: +44(0)141 302 0000
www.advanceddecorative.com

JSP Ltd
Tel: +44(0)1993 824 000
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info@jsp.co.uk

Labone Castleside Ltd
Tel: +44(0)1207 509 450
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Lettergold Plastics Ltd
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www.lettergold.co.uk
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L H Plastics Ltd
Tel: +44(0)1274 736 330
Fax: +44(0)1274 736 332
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paulh@lhplastics.co.uk

LINPAC Group Ltd
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McKechnie Plastic Components
Tel: +44(0)1759 371 551
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McLaren Plastics Ltd
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Mecaplast Peterlee Ltd
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Melba Products Ltd
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Moller Tech Ltd
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Moss Plastic Parts
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Numatic International Ltd
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Oxford Plastic Systems Ltd
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Plastic Omnium Automotive Ltd
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Powell Plastics Ltd
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RGE Engineering Co
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Richard Sankey & Son Ltd
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Ricoh UK Products Ltd
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RPC Containers Ltd
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R-Tek Ltd
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Fax: +44(0)191 415 7070
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Sherwood Plastic Products Ltd
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Silkjet Plastics Ltd
Tel: +44(0)116 276 2350
Fax: +44(0)116 276 1152
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Recycling

	BUY RECYCLED PLASTICS																FORMAT	
	ABS	EPS	HDPE	HIPS	LDPE	LLDP	MDPE	MIXED	NYLON	PC	PET	PP	PS	PVC	PET	OTHER	COMPOUND/PELLET	FLAKE
AWS Eco Plastics Limited	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√
Axion	√			√				√				√	√				√	√
Baylis Recycling/plastics sorting ltd			√															√
BPI Recycled Products			√		√	√	√										√	√
Centriforce Products Ltd			√		√	√	√					√					√	√
Chase Plastics			√		√		√										√	√
Express Recycling & Plastics Ltd			√				√	√				√					√	√
JFC Plastics Ltd			√		√	√	√	√				√				√	√	√
LINPAC Plastics Recycling	√		√	√	√	√	√			√		√				√	√	√
Luxus Ltd	√		√	√	√		√		√	√		√	√				√	
Norpol Recycling Limited			√	√	√	√						√	√				√	
Oxford Plastic Systems Ltd																		
Philip Tyler Polymers Ltd	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√
PPR WIPAG Ltd	√				√			√		√		√				√		
T D G	√		√	√	√	√			√	√	√	√	√	√			√	√
Wellman Recycling											√						√	

	RECYCLER/TRADER																Format		
	ABS	EPS	HDPE	HIPS	LDPE	LLDP	MDPE	MIXED	NYLON	PC	PET	PP	PS	PVC	PET	OTHER	BOTTLE	FILM	RIGID
AWS Eco Plastics Limited	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√	√	√
Axion	√			√				√				√	√						√
Baylis Recycling/Plastics Sorting ltd								√			√						√		
BPI Recycled Products			√		√	√	√										√	√	√
C K Polymers	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Centriforce Products Ltd			√		√	√	√					√						√	√
Chase Plastics			√		√	√	√										√	√	
Closed Loop Recycling Ltd			√					√			√						√		
Cromwell Polythene Ltd					√	√		√				√						√	
Express Recycling & Plastics Ltd			√		√		√	√				√					√	√	√
JFC Plastics Ltd			√		√		√	√				√					√	√	√
LINPAC Plastics Recycling		√	√	√	√	√	√			√	√	√	√				√		√
Luxus Ltd		√	√	√	√	√	√	√	√	√	√	√	√				√	√	√
Norpol Recycling Limited		√	√	√	√	√	√	√			√	√	√	√	√	√	√	√	√
Philip Tyler Polymers Ltd	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
PPR WIPAG Ltd	√		√		√					√		√				√			√
RECOUP								√			√						√		
Roydon Holdings Plc					√			√	√		√	√	√	√			√	√	
Severnside Recycling	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√
T D G	√		√	√	√	√			√	√	√	√	√	√			√	√	√
Wellman Recycling											√						√		

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MATERIALS PROCESSED												
Nylon	✓		✓		✓						✓	✓
Polyethylene	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Polypropylene	✓			✓	✓	✓		✓			✓	✓
MATERIALS PROCESSED												
Automotive				✓	✓	✓				✓	✓	✓
Farm & Garden		✓		✓	✓	✓				✓	✓	✓
Furniture	✓			✓							✓	✓
General Industry			✓	✓		✓		✓	✓	✓	✓	✓
Tanks - High Spec		✓		✓	✓		✓		✓		✓	✓
Tanks - Low Spec				✓	✓	✓	✓		✓		✓	✓
Packaging				✓					✓		✓	✓
Sports & Leisure				✓		✓					✓	✓
MATERIALS PROCESSED												
Carousel	✓	✓	✓	✓	✓				✓	✓	✓	
Shuttle	✓			✓				✓	✓		✓	✓
Rocking Oven / Open flame		✓				✓	✓				✓	
MATERIALS PROCESSED												
1m - 2m	✓			✓								
2m - 3m				✓	✓	✓						
3m - 4m			✓	✓			✓	✓	✓			
Above 4m		✓									✓	✓
MATERIALS PROCESSED												
Tool Design	✓		✓	✓	✓	✓			✓		✓	✓
Tool Manufacture					✓	✓						✓
Rapid Prototyping Facilities				✓		✓						✓
Silkscreen Printing			✓	✓					✓			
In-Mould Labelling	✓			✓		✓		✓	✓		✓	✓
Assembly	✓	✓			✓	✓	✓	✓	✓		✓	✓
Machining	✓				✓	✓			✓		✓	✓
Welding					✓	✓					✓	

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BPF BUSINESS SUPPORT NETWORK

What Is The Business Support Network?

The Business Support Network is a unique BPF Group which consists of companies working in support of the Plastics Industry. The Network aims to give executive decision-makers from the plastics industry a competitive advantage by highlighting 'best-in-class' suppliers, who are invited to join the Business Support Network after recommendation by the BPF Membership.

www.plasticssupport.net

SERVICE PROVIDERS

	ASSET FINANCING	COMMERCIAL BANKING	ELECTRICAL COMPLIANCE	FINANCIAL SERVICES	HEDGING	INSURANCE BROKER	INTERNATIONAL PAYMENTS	INTERNATIONAL STANDARDS	LAWYERS	MANUFACTURING EFFICIENCY	PENSIONS	RECRUITMENT & HR	SALES FINANCING	SKILLS DEVELOPMENT	TRAINING & COURSES	BUSINESS SKILLS DEVELOPMENT	ELECTRICAL	FINANCIAL MARKETS	POLYMER TRADING AND HEDGING
Barclays Corporate	✓	✓									✓		✓					✓	
Conaught			✓											✓			✓		
Greystone				✓							✓								
IMSM								✓											
Listgrove												✓				✓			
LME					✓									✓				✓	✓
Moneycorp							✓											✓	
PERA														✓		✓	✓		
PICME										✓				✓		✓			
Travers Smith									✓										
Willis Commercial Network						✓													

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www.barclayscorporate.com
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F: +44 (0) 20 7603 6415
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Polymer Training & Innovation Centre
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T: +44 (0) 1952 610 101
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IN-HOUSE TESTING FACILITIES

IN-HOUSE TESTING	BRADFORD UNIVERSITY *	DURHAM UNIVERSITY *	IMPACT SOLUTIONS	LEEDS UNIVERSITY *	LONDON METROPOLITAN UNI	LOUGHBOROUGH UNIVERSITY	NANOFORCE	SHEFFIELD UNIVERSITY *	WOLVERHAMPTON PTIC **
Absorbtion			✓						
Atomic Force Microscopy	✓	✓		✓		✓	✓	✓	
Ballistic Testing						✓			
Ceramic Processing	✓					✓	✓	✓	
Characterisation Tools					✓	✓		✓	
Coating Technology	✓					✓	✓	✓	
Density	✓		✓	✓	✓	✓		✓	
Electro Spinning Unit	✓	✓				✓	✓		
Electron Microscopy						✓		✓	
Filament Winding						✓			
GPC							✓		
Impact Testing			✓		✓				
Injection Moulding	✓		✓		✓	✓	✓		✓
Imaging SIMS							✓		
Micro Moulding Injection Machine	✓				✓	✓	✓		
Mini Extruder	✓			✓	✓	✓	✓	✓	
Nanospider						✓			
NMR		✓			✓				
PCFC Micro Calorimeter						✓	✓		
Performance Tests			✓	✓	✓	✓		✓	✓
Platen Hot Press	✓			✓		✓	✓		
Polymer Processing	✓		✓		✓	✓	✓		✓
Resistance			✓		✓	✓			
Rheometry	✓				✓				
Single Screw Extruder	✓		✓	✓	✓	✓	✓		
Size Exclusion Chromatography		✓			✓				
Spark Plasma Sintering						✓			
Tensile	✓	✓	✓	✓	✓	✓		✓	
Thermal Analysis		✓	✓		✓	✓		✓	
Twin Screw Extruder	✓			✓	✓	✓	✓		
X-Ray Unit						✓		✓	

COURSE PROVIDERS

	BRADFORD UNIVERSITY *	DURHAM UNIVERSITY *	IMPACT SOLUTIONS	INSTITUTE OF MATERIALS (IOM3)	LEEDS UNIVERSITY *	LONDON METROPOLITAN UNI	LOUGHBOROUGH UNIVERSITY	SHEFFIELD UNIVERSITY *	WOLVERHAMPTON PTIC **
PROCESSES									
Blow Moulding						✓	✓		✓
Compound Moulding						✓			
Compounding						✓	✓		
Extrusion				✓		✓		✓	
Health & Safety			✓						
Injection Moulding				✓		✓	✓	✓	✓
Polymer Engineering	✓		✓	✓	✓	✓	✓	✓	✓
Specialist Processing (EPS)						✓			
Thermoformers						✓			✓
MATERIALS									
Automotive Materials							✓		✓
Bio Materials		✓						✓	
Composite					✓	✓		✓	
Plastics Materials			✓		✓	✓	✓	✓	✓
Product Design			✓	✓		✓			✓
Sustainability & The Environment						✓	✓		✓
OTHER COURSES									
Adhesive Bonding				✓			✓	✓	
Construction									
Introduction to Plastics	✓	✓	✓		✓	✓		✓	
Laboratory Capabilities		✓	✓		✓	✓			✓
Nanotechnology		✓			✓			✓	
Packaging			✓	✓			✓		✓
Polymer Physics		✓	✓		✓			✓	
Polymer Technology	✓		✓		✓	✓	✓	✓	
PVC						✓	✓		
DEGREES AND QUALIFICATIONS									
PHD / Mphil / Eng D / M Res	✓	✓			✓	✓	✓	✓	
MSc / MA / MChem	✓	✓			✓	✓	✓	✓	
BTEC National Certificate									✓
BA / BSc / Beng / BTEC	✓				✓	✓	✓		
HND / HNC									
NVQ / GNVQ						✓			✓
CONSULTANCY SERVICES									
Applications					✓				
Behaviour & Properties					✓				
Commercialisation			✓				✓		
Intellectual Property							✓		
Materials Information Service			✓	✓		✓			
Measurement and Design	✓		✓			✓			
Polymer Characterisation		✓	✓		✓	✓			
Polymer Physics		✓	✓						
Polymer Processing	✓		✓		✓	✓			
Polymer Synthesis/Chemistry		✓	✓		✓	✓			
Product Prototyping	✓		✓						
Product/Process Development			✓		✓	✓			
PVC Research and Consultancy						✓			

* INDICATES POLYMER IRC UNIVERSITY ** WOLVERHAMPTON POLYMER TRAINING & INNOVATION CENTRE

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PRODUCED IN CONJUNCTION WITH

Knowledge Transfer Network
Materials