Institution: BRUNEL UNIVERSITY (H0113)

Unit of Assessment: 12 – Aeronautical, Mechanical, Chemical and Manufacturing Engineering

Title of case study: Recycling Mixed Plastics

1. Summary of the impact (indicative maximum 100 words)

Research at Brunel University demonstrated how the Powder Impression Moulding (PIM) process can be adapted to form a solid-skinned and foamed core polymer lightweight sandwich panel from 100% mixed post-consumer polymers. The research showed that unlike conventional plastic recycling technologies, this process was tolerant to high concentrations of impurities. It was also shown that coarse flakes could be used as feedstock, removing the need to grind the feedstock to a fine powder. This, for the first time, established the PIM process as a recyling method and provides a source of income for industries collecting post-consumer plastics. In 2009, ERT Plc, who own the IP associated with PIM, signed a licence agreement with 2K Manufacturing Ltd to manufacture and sell a range of flat-board products made from 100% mixed post-consumer plastics. These boards are sold as EcoSheets and are 2K Manufacturing's only product. 2K buy post-consumer recycled plastics from recycling firms who run Municipal Recycling Facilities, (MRF), providing them with increased income from waste collected from consumers, and sell EcoSheets to a variety of industries and distributors for applications in construction, agriculture, flood control facilities and military uses. For commercial reasons, exact production and sales figures are not available, but we estimate that at least 1 million boards have been produced and sold since 2009. The impact on the end user is that, although the price of an EcoSheet is comparable to the plywood board it replaces, EcoSheet does not rot, is more workable, and can be recycled several times.

ERT Plc have licensed the technology enhanced by the Brunel research to a number of other businesses.Thus the research at Brunel has assisted the creation of a new industrial sector, and a new product with many advantages, including reduced reliance on virgin polymers and reduced environmental burdens (such as landfill costs), over the product it replaces. This has created economic and environmental benefits at all stages of the consumer plastic cycle, creating new industries and jobs.

2. Underpinning research (indicative maximum 500 words)

The Powder Impression Moulding (PIM) process converts plastic powder into reusable lightweight sandwich structures. The process involves formation of two skin layers by sintering plastic powder on a mould surface, creation of the core in between and foaming of the core to produce an integrated sandwich structure with solid skins. Depending on the formulation, PIM materials offer similar performance features to foam boards, fibre boards, floor boards and insulation boards. Before the Brunel University research took place these have only been manufactured with virgin polymers.

The Technology Strategy Board-funded project, Advanced Material: Materials for Extended First Use and Re-Use(PIM) (2007-2009) explored product opportunities for the materials produced by the PIM process using mixed plastic recyclates. It was led by Prof Jim Song from Brunel University (the academic investigator) and Environmental Recycling Technologies Ltd (the industrial lead) along with other industrial partners Bovis Lend Lease, Tesco, St Regis Paper Company Ltd, Philip Tyler Polymers and PERA.

It is well known that flat-board PIM materials have similar performance features (although their usage is not widespread) to insulation boards, timber, plastic foams, and so on, all widely used in UK industry, in particular in the construction industry. The project aimed to develop pallets, packaging and simple furniture using mixed post-consumer plastics through the PIM process, which would be commercially competitive and technically robust.

Prof Song investigated variants of the PIM process using different mixtures of plastic waste. He identified a novel approach that could produce sustainable PIM sandwich panels from plastics with up to 100% mixed post-consumer plastic waste.

The team established that the novel PIM process was (i) exceptionally tolerant to contaminations

within the recyclate feedstock (sand, soil, paper, metal and other non-polymer debris) [1] minimising the need for cleaning pre-treatment of the waste plastic; (ii) that the process tolerates high concentration of dissimilar polymers in the feedstock, reducing the cost of polymer segregation and purification [2] and (iii) feedstock from MRF in medium sized flake forms can be directly used in PIM panels, saving excessive powder pulverisation as in the conventional PIM process [2].

These findings demonstrate that the process can operate with minimum sorting, purifying and cleaning and resizing of mixed waste plastic recyclates as long as waste streams from different sources are monitored so that the dominating polymer concentration is sufficient for appropriate melting, encapsulation of high melting point foreign particles and foaming. Hence the novel process is both energetically and economically cheaper than the conventional process.

Thus, by demonstrating that mixed post-consumer plastics could be used in the PIM process, the project established the PIM process as a recycling method for the first time.

3. References to the research (indicative maximum of six references)

1) Kun Qi, Jim Song, Karnik Tarverdi, Recycling of mixed plastics using PIM technology Part I - Influence of impurities in the feedstock on mechanical properties of PIM sandwich panels, Proceeding of 1st International Conference on Recycling and Reuse of Materials, ICRM 2009. Kottayam, Kerala India, 17-19 July 2009. http://bura.brunel.ac.uk/handle/2438/7660

2) Kun Qi, Jim Song, Karnik Tarverdi, Recycling of mixed plastics using PIM technology Part II - Influence of loading and flake size of mixed plastics on mechanical properties of PIM sandwich panels, Proceeding of 1st International Conference on Recycling and Reuse of Materials, ICRM 2009. Kottayam, Kerala India, 17-19 July 2009. http://bura.brunel.ac.uk/handle/2438/7661

Grants

- *Re-Plas Materials for Extended First Use and Re-use* (2007-2009) Technology Strategy Board, £1.2M, PI Prof. J Song.
- *A Process to Engineer and Manufacture Medium to High Value 3D Products Using Mixed Polymer Recyclate* (3DPIM) (2010-2013), European Commission, 1.8M euro, PI Prof. J Song.

4. Details of the impact (indicative maximum 750 words)

The project developed a novel Powder Impression Moulding (PIM) process which can manufacture lightweight sandwich structures from 100% mixed post-consumer polymer. The process has exceptionally high tolerance to feedstock variations (contamination, dissimilar materials and particle size) and thus it is energetically and economically competitive to conventional PIM and uniquely effective recycling technology for dealing with mixed/comingled plastics difficult to recycle using other existing technologies.

Potentially, these panels can replace plywood in construction applications, of which over 25 milion sheets are used every year in the UK. This process also creates a value-added market for mixed waste plastics by capturing waste plastics for reuse. The UK uses over 5 million tonnes of plastic each year, of which only 19% is being recovered or recycled (source: British Plastics Federation 2010).

Environmental Recycling Technologies Plc (ERT), the lead industrial partner on the TSB grant, owns the worldwide IP for the PIM process, sells licences to manufacturers and retailers to produce and sell PIM products. Extending the use of PIM to mixed post-consumer plastics, and reducing the need for extensive segregation, cleaning and grinding, has increased the value of this IP.

In 2009, 2K Manufacturing Ltd was launched to exploit the new technology. They signed an exclusive £2M licence with ERT to manufacture EcoSheet, produced by the novel PIM process, made of 100% recycled waste plastics in the UK. 2K Manufacturing Ltd now employs 16 people and has ramped up production very quickly. In 2011 the Economist reported that 2K Manufacturing could produce 360,000 EcoSheets per year and ERT have reported since then that the capacity of the plant has increased substantially. For commercial reasons, exact production and sales figures are not available, but we estimate that at least 1 million boards have been produced and sold since 2009. Both ERT and 2K Manufacturing acknowledge the contribution of Brunel University research to the early commercialisation of EcoSheet on their respective websites.

EcoSheets received a Federation of Small Business Award in June 2012, a National Recycling Award in July 2011 and a Manufacturing Excellence Award in July 2011. EcoSheet retails at the same price as plywood, but it is easier to work because it does not produce dangerous splinters. It does not rot, so has substantial advantages in a number of application areas, such as in the agricultural sector, where it is used for animal shelters. Finally, whereas the plywood it replaces would end up in landfill, EcoSheet, even if it has been painted and is full of nails, can be recycled into more EcoSheet.

ERT Plc have granted further licences to:

- Contour Showers Ltd to manufacture high-value shower trays from over 90% recycled material.
- Brownwater Plastics in Kentucky, USA to manufacture long-span barge covers.
- Dodge Dakota to manufacture a complete truck bed section of pick-up trucks.

The novel PIM process can also produce encapsulated automotive parts to protect them from corrosion, as well as defence shields, flood barriers, roll cages, pallets and fence panels.

5. Sources to corroborate the impact (indicative maximum of 10 references)

1. Construction Consultant at Environmental Recycling Technology Plc http://www.ert4c.com/funding

2. Sales Director for 2K Manufacturing Ltd http://www.ecosheet.com/

3. The Economist, *The Plastic Sausage Machine*, 2009 http://www.economist.com/node/14255246