Technical Bulletin

October 2010

Self Reinforced Polymer composites with impact!

There is an urgent and growing desire for light-weight composite materials to provide solutions to a variety of new environmental challenges. Reducing the energy needed to create and process materials, reducing the volume of materials needed and benefitting from the improved performance they offer are all hot topics in the world of polymer research.

The Esprit Project

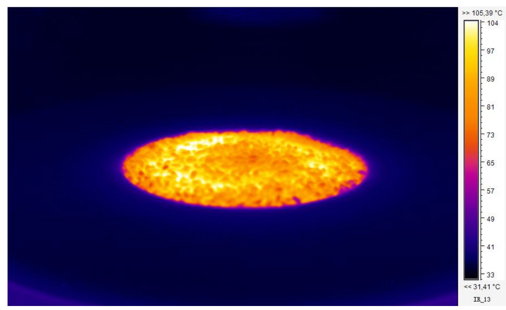
The Esprit project was created to address these issues by means of Self Reinforced Polymer composites, a new and rapidly developing family of materials. This project, funded by the EC FP7 programme, which started in 2008 and due to last three and a half years, aims to develop production-ready technology utilising new material combinations, advanced selective melting processes and process techniques allowing the materials to be flow-moulded without affecting the reinforcing fibre properties.

Self Reinforced Polymer (SRP) composites are a combination of thermoplastic matrix and thermoplastic reinforcement fibres, typically both of the same polymer family, giving the usual advantages of composite materials such as light weight, stiffness and excellent impact properties but with the added advantage of full recyclability. There are successful SRP composites in the market today, in the form of fabrics or pre-consolidated sheets which are making inroads into ballistic, sports, luggage and automotive applications. What would further the acceptance of SRP composites is a flowing version, which would increase hugely the design and manufacture possibilities, opening the possibility of compression and injection moulding.

With one third of the Esprit project remaining, some major successes have already been made. The SRP composite families selected, after exhaustive testing, are Self Reinforced Polyolefins (srPO), Self Reinforced Nylons (srPA) and Self Reinforced Polyesters (srPet) giving a wide range of characteristics.

Selective Heating

One of the key developments of Esprit is to perfect the technique of selective heating. The concept of SRP composites is to soften or melt the matrix phase, allowing it to be formed, without affecting the reinforcement phase. This requires careful processing as there is a limited 'window' of temperatures which allow processing without damage. The selection and modification of the polymers, both matrix and reinforcement, can



have a significant effect on the ease of processing, and the materials being selected for the Esprit project have been carefully examined. The innovation being developed in this project is to include additives into the matrix part of the composite which are susceptible to external energy sources, in this case electromagnetic, which allows the selective heating of just the matrix. The research has shown which additives are most successful and also that homogenous distribution of the additives is critical. This distribution has been improved dramatically, even in difficult materials such as polypropylene. The result is that more even heating can be achieved, with lower percentages of additives and with less energy.

The selective heating will primarily be used to heat sheet materials but has also been shown to work with pellets which could be subsequently used, for example, for compression moulding.

The focus now is to understand and optimise the relationship of time, power and additives on the effectiveness of heating. The heating effect is supplied by means of microwave or induction energy. The effects of mono-mode and multi-mode microwave energy have been found to be distinctly different. The effects are also not linear; as the polymers heat up their reaction to the energy input changes as their molecular structure changes and, of course, the polar characteristics of different polymers vary the heating effects.

Impregnation Techniques

There are a number of ways to combine the matrix and reinforcement to achieve SRP composites and, for Esprit, the development has been in melt impregnation, commingling and powder impregnation. Melt impregnation uses a reinforcement yarn which is passed through a heated die into which a melted matrix polymer is injected, coating the yarn and resulting in a rod which can be chopped into pellets. Commingling uses yarns for both matrix and reinforcement and combines them in an air jet, making a yarn with a controlled ratio of each. An innovation within the Esprit project has been an integrated line which commingles the yarns, pultrudes a rod and then chops pellets, improving efficiency for this technique. Finally, powder impregnation has been successfully adapted to make sheets of chopped and continuous fibre pre-consolidated sheets. The technique involves passing the sheets through an electrostatically charged zone, in a continuous process, which intimately distributes a fine powder into the substrate. It is possible to include the selective heating susceptors onto all of these techniques, creating a very diverse set of intermediate materials.

Moulding Processes and Control Systems

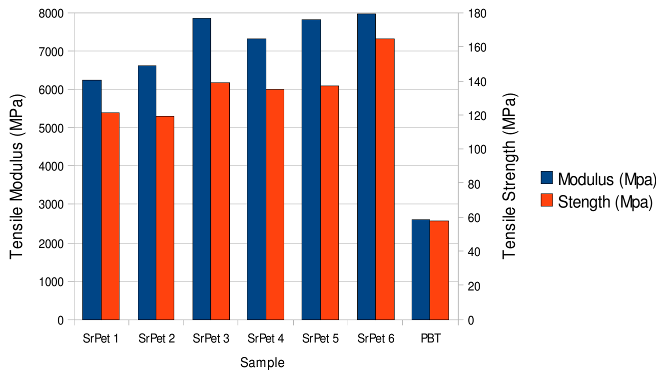
In its final stages the project will be processing the materials in volume, to manufacture case study parts in a variety of techniques. The most challenging is injection moulding as the combined matrix and reinforcement has to work its way through a conventional screw and barrel combination, a rather harsh and uncontrolled environment for pellets with a small processing window. However, through material developments and careful analysis of the processing system, success is now being achieved. It is apparent that optimal, successful injection (or LFT style) processing is possible only through a complete system of material combinations, processing control and adapted machinery.

Compression moulding is also being carried out on sheet materials and pellets. The sheet materials can be pre-consolidated, powder impregnated sheet or extruded sheets from SRP pellets. There is the possibility of combining sheet and flowing technologies to achieve localised reinforcement which could be used for improved impact strength in local areas.

In parallel to the moulding techniques, control systems are being improved to facilitate the use of these new materials. One of the possible processing routes for SRP composites is variothermic moulding technique where a tool is rapidly heated and cooled to form parts. The particular area of development in this area for Esprit is a high-pressure, dual-circuit heating system for heating and cooling tools rapidly and with fine control.

Results

The work of the project is generating promising material properties. A polypropylene SRP has been created with extremely high impact strength. The composite, containing relatively long fibres, shows an unusual but highly attractive combination of high modulus, high strain at break, high impact resistance and low notch sensitivity. Compared to the polypropylene base material the modulus is increased by almost 100%, the strength is increased by more than 50%, while at the same time the strain at break is still high at over 20%.The most remarkable property is the notched impact strength: it increases from 3 to 55 kJ/m^2. This is much higher than even the best impact modified polypropylenes, while the modulus is much higher.



A PBT-based self reinforced polyester (srPet) has been developed that shows a 200% increase in the tensile modulus compared to unreinforced PBT, without increasing the density of the material. The material also shows an increase in tensile strength of around 180%. The graph shows the tensile modulus and strength of the PBT based srPet at various processing conditions compared to the unfilled PBT matrix. These results show that, through careful material selection and processing, some truly impressive mechanical properties can be achieved.

Esprit consortium:
AIMPLAS, AVK, EATC, Comfil, Fibroline, Fricke und Mallah Microwave Technology, IVW, NetComposites(coordinator), PEMU, Polisilk, Promolding, Regloplas, StructoForm, Ticona.

Project website:
www.espritproject.eu

All Enquiries:
Chris Hare, phone: +44 (0)1246 266244 or chris.hare@netcomposites.com

The research leading to these results has received funding from the European Community's Seventh Framework Programme NMP-2007-2.4.1 under grant agreement 214355