The editorial board has selected the prize-winning articles for the contest presented in Structure 37. Contributions were invited in the field of composite materials; those articles that the board found suitable have been printed in Structure 38 and 40.

We would like to thank all participants for their interesting contributions.

The 1st prize has been awarded to Luther M. Gammon, The Boeing Company and Brian S. Hayes, University of Washington for the article: Microscopy of Composite Materials

The 2nd prize goes to Martin Braekvold, Bekaert Technology Center for the article: Metallographic preparation of Steel cord cable sections

and the 3rd prize goes to Pedro Vasconcelos, ESTG – Instituto Politécnico de Viana do Castelo, F. Jorge Lino, FEUP – Faculdade de Engenharia da Universidade do Porto and R. J. Neto and Armanda Teixeira, INEGI-CETECOFF for the article: Glass and Carbon Fibre Reinforced Hybrid Composites for Epoxy Tooling

Many congratulations to the winners
Glass and Carbon Fibre Reinforced Hybrid Composites for Epoxy Tooling

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INEGI is a research institute that has been developing a noticeable activity promoting the use of Rapid Prototyping (RP) and Rapid Tooling (RT) technologies. Using these technologies, companies are able to reduce costs and the time to market of the new products with better design and quality, thus improving their competitiveness.

This communication is part of the work that has been conducted in a project that uses an indirect rapid tooling process to manufacture innovative tools for product development. Polymeric composite tools are produced pouring its mixtures over RP models. The tools produced are used in processes such as injection moulding, thermforming of different types of thermoplastics, and sheet metal forming.

Introduction

Frequently, indirect RT processes are based in a RP model and in traditional technologies, which have low cost processing and equipment1,2. The objective of this work is to develop an indirect RT process, based in RP models and in composite materials, to manufacture prototyping tools, which will then be used to produce functional prototypes and pre-series3-5. This indirect RT technique ("firm tooling") offers a high potential for a faster response to market needs, creating in this way a new competitive edge. Using this process, companies will be able to produce thousands of parts, but with restricted geometries and poor tool reliability. This does not necessarily mean a significant disadvantage, because a typical tool for prototypes is often used to produce a relatively small quantity of parts (around one hundred), and the strength of a long cycle run tool is not required. Although the indirect methods are more time consuming when compared with direct RT methods, such as DMLS (direct metal laser sintering), their low cost processing and equipments makes them a very attractive alternative1.

The tools developed are composed by an epoxy resin and aluminium particles, added to improve the thermal conductivity of the tool, which is an essential parameter for plastic injection tools moulding6,7,8. However, this procedure also lowers the mechanical properties of the tool. In order to overcome this problem, fibres were added to the composite.

Experimental procedure

A high temperature epoxy, based on aromatic glycidyl amine, that exhibits a suitably viscosity to be mixed with aluminium powder of 80 mm medium equivalent diameter, was employed. The curing agent was a cyclosilicone polyamine showing a good level of reactivity.

To obtain a multifunctional material with good mechanical and thermal properties, a layered structure was produced. This objective was performed combining aluminium filled epoxy outer layers with continuous fibres reinforced epoxy inner layers (glass and carbon woven fabrics).

Specimen laminates were produced by the lay up manufacturing process. Aluminium rich outer layers were stacked with eight reinforced woven fabric inner layers and subjected to a 30 kPa consolidation force and the respective curing method. Two types of woven fabric, plain weave, with similar warp and weft weights, were used: E glass fibres (280 gr/m²) and HS carbon fibres (196 gr/m²) based in PAN (polyacrylonitrile) precursor.

To determine the mechanical properties of the composite tool to be produced, standard specimens for tensile test, impact test and thermal conductivity were made.

Sample Preparation

After curing, the specimens were sectioned with a water-cooled metal-bonded diamond cut-off wheel on a Struers Accutom-5 machine and, then, embedded in a low viscosity, cold hardening epoxy resin (Epoxyk). Samples were mounted into a six-specimen holder for semi-automatic grinding-polishing (Struers Pianopol-3 and Pedemax-2). Mounted samples were ground with different grades of SiC papers and, finally, polished using an alumina suspension (Struers AP-Paste) on a Struers SP-PoliFloc 1 cloth. The details of all these steps are indicated in Table 1. After polishing, glass fibre reinforced composite samples were chemically etched for ten seconds, using dilute 10 vol% hydrofluoric acid, to enhance fibre visibility.

Results

As one can see in Table 2, aluminium filled epoxy samples have slightly lower deformation capacity. However, the aluminium addition significantly improves the thermal conductivity of the epoxy resin.
Table 1: Sample preparation details for materialographic analysis of hybrid composites epoxy matrix based.

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<tbody>
<tr>
<td>Grinding</td>
<td>-</td>
<td>SiC</td>
<td>320</td>
<td>Water</td>
<td>150</td>
<td>120</td>
<td>2</td>
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<tr>
<td></td>
<td>-</td>
<td>SiC</td>
<td>500</td>
<td>Water</td>
<td>150</td>
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<tr>
<td></td>
<td>-</td>
<td>SiC</td>
<td>1000</td>
<td>Water</td>
<td>150</td>
<td>120</td>
<td>3</td>
</tr>
<tr>
<td>Polishing</td>
<td>SP - PoliFlo1</td>
<td>Alumina</td>
<td>F</td>
<td>-</td>
<td>150</td>
<td>120</td>
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Table 2: Mechanical and physical properties of the epoxy matrix based tools.

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<tbody>
<tr>
<td>Epoxy system</td>
<td>40-50</td>
<td>3</td>
<td>2</td>
<td>65</td>
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<tr>
<td>Epoxy system + Al</td>
<td>40</td>
<td>7.5</td>
<td>0.9</td>
<td>65</td>
<td>2.1</td>
</tr>
<tr>
<td>Epoxy system + Al + GF</td>
<td>165</td>
<td>15.3</td>
<td>5</td>
<td>72</td>
<td>1.25</td>
</tr>
<tr>
<td>Epoxy system + Al + CF</td>
<td>295</td>
<td>40</td>
<td>0.75</td>
<td>73</td>
<td>2.1</td>
</tr>
</tbody>
</table>

AF: Fine Aluminum; GF: E Glass Fibre - plain weave (280 gr/m²); CF: Carbon Fibre KS3K - plain weave (196 gr/m²).

The thermal behaviour of these composites shows a straight dependence on the aluminum packing in the epoxy matrix, as one can see in the optical micrograph of Figure 1. Combining high conductive aluminum filled external layers with woven fabric reinforced inner layers, a tailored hybrid composite material can be obtained with optimised characteristics that were not possible to obtain with the single components. Carbon fibres, when compared with glass fibres, exhibit better quality. With carbon fibres, the strength, the stiffness, the thermal conductivity and the materials processing are substantially improved. Nonetheless these composites are more expensive.

Materialographic analysis, using an optical microscope (Olympus PMG3), of the aluminum reinforced composite demonstrate that the aluminum and the fibres are well distributed in the tool, which is a result of an adequate processing of these materials. Optical micrographs obtained with different raw materials combinations show interesting patterns of the resultant hybrid laminate composite (Figure 2). Black points are pores that result from the air retention during the processing cycle. This is an imperfection that is always present in the manufacture of fibre reinforced resins.

Conclusions
The manufacturing process presented, which is based in an epoxy resin, aluminum fillers and continuous fibre reinforcement, is expected to be a valuable alternative for indirect rapid tooling.

Materialographic analysis of the composites provides important information about the degree and quality of the components mixture. The high thermal conductivity of aluminum powder and the carbon fibres resistance allow the manufacture of multifunctional laminates that meet the most important requirements of rapid epoxy tooling for plastic injection moulding applications, such as high tensile strength and thermal conductivity.

Acknowledgements
The authors would like to acknowledge the financial support from FEDER through the project POCTI/EME/41199/2001, "Development of an Indirect Rapid Tooling Process Based in Polymeric Matrix Composites", approved by the Fundação para a Ciência e Tecnologia (FCT) and POCTI.

Figure 1: The thermal conductivity of the aluminum filled epoxy depends on the packing density of the aluminum powder. (A) system presents a thermal conductivity about twice the one of (B) system.
References

Figure 2: Layered microstructure obtained in an optical microscope (Olympus PMG3) showing spherical aluminium particles and glass and longitudinal sections of glass fibers (A), (B), and carbon fibers (C) and (D).
Article Contest on the Preparation of Composite Materials

The editorial board has awarded the

3rd Prize

to the authors

Pedro Vasconcelos, ESTG - Instituto Politécnico de Viana do Castelo, F. Jorge Lino, FEUP - Faculdad de Engenharia da Universidade do Porto and R. J. Neto and Armanda Teixeira, INEGI-CETECOFF for the article

Glass and Carbon Fibre Reinforced Hybrid Composites for Epoxy Tooling

The winners will share the prize

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Michael Rückert
Bente Freiberg
Structure Award, 3rd Prize

Copenhagen, March 2003

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Danish crowns: Seven hundred twenty five

To: F. Jorge Lino, FEUP - Faculdade de Engenharia da Universidade do Porto

Signature:

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Structure Award, 3rd Prize

Copenhagen, March 2003

Pay this check DKK: 725.-
Danish crowns: Seven hundred twenty five

To: Armanda Teixeira, INEGI-CETECOFF

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