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Fabricación flexible, eficiente y automatizada de componentes en composite de altas prestaciones

Los materiales compuestos con claros candidatos para componentes de vehículos que permitan mejorar la eficiencia y sostenibilidad en muchos medios de transporte. Las ventajas de estos materiales son numerosas e incluyen la ligereza y la posibilidad de reducir costes de montaje debido a su potencial de integración. Esto supone una mayor reducción de peso, mayores prestaciones y capacidad de carga de los vehículos así como una reducción de consumo de combustible y de emisiones.

Sin embargo, los procesos de fabricación actuales utilizados en aeronáutica y automoción conllevan una inversión muy elevada para empresas PYMES lo cual supone una barrera para su implementación masiva en sectores como automoción y otros.

En este contexto, durante el proyecto LOWFLIP, Tecnalia, Fill y otros partners han desarrollado recientemente un proceso de bajo coste para la fabricación de componentes en composite en sectores como automoción y otros, con las siguientes características:

- nuevo proceso automatizado basado en concepto pick & place para gran capacidad de produccion y piezas de altas prestaciones/ calidad, con una inversión reducida accesible para las PYMES
- proceso rápido de conformado, calentamiento y curado con prepregs de curado rápido y un muy significativo ahorro de consumo energético durante el proceso mediante utillajes innovadores

La célula automatizada desarrollada está disponible para su implementación en los principales sectores.

Flexible, efficient and automated fast manufacturing of high performance composite parts

Fibre-reinforced polymer composite materials are leading candidates as component materials to improve the efficiency and sustainability of many transport modes. Advantages of high performance composites are numerous including lighter weight and reduced assembly costs due to high level of integration potential. This translates into greater weight savings resulting in improved performance, greater payloads, fuel savings and emissions reductions.

However, the current manufacturing processes used in aeronautical and automotive still represent high capital investments for SMEs and this represents a major barrier for their deployment in sectors like automotive and others.

In this context, during the LOWFLIP project, Tecnalia, Fill and other partners have recently developed a low cost manufacturing process dedicated to structural composite parts for sectors like automotive and others, with the following features:

- New fully automated process chain with pick and place multigripper solution providing high production capacity and high quality/ structural performance, with low level of investment, accessible for SMEs.
- Fast preforming, heating and curing with snap cure prepregs and very significant reduction of energy consumption during the process due to innovative toolings

The automated cell developed is ready for implementation in the main sectors using composites.
1 Introduction

The cost structure involved in the manufacture of an advanced composite part is dominated by process costs that can reach up to 70% of the overall cost in some cases. This factor also limits the production capacity for some mass production applications. In this context, Tecnalia has developed a new flexible and fully automated cell called “Tecnacomp” (Figure 1) for the manufacture of small/medium-size 3D dry preforms. The process approach consists of a pick & drape & place unit mounted on a robot, and then combined with fast and flexible heating and compaction solutions.

Figure 1- “Tecnacomp” automated cell developed by TECNALIA

This process concept originally developed by Tecnalia for dry fiber preforms, during the LOWFLIP project, has been validated also for fast curing prepregs by Tecnalia and has been then scaled up by the partner FILL to be able to address bigger parts and with appropriate equipment at industrial level.

The project LOWFLIP aimed at developing new technologies in many different areas along the process chain of fiber reinforced polymers with the goal to set up automated production processes which require significantly lower invest than comparable state-of-the-art technologies (see Figure 2).

2 Snap curing prepreg material development and characterization

The development of a tailored resin formulation for the novel prepreg materials was a crucial point. A new resin system has been developed by SGL and tested during the project, featuring out-of-autoclave snap-cure capabilities and the following properties:

- **Rapid cure:** e.g. 15 min @ 120 °C or 3 min @ 150°C
- **Long shelf-life at room temperature:** ≥28 days
- **Glass transition temperature of 120 °C**
- **Suitable for out-of-autoclave curing**
- **Tailored tack for automated processing**

This resin system has been combined with a specific carbon prepreg/ semipreg material to help with the automated handling operations. In particular, a biaxial ±45° non-crimp fabric (fiber areal weight 400 g/m²) that was asymmetrically impregnated (“semi-preg”) to provide best processability in pick & place handling was developed and tested.

Figure 3- kinetic characterization of the snap cure resin

Figure 4 - semipreg material sample and concept
### 3 Process and tooling concept development and validation

**Low investment process concept:**

A low investment process based on forming and curing under vacuum was developed including the following steps (for a sandwich structure):

- Handling and draping of the bottom skin onto the main tool
- Forming of the bottom skin
- Positioning of the core
- Handling, draping and forming the top skin
- Curing with a heated membrane
- Cooling and demolding

![Figure 5 - Process concept based on forming and curing under vacuum](image)

**Low cost tooling concept:**

Innovative tooling concepts with fast heating and low energy-consumption were developed together, in comparison with state-of-the-art tooling that are typically a metallic solution milled out of block materials such as aluminium or invar steel with high thermal masses. Therefore, the following different concepts were developed and validated:

- Selection of the appropriate heating wires in order to provide the necessary thermal power
- Definition of the appropriate circuit shape and support materials to provide a good balance between flexibility and durability
- Durability tests were performed. The results showed that the right membrane material is crucial to obtain a robust process, especially as epoxy based resin systems can significantly reduce the membrane properties after several curing cycles. Finally, a material with a good combination of flexibility and robustness was found.

![Figure 6 - Main tool picture and heating performance](image)

**3D membrane with resistive heating circuit:**

As the target part established is a sandwich structure, it was important also be able to provide heating also for the curing of the upper skin but without the need of an additional expensive metallic upper tool. Therefore, a 3D self heated membrane was developed in order to provide this functionality as well as the requested fast heating requirement.

For the development of the 3D self heated membrane, the following main activities were conducted:

- Selection of the appropriate heating wires in order to provide the necessary thermal power
- Definition of the appropriate circuit shape and support materials to provide a good balance between flexibility and durability
- Durability tests were performed. The results showed that the right membrane material is crucial to obtain a robust process, especially as epoxy based resin systems can significantly reduce the membrane properties after several curing cycles. Finally, a material with a good combination of flexibility and robustness was found.

![Figure 7 - 3D self heated membrane picture and heating performance](image)

**Fluid heated metal tooling:**

The main tool was developed and provided by the partner ALPEX, based on a hollow metal tool with low thermal inertia for fast heating and cooling capabilities with internal fluids. The tool was tested and fast heating capabilities were demonstrated providing heating rates in the range of 6-10$^\circ$/min.

![Figure 8 - thermal validation of the 3D self heated membrane](image)
The main results obtained for the 3D self heated membrane developed are the following:

- Heating rates: approx 10º/ min
- Total process energy consumption: aprox. 5KWh/ part

4 Automated cell concept development, implementation and validation

In the final implementation, the pick & drape & place device based on Tecnalia’s “Tecnacomp” system has been combined with two different types of membranes: a highly elastic membrane in order to drape the material on the complex mould and a 3D-membrane with integrated resistive heating circuits that is later heated up to cure the part. In this way, the automated process chain can be applied to varying geometries and materials with flexibility and low investment capabilities.

For validation purposes, an automotive cross-beam structure (proposed by the partner Carbures) has been developed and produced, which has to withstand bending and torsion loads. It has a length of about 1.2m and consists of a sandwich structure with CFRP skins and a 3D milled foam core. The part complex shape in combination with its sandwich layup requires a highly flexible production process. The targeted volume of production has been defined as 10,000 parts per year, which results in a required curing cycle of about 15-30 mins.

5 Conclusions

With the obtained results, a trade off has been done (see figure 13) comparing the main aspects (cycle time, investment level and energy consumption) with the state of the art process reference (an automated HP RTM process).

<table>
<thead>
<tr>
<th>Concept</th>
<th>Reference: Automated HP RTM</th>
<th>Lowflip process/ cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cycle time (materials handling, preforming/ forming and injection/ curing)</td>
<td>&lt;5 min</td>
<td>10-15 min (with one mould)</td>
</tr>
<tr>
<td>Total process energy consumption (handling, preforming/ forming and tooling heating/ cooling)</td>
<td>100</td>
<td>&lt;10%</td>
</tr>
<tr>
<td>Equipment investment (handling, preforming/ forming, injection/ curing and tooling)</td>
<td>100</td>
<td>&lt;20%</td>
</tr>
</tbody>
</table>

In the future, the promising results obtained for the moment will be combined with the automated manufacturing of customized zero scrap 2D stacks.
Acknowledgements

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Figure 14- LOWFLIP project consortium

References
