Environmental and Cost Assessment of New Thermoplastic Composite Manufacturing Techniques for Transport Applications

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Context

Nowadays, the increasing need of energy and international requirements for environmental sustainability are pushing the transportation industry and the scientific community to reduce fuel consumption and carbon emissions through the reduction of overall car weight. Long fiber thermoplastic composites (TPCs) have been recognized as ideal candidates to replace steel in vehicle structural applications due to their toughness, workability and potential recyclability. Researchers are investigating new manufacturing techniques in order to make long-fiber TPCs more attractive to mass-production industries. This must be accompanied by a comprehensive examination of all the aspects involved, in particular the environmental impact and the cost assessment of the product.

Objective

The ultimate goal of the project is to make an assessment of cost and environmental impact of manufacturing processes for the production of thermoplastic composite components using continuous glass fibers with a PA6 melt supplied by Solvay.

In order to evaluate the cost and impact of thermoplastic manufacturing routes, two different software were used:

- Intelligent Cost Analysis (InCA), for the modeling and full parametric analysis of manufacturing processes.
- Brightway2, an open source framework for life cycle assessment (LCA).

Experimental Setup

Melt resin transfer molding

Melt-RTM, developed at EPFL, uses in-plane flow to impregnate the glass fiber fabric with the thermoplastic melt. It is best suited for small, complex parts.

Injection-compression molding

The C-RTM found at the FHNW uses through thickness impregnation of the glass fabric for component fabrication. It is best suited for simple, large parts.

The data measured for LCA and cost analysis of the lab-scale processes were the cycle time, the power profile of the machines, the material input, the tools, consumables and process related auxiliary measurements.

3-station splitting

After studying the lab-scale processes, upscaled is the next step to bring the study closer to an industrial level relevant to automotive sector. Having access to a large-scale thermoplastic composite compression RTM (TP-CRTM) machine, developed by the Solvay research center in Lyon, the same data than the one found at a lab-scale was measured. In order to have a comparison, a separation of the lab-scale processing phases was set up theoretically to increase machine output, with the same lab-scale parameters upscaled to fit an industrial production scheme.

Results

![Graph showing the process cost vs. product volume for Solvay TP C-RTM vs. 3-station split.

The cost modeling showed that the most impactful factors concerning cost were the process cycle time and initial capital investment. Due to depreciation, for higher number of parts produced, the process cost per part decreases significantly.

Conclusion

For low production volumes (<25k parts), C-RTM is too expensive and has a high environmental impact. For higher production volumes (>50k parts), trade-off between initial capital investment, cycle time and environmental impact importance. Part complexity and dimensions can rule out a process completely.

Outlook

The next step in this research would be to focus on comparing classic thermoset processes (epoxy & glass fiber) with the thermoplastic manufacturing routes. Ideally, the future lowering of carbon fiber prices could enable them to be included in the next process and methodology iterations.