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*Abstract*

# Reproducibility Study of the Thermoplastic-Resin Transfer Moulding Process for Glass Fiber Reinforced Polyamide 6 Composites †

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Climate changes are one of the main adversities of XXI century and can cause serious consequences on biodiversity preservation and available resources. In 2014, road transport was responsible for 20% of $CO_2$ emissions from fuel combustion. Aware of this situation, in the last years, the automotive industry has investigated new solutions for the reduction of gaseous emissions [1].

Automotive weight reduction is a strategy that has been studied to decrease fuel consumption and as a result, the reduction of air pollution. One of the heaviest parts of an automobile is typically its body-in-white (BiW) structure. Steel has been the most common material used on these automotive structural parts because of its mechanical performance; however, it contributes significantly to the final weight of the car. The weight percentage of the BiW structure in a conventional car is typically around 20%, and thus it is essential to develop a new generation of lightweight materials and processing techniques ensuring the required mechanical behaviour [2,3].

Polymers have been increasingly used by the automotive industry because of their low density, corrosion, and fatigue resistance. To incorporate these types of materials in automotive structural applications, it is necessary to reinforce them. Traditionally, glass and carbon fibres are used as reinforcements. Thermosetting composites have already been applied in BiW, although these composites are harder to recycle compared with thermoplastics and metals. The introduction of continuous reinforcing fibres in a thermoplastic matrix can mitigate this problem.

Thermoplastic composites can be manufactured by a liquid moulding technology named Thermoplastic-Resin Transfer Moulding (T-RTM). Polyamide 6 (PA6) is the most promising thermoplastic for this process being synthesised by anionic ring-opening polymerisation (AROP) of ε-caprolactam (ε-CL) monomer inside the mould, in the presence of a catalyst and an activator. The low viscosity of ε-CL has the advantage to contribute to a better impregnation of the continuous fibres and to a higher matrix–fibre adhesion. One of the main challenges of T-RTM is the lack of process reproducibility and therefore parts homogeneity, caused mainly by the highly reactive nature of the resins and processing temperature gradients along the process, which induces a simultaneous and unbalanced polymerisation and crystallisation throughout the part. The existence of voids during the filling stage is also a common problem in liquid moulding technologies. In the literature there is a lack of studies addressing these problems. Thus, T-RTM is still not viable from an industrial point of view.

This work studied the influence of holding pressure throughout the filling and polymerisation stages. It is expected that the holding pressure will help to minimise the voids content and compensate an unbalanced reaction. PA6 and glass fibre-reinforced PA6 plates were produced using AP-Nylon® Caprolactam as ε-CL, catalyst Bruggolen® C1, activator Bruggolen® C20P. The glass fibres used were Saertex X-E-573g/$m^2$-1270 mm with around 50% fibre volume fraction. To assess the process reproducibility, physical, thermal and mechanical properties were analyzed in different areas of the part. These results will be used for establishing the actual state of the technology and will be a base for future process optimisation.

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