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Melt impregnation of carbon fibre fabrics by injection moulding

One approach to reduce the CO_2 emission of automotive transportation is the lightweight design with composite materials. The main disadvantages of composite materials are the long cycle time and high material costs. A process for the direct impregnation of fabrics with thermoplastic on an injection moulding machine is developed. The process has a high potential for fast cycle time and reliable part quality. The feasibility of the process was demonstrated by the characterisation of the used materials, process simulation and model experiments. By using an injection moulding machine, a high production rate and reliability of the process is possible which makes it more attractive for the automotive sector.

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Material characterisation

Lightweight design in transportation, especially in automotive industry is getting more important with the stricter regulations on CO_2 emissions of the European Union. One way for implementing this is the use of thermoset or thermoplastic composite materials. However, to make these materials attractive for high volume automotive industry, fast processes are needed. The processing concept investigated here is the through thickness impregnation of dry fabrics with thermoplastic melt via injection moulding (Fig.1).

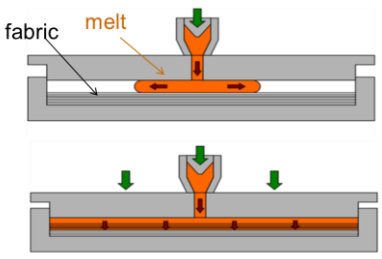

Fig. 1: Processing concept

Matrix: Low viscosity (15-50 Pas) Polypropylene (PP)
Fabric: Two carbon fibre fabrics were used: (200 g/m2 3K tows) and (400 g/m2 12K tows). The fabric compaction and permeability were measured [1], the results for the permeability are shown in Fig. 2.

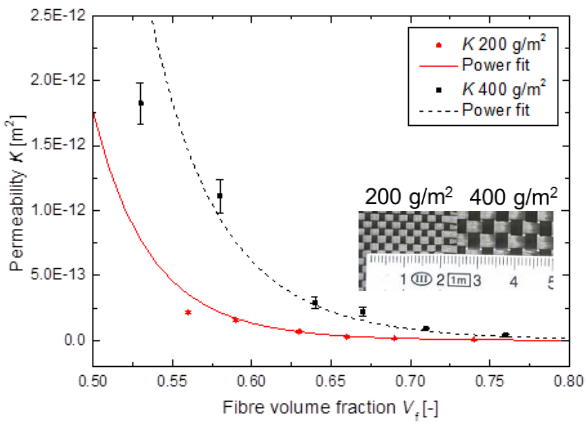

Fig. 2: Permeability of the carbon fabrics

Process simulation

With the determined input parameters of the matrix viscosity, the fabric compaction behaviour and the fabric permeability, a through thickness impregnation was simulated to determine the influence of the process parameters viscosity and pressure [2]. The pressure distribution in the partially impregnated fabric and the resulting gradient in fibre volume content (Fig. 3) and permeability is implemented in the model.

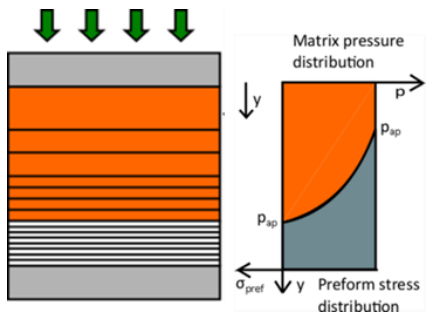

Fig. 3: Pressure distribution and resulting gradient in Vf

Model experiment of the process

To directly observe the impregnation process, a setup for an impregnation experiment was developed. A model fluid (e.g. silicone oil or syrup) with the same viscosity as the melt is used. During the impregnation (Fig. 4) the position of the flow front and the preform top are observed and the simulation can be verified.

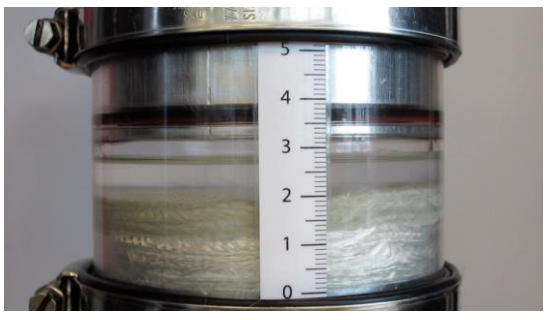

Fig. 4: Impregnation experiment with silicone oil

Processing and characterisation

Impregnation experiments of the fabrics with the PP melt were conducted on a hot press in a closed mould, with the melt flowing only in one direction. The impregnation quality is then checked with fluorescence microscopy, red indicating unimpregnated bundles and voids (Fig. 5).

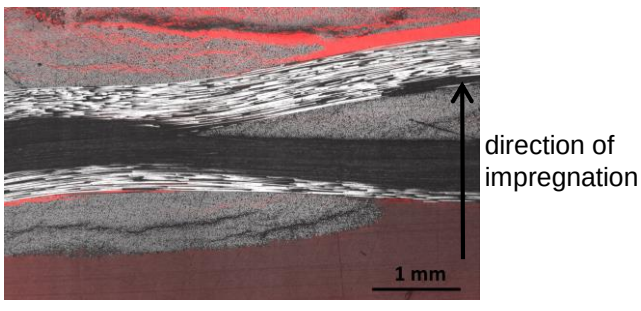

Fig. 5: Micrograph of a partially impregnated plate

Compared to thermosets, thermoplastic matrix materials have the advantages of recyclability and high fracture toughness. On the other hand the thermoplastic matrix materials have a higher viscosity than thermoset resins, which makes the impregnation of fabrics more difficult, especially if a high fibre volume fraction is needed. By using an injection moulding machine, a high production rate and reliability of the process is possible which makes it more attractive for the automotive sector.

References

[1] Studer, J., Dransfeld, C., and Fiedler, B. *Direct thermoplastic melt impregnation of carbon fibre fabric by injection moulding*. in *ECCM17 - 17th European Conference on Composite Materials*. 2016. Munich, Germany.

[2] Masania, K.Bachmann, B., Dransfeld, C. *The compression resin transfer moulding process for efficient composite manufacture*. in *The 19th International Conference on Composite Materials*. 2013. Montreal, Canada.

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