Rapid Thermoforming of Hybrid Yarn Preforms

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10) Partner organizations:
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11) Short Summary: The direct stamp forming of previously unconsolidated discontinuous aligned carbon fibre reinforced thermoplastic composites made of from commingled yarns is studied
12) Keywords: Engineering Sciences, Materials Technology

13) Project description:
The direct stamp forming of previously unconsolidated discontinuous aligned carbon fibre reinforced thermoplastic composites made from commingled yarns is studied in this work (Figure 1), focusing on the influence of processing conditions and yarn architecture on laminate quality and deformation behaviour under thermoforming conditions. Tool design and processing methodology to obtain sample laminates with unidirectional fibre orientation directly from the yarn bobbins without employing any textile intermediate steps are presented. Mechanical properties such as flexural and tensile strength along and transverse to the fibre direction, respectively, and void content serve as quantitative criteria for the achieved laminate quality.

A number of different yarn architectures including two different polymerspoly (laurolactam) and poly (butylene terephthalate), different reinforcement fibre fractions, and fibre length distributions are considered. Various heating strategies are reviewed and infra red radiation heating as the mainly applied heat source throughout this work is closely examined by means of experimental investigations and theoretical considerations. Additionally, direct electrical resistance heating is presented as an interesting alternative heating strategy.

Due to the limited flow capacity of the viscous polymer melt it is important to provide either sufficiently long consolidation times or short flow distance, to obtain satisfactorily consolidated laminates. As the stamp forming process is, however, non isothermal with the initial and final temperatures being defined by the preform temperature prior to moulding and the mould temperature, respectively, the former criterion can only be met with in a limited way by using thermally insulating tool materials. Experiments performed with a blank aluminium mould and the same mould lined with 4 mm thick sheets of poly(tetrafluoroethylene) show that the consolidation time can be significantly expanded if the mould is thermally insulated. The so extended consolidation time leads to laminates with lower void content and increased mechanical properties compared with the laminates stamp formed between blank metallic moulds.

The remaining alternative to the somewhat difficult task of designing thermally insulated tools is to employ a commingled yarn with exceptionally high blending quality to provide the shortest possible flow distance for the polymer melt. Yarn and fibre parameters to influence the blending quality are discussed and conditions to achieve the best possible degree of commingling are formulated. Best laminate quality is achieved, if both insulated mould and yarns at high blending quality are employed. Consolidation pressure investigated in the range of 2 to 8 MPa is found to have got only minor influence on mechanical properties and void content.

An integrated heat transfer and consolidation model is developed to predict the laminate temperature as well as the degree of consolidation in coordinates of consolidation time and laminate thickness (Figure 2). The proposed model is different from the classical finite differences approach in that it takes variations of laminate density and thermal conductivity due to progressing degree of consolidation into account. Model predictions show good agreement with experiments performed with four ply laminates of commingled yarn woven fabrics directly consolidated between poly (ether ether ketone) plates. The here proposed thermal model can provide information about the required mould temperature to achieve the optimum degree of consolidation for various laminate thicknesses at a given mould material. Finally, the axial deformation behaviour in the direction of the fibre axis at processing temperature is addressed. Experimental results of tensile tests of unconsolidated but molten specimens of different reinforcement fibre fractions and different reinforcement fibre length distributions measured at different temperature levels are presented. A flow
curve model based on the anisotropic rheological properties of aligned fibre filled viscous fluids is developed (Figure 3. The suggested flow curve model agrees well with the measured flow curves at all investigated parameter levels. The additional deformation capacity provided by the here employed commingled yarns can improve the achievable geometry complexity of stamp formed parts. In that, the here presented flow curve model represents a first step towards full scale moulding simulation of multi directional fabric plies of stretch broken commingled yarns.

14) Popular description: no entry

15) Graphics:

Micrograph of a representative hybrid Yarn Cross-Section

IMES, Structure Technologies

Simulated and measured Temperatures
IMES, Structure Technologies

Measured and Calculated Flow Curves
16) **Publications:** no entry

17) **Links to important web pages:**
   - [http://www.imes.ethz.ch/st](http://www.imes.ethz.ch/st)