INFLUENCE OF GEOMETRY ON COMPONENT QUALITY AND PROPERTIES IN OVERMOULDED THERMOPLASTIC COMPOSITE PARTS

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Introduction

The development of Thermoplastic composite overmoulding (TCO), through the combination of thermoforming and injection moulding technologies, has enabled the rapid manufacture of composite structures with combined continuous fibre and short fibre reinforcements. Such structures benefit from the excellent mechanical properties provided by the continuous fibre base, geometric complexity of the short fibre-reinforced injection overmoulded architecture and significantly reduced cycle times due to the fast processing of thermoplastics [1]. During part fabrication, a pre-consolidated continuous fibre reinforced laminate with thermoplastic matrix (organosheet) is pre-heated and subsequently thermoformed during closing of the mould platens, upon which a short fibre-reinforced polymer is injection overmoulded onto the hot laminate to form a fully bonded component. The overmoulded sub-structure is capable of serving as a stiffening or functional feature [2]. This multi-material design is particularly well suited for high-volume manufacturing applications where structural performance is critical and would otherwise be difficult to achieve with traditional thermoplastic processing techniques alone. The consolidation mechanics at the interface between the continuous fibre and short fibre materials are unique to overmoulded components since the regions of the organosheet that are pressed into the cavities experience a substantial level of deformation, a feature observed by Stegelmann et al. [3]. The interface bond strength is considered to be a key property as well as a useful metric to assess the part quality since it is the load-carrying region between the two substructures and where inadequate processing can lead to debonding and subsequent component failure.

Materials and Component Geometry

For this study, the manufactured component features a 230 x 190 x 2.5 mm base plate (organosheet) with four 120 mm long overmoulded ribs of varying feet geometry as shown in Figure 1. The organosheet material is *5HS Cetex® TC1100 CF-PPS*, supplied by *TenCate Advanced Composite*. The injection grade material used for the overmoulded rib structure is 33 % carbon fibre reinforced PPS (*Luvocom® 1301-0824*), supplied by *Lehmann & Voss*.

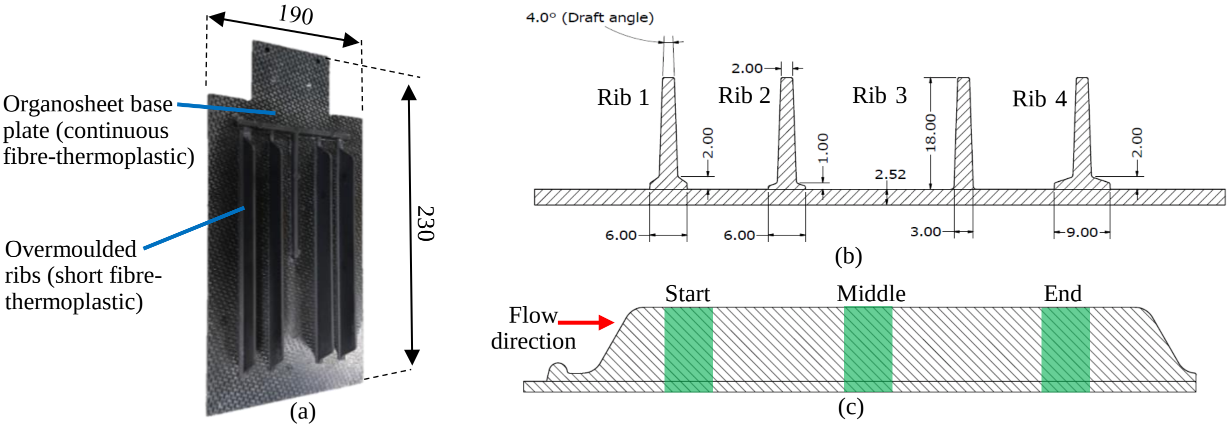


Figure 2: *TU Dresden ribbed plate (a), cross section displaying key dimensions in mm (b) and specimen cut regions along the length of Rib 3 (c) shown by the highlighted areas.*

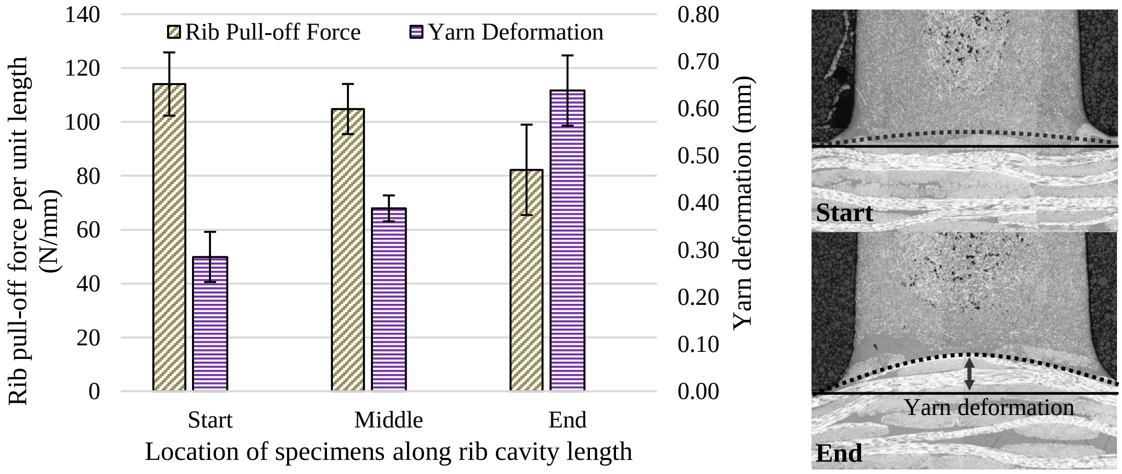
Methodology

For the overmoulding process, the base laminate is placed on two guide pins located in between the mould platens of the injection machine (ARBURG 270C ALLROUNDER). An infrared heater (KRELUS G14-25-2.5 MINI 7.5) is used to raise the temperature of the laminate beyond the matrix melting point. A target temperature of 350 ºC is held for 60 seconds, after which the IR heater (mounted on a pneumatic arm) moves out of the machine and the mould platens close for the injection stage to commence. After the short fibre polymer melt has filled the cavity and formed the bond with the laminate, the holding pressure profile is applied (650 bar for 6 s, 550 bar for 3.5 s and 400 bar for 2 s) to compensate for material shrinkage. The part is ejected and allowed to cool at room temperature.

8 mm and 5 mm long specimens for the tensile and microscopy tests respectively were cut from the start, middle and end regions of Rib 3 in order to compare the yarn deformation and bonding force for different regions of the mould cavity, given that the overmoulded polymer takes a finite time to reach each point along the flow path, resulting in varying consolidation profiles. The microscopy samples were mounted in a fast-curing VersoCit-2 acrylic resin, ground, polished and analysed using a Carl Zeiss Imager M2 Optical Microscope at 20x magnification. A custom fixture was designed and manufactured for the mechanical tests, ensuring that the organosheet plate remains immobilised when the ribs are pulled, thus isolating the interface region. The samples were tested in a universal testing machine (Zwick 1445) at 2 mm/min. The bonding force is taken as the peak load and normalised to account for specimen length.

Results & Discussion

The yarn deformation increases along the cavity length as shown in Figure 2. Upon closing of the mould platens prior to injection stage, the organosheet surface begins to "freeze" immediately at areas in direct contact with the mould whilst the regions exposed to the cavity see a much slower cooling rate and remain in a molten state. This causes the yarns to protrude into the rib cavities until the overmoulded polymer consolidates them via the holding pressure, forcing the yarns partially back to their original state. A 33 % reduction in the rib pull-off force is observed from the specimens at the end of the cavity compared to the start and middle locations, where there is no variation in failure load. The findings show that very good bonding can be achieved between the organosheet and overmoulded ribs and that analysis of the interface can provide an insight into the consolidation mechanisms during manufacture.



(a) (b)

Figure 2: *(a) Rib pull-off force and yarn deformation along cavity length (a), error bars indicate standard deviations. Optical micrographs (b) of Rib 3 at the start and end locations of the cavity length, showing the yarn deformation with a dotted curve at the overmoulded interface.*

References

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