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A new approach on integrating joining inserts for composite sandwich structures with foam cores

J. Schwennen*, V. Sessner, J. Fleischer

wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, 76131 Karlsruhe, Germany

* Corresponding author. Tel.: +49 721 608-41674; fax: +49 721 608-45005. *E-mail address:* jan.schwennen@kit.edu

Abstract

Due to their high potential in lightweight designs composite sandwich structures with foam cores are gaining in importance in the automotive industry. To carry localized loads, sandwich structures require load introduction elements. In current solutions applied in the aerospace industry the inserts are embedded after the sandwich panels have been manufactured. This is very time consuming and therefore too expensive for automotive industry. In this paper, two new approaches are investigated experimentally, where the inserts get integrated during the preforming process or during the foam core manufacturing. With these manufacturing methods the performance and failure behavior of various insert geometries and different foam core densities will be determined by static pull out tests.

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Keywords: joining; insert; composite; sandwich; RTM

1. Introduction

Increasing demands for lower CO_2 emissions and fuel consumption in the automotive industry require new lightweight structures. Therefore designs from the aerospace sector are gaining importance for high volume productions of automotive components. Fiber-reinforced plastics (frp) offer great stiffness and strength to weight ratios thus have an outstanding potential for lightweight design. Used in sandwich structures with light core materials and facesheets made of frp, these characteristics can be applied even more effectively. By adding only little weight due to the additional core the structure becomes a lot more rigid for bending, thus less material is needed and lighter parts can be designed. Common core materials are honeycomb structures or polymeric foams. Honeycomb cores are already widely spread in the aerospace industry due to their high specific mechanical properties. They can outperform foam cores in terms of stiffness to weight ratios [1, 2]. However this advantage is balanced out by higher costs [3], making foam cores more suitable for applications in the automotive industry. A further advantage of foam cores is that complex 3D core geometries can be easily manufactured by filling an appendant tool with foam. They also provide good insulation characteristics [4], and show great energy absorption capabilities [5].

In order to join sandwich panels and carry local loads subjected to the surface, the structure needs reinforcements in the form of so-called inserts to prevent premature failure. Their task is to introduce the loads widespread and avoid stress concentrations [6]. So far many investigations on inserts in different sandwich structures have been carried out. The inserts are commonly classified as partial when the core is only partly substituted by the insert, and through the thickness, when the complete thickness of the core is substituted by additional potting material or the insert itself. Nguyen at al. [1] examined the failure behavior of cylindrical through the thickness inserts in foam core sandwich structures. Several failure modes were observed showing different peaks in the load displacement curves. The most

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critical failure mode was identified as shear cracking in the foam core and was also predicted with a finite element analysis. Shipsha et al. [7] showed that the failure loads of partial and through the thickness inserts can be increased by optimizing the geometry of the insert which reduces stress concentrations. Nevertheless it is still hard to predict which geometry is generally the best and how the inserts will behave, due to the large variety of examined insert geometries, sandwich materials and dimensions of the structures. Consequently, experimental investigations still need to be carried out to examine the failure behavior and load bearing capacities for specific part dimensions, insert types and material properties.

To increase the use of frp sandwich structures in the automotive industry, also new manufacturing chains will have to be developed, which will enable cheaper components in high volume productions. In the aerospace industry it is common to integrate the insets after the sandwich manufacturing in an additional production step [8]. However, for the automotive industry this is too time-consuming and expensive. Great potential for frp manufacturing in the automotive industry is seen in resin transfer molding (RTM) and especially high pressure resin transfer molding, because of its suitability for automated manufacturing of parts with high quality surfaces [9]. Consequently in this paper a new manufacturing approach for frp sandwich structures with embedded inserts has been investigated. Furthermore the failure behavior of various insert geometries, manufactured with these methods, will be examined.

2. Integration of inserts into sandwich structures

Under the new approach for manufacturing composite foam sandwich structures with embedded inserts, using the resin transfer molding process, the reinforcements will be integrated before the sandwich is manufactured. Accordingly, rework after the resin injection is reduced. In order to do so, two different methods have been used. Figure 1 shows the production chain for sandwich manufacturing using the RTM process. The important steps are foaming of the core, stacking the fiber textiles onto the core, resin injection in the RTM mold and potential rework after demolding the finished sandwich structure. Inserts can be

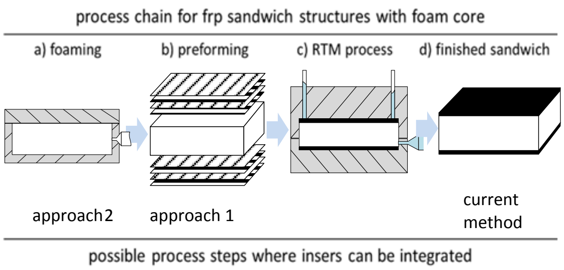

Figure 1: Process chain for fiber reinforced sandwich structures. Inserts can be integrated during different steps of the manufacturing process

integrated into the structure on various steps of the process chain, having specific advantages and disadvantages.

The current most frequently used method is to embed the inserts after the sandwich manufacture has been completed. This results in additional process steps which leads to higher costs. A hole has to be drilled in the sandwich structure, then the insert is placed in the hole and the surrounding is filled with potting material. Additional cure time is needed for the potting material. Also the facesheets have to be damaged locally which lowers the failure loads.

A new approach is to embed the inserts during the preform process (approach 1). Thus, no additional machining after the RTM process is necessary and no extra cure time is needed, as the resin of the RTM process can be used as potting material. In addition, the fiber continuity can be maintained by placing the fibers around the bolt of the insert. This leads to an increased maximum pull out force of the inserts as described in [10]. However with this method only simple insert geometries can be embedded without performing complex and time consuming machining to the core. Welding studs on thin metal plates which can be seen in Figure 4 were chosen for this method because they can be easily embedded in the structure by placing them on top of the core or putting them through clearance holes. Cones are used to slide the fiber textiles around the bolts during preforming and seal the inserts during the RTM process, preventing the resin to flow into the threat. Further methods to seal inner and outer threaded bolts during the resin injection were also tested by Ballier et al. [11].

In order to further reduce the process scope for high volume productions the second new approach is to foam the inserts into the core during the foam manufacture (approach 2). To do so the inserts are placed in the foaming tool. With this method both simple and complex insert geometries can be easily embedded into the core and no machining to the core or additional potting material is needed. Ideally the inserts are already sealed for the RTM process, when placed in the foaming tool and have cones to easily push the fiber textiles over the insert bolts for automated preforming. The only rework step after the RTM process is to remove the sealing from the insert. Thus the process time for the insert integration with this method compared to the insert integration after the sandwich manufacture can be reduced by several process steps, what saves time and therefore money.

3. Setup for experimental investigations

The new manufacturing approaches are now applied to fabricate sandwich structures with different insert geometries. Then quasi-static pull-out tests will be performed with the specimens.

Figure 2 shows the dimensions of the specimens with the embedded inserts. The sandwich plate has a 20 mm thick foam core and the facesheets are 2.7 mm thick. The structures will be manufactured by resin transfer molding. The used epoxy resin system is from Sika® (Biresin®