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Experimental investigation and performance enhancement of inserts in composite parts

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Abstract

New joining technologies are needed due to the increased use of carbon fibre reinforced plastics (CFRP) in the automotive industry. Traditional joining technologies cannot fulfill the requirements, especially for multimaterial assemblies of CFRP and metal. A suitable technology for the integration of mounting points in CFRP parts is the embedding of inserts. In this paper, two approaches to increase the tensile and bending strength of inserts are evaluated experimentally. Bead patterns are added in the metal sheet of the inserts to increase stiffness. Furthermore, surface treatments are used to enhance the co-cured bonding strength between insert and CFRP.

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Keywords: composite; joining; insert; RTM process

1. Introduction

The significant importance of lightweight design in the automotive industry is leading to an increased replacement of metal parts by parts made of carbon fibre reinforced plastic (CFRP). New joining technologies are needed to install these parts in multimaterial assemblies of CFRP and metal.

Nowadays, a frequently used way to mount components on the metallic bodywork of a car is to weld threaded M6 bolts on it. These bolts can be used for the detachable installation of other parts. Since this welding process is not suitable for CFRP, alternative ways for the integration of mounting points have to be found. One promising alternative is the integration of metal inserts into the CFRP material. These inserts can directly be embedded during the part manufacturing in the resin transfer molding (RTM) process. Thus, no additional drilling process is needed and the continuity of the carbon fibres is not interrupted.

Metal inserts for CFRP parts manufactured by injection molding or compression molding processes are already frequently used [1]. These inserts are not suitable for thin-walled continuous fibre reinforced plastic parts manufactured by the RTM process. Inserts for thin-walled continuous fibre reinforced parts usually consist of a thin metal sheet which is embedded between the plies of the laminate. A threaded bolt on the metal sheet is used to introduce the loads through the metal sheet in the laminate. However, this type of insert has only been investigated in a few studies yet. The mechanical characteristics of different types of bigHead® inserts were investigated in [2]. A parameter variation for inserts manufactured by the hand lay-up technique was performed in [3].

Within this paper, possibilities to enhance the performance of embedded inserts are demonstrated. Therefore, CFRP plates with metal inserts are manufactured by the RTM process. Quasi-static tests are performed to measure the tensile and bending strength of the embedded inserts.

Based on the results of investigations of standard inserts, two ways for possible improvements of the performance are derived: A bead pattern in the metal sheet of the insert is used to increase the bending stiffness and thus the bending strength of the embedded inserts. Surface treatments of the metal

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inserts are used to increase the co-cured bonding strength between the metal and the CFRP.

2. Experimental conditions

The tested standard inserts consist of a flat round metal sheet with a diameter of 30 mm and a height of 1 mm. The parameters are assessed based on previous tests [4], [5]. A bolt with an inner M6 thread is welded on the metal sheet by stud welding. This enables low-cost manufacturing of the inserts, which is an essential requirement for fasteners, especially in the automotive industry. Both, the metal sheet and the bolt are made of stainless steel (1.4301) to prevent corrosion. Figure 1 shows the dimensions of the tested standard insert.

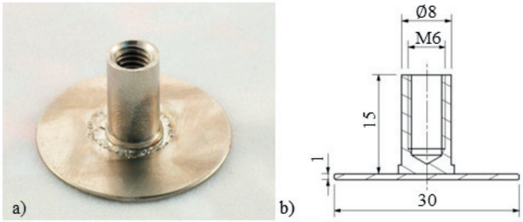

Fig. 1. a) Tested standard insert b) Dimensions of the tested inserts

The inserts are embedded in flat CFRP plates with dimensions of 150 x 150 x 2 mm³. The used resin is an epoxy system by Sika® (Biresin® CR170/Ch150-3). The reinforcement consists of eight plies of a multiaxial non-woven carbon fibre fabric (0°/90°, 200 g/m²), leading to a fibre volume fraction of .46.

For the manufacturing in the RTM process, the metal sheet of the inserts is placed between the single plies of the laminate during preforming. Thereby, the inserts are integrated in the middle of the laminate, with four plies above and four plies below the inserts. The threaded bolt of the insert is slid through the upper plies of the laminate with the help of a cone to maintain the fibre continuity. The infiltration of the parts is done in an especially adapted RTM mould with exchangeable cavities for different insert geometries described in [5].

The dimensions of the specimens and an exemplary picture of a manufactured specimen are given in figure 2.

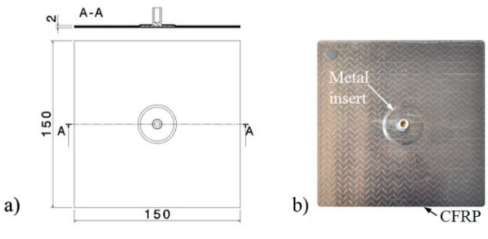

Fig. 2. a) Dimensions of the specimens b) exemplary picture of a specimen

Tests with the manufactured parts are carried out in a quasi-static material testing machine (Co. Zwick GmbH & Co. KG). Two different test devices are used to measure the tensile (pull-out) and bending strength of the embedded inserts. The used devices are shown in figure 3. At least five specimens with each type of insert are manufactured and tested.

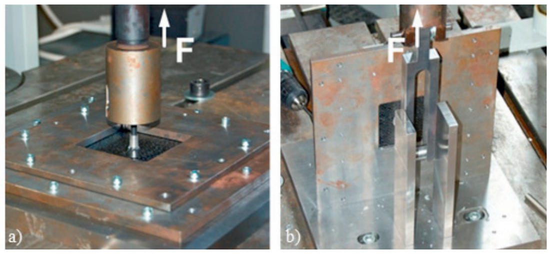

Fig. 3. Test devices for a) tensile tests and b) bending tests

3. Investigations of standard inserts

In the following, the results of the experimental investigations of the standard inserts described above are presented.

3.1. Results

Figure 4 shows exemplary runs of the test curves in the tensile and in the bending tests.

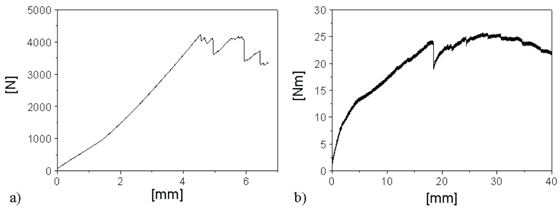

Fig. 4. Exemplary course of the test curves in tensile (left) and bending (right) tests

3.1.1. Failure behaviour

In the tensile tests, the course of the test curves reveals a linear behaviour up to high loads (with a small change of the slope resulting from the subsidence of the plates in the support). At high loads, the laminate above the inserts fails in a crosswise way, beginning from the bolt of the insert. The failure of the fibres is clearly visible on the failed specimens. Additionally, a plastic deformation of the insert's metal sheet and a failure of the co-cured bonding connection between the lower side of the insert and the lower plies of the laminate can be seen in the polished cut images of the failed specimen (cf. Fig. 5).

In the bending tests, all specimens fail because of a delamination between the upper and lower plies, which is revealed in the run of the test curves (cf. Fig. 4, at ~20 mm) and can also be observed by a sudden buckling of the laminate around the inserts during the bending tests. Furthermore the failed specimens reveal a failure of the co-cured bonding connection between the insert and the plies of the laminate