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PII: S0263-8223(15)01043-0
DOI: http://dx.doi.org/10.1016/j.compstruct.2015.11.040
Reference: COST 6995

To appear in: *Composite Structures*

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Abstract

A numerical study on the structural mechanics of bonded composite structures, which were interlaminary reinforced by metallic sheet and pin elements, is presented in this paper. For the investigation of the potential of this reinforcing technology, finite element models on meso and macro scale were studied, which were successfully validated against experimental test results. On the example of quasi-statically loaded single-lap shear test specimens, the macro scale model was used to implement different configurations of the reinforcements including variations of the pin geometry as well as their arrangements. Passing a variable search according to Shainin, the influences of various design factors on the structural performance of the reinforced joints were evaluated. In addition, the main effects were identified as the pin and sheet thickness among others concerning the applicable load as well as the elongation of the joint. Furthermore, the analyses of the interdependencies showed, that the majority of the variables weakens the effects of the other ones.

Key words: joining technique, pinning, reinforcement, simulation, hybrid structure, design of experiments

1. Introduction

In recent years, the mass share of carbon fiber reinforced plastics (CFRPs) in important structural aerospace components has been increased significantly, which is demonstrated by the Airbus A350XWB or the Boeing 787 Dreamliner. In the automotive industries, composites played a rather subordinate role in case of primary structures of cars produced in large quantities. This fact was essentially changed with the market introduction of BMW's i-series. As a result from the rising importance of composite materials, the need for appropriate joining techniques has been emerging. These are necessary to realize structures, which can take advantage of the whole lightweight potential of CFRP and fulfill the demand of structural integrity. Adhesively bonding would meet those requirements, however, is suffering on unsatisfactory damage tolerance in case of failure. As a consequence, certification of this joining technique for the application at primary aircraft structures implies the request of a secondary load path. In practice, these requirements are satisfied by the supplementary usage of state-of-the-art joining techniques as bolts or rivets, as it is described by Camanho et al. [1], despite of their detrimental influence on the structural mechanics of the FRP material. These drawbacks are primarily caused by drilling holes, which are necessary to affix the reinforcements. By those, the load-carrying fiber structure is cut, which leads to stress concentrations around the holes, as the load is bypassed to the fibers located nearby. These regions are often identified as the weak areas in the joined structure as described by Grüber et al. [2]. As consequence, the design of such fail-safe structures leads to an additional introduction of mass by the own weight of the metallic elements and, in addition, by the obligatory enhancement of the composite cross-section to meet the requirements.

Focus of the presented task was the investigation of a novel joining method based on the reinforcement of bonding between two composite parts, whose capability was proven by Nogueira et al. [3]. The covered interlocking is created on meso scale by the implementation of three-dimensionally formed metal inserts, which avoids the disadvantages of conventional form closure techniques described above. The structural performance was numerically analyzed on single-lap shear geometries fea-

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