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Procedia Engineering 183 (2017) 227 – 232

Procedia Engineering

www.elsevier.com/locate/procedia

17th International Conference on Sheet Metal, SHEMET17

Forming and Joining of Carbon-Fiber-Reinforced Thermoplastics and Sheet Metal in One Step

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Abstract

The processing and component properties of metals have led to their worldwide success in mechanical engineering. Their advantages are high ductility, efficient production methods, good joining ability and nearly isotropic mechanical properties. Fiber-reinforced plastics (FRP) are known for an excellent lightweight design potential, due to low density as well as high and anisotropic tensile stiffness. By using thermoplastics instead of thermoset matrices, processing times and therefore component costs have already been reduced significantly and thus have become affordable in large-scale application. If the advantages of both, metal and FRP, are intelligently combined, a part with tailored properties is created. However, suitable forming processes, which take the different forming effects of both materials into account, have to be developed yet.

The scope of this research was to enable the combined forming, joining and impregnation of pre-impregnated FRP-sheets and sheet metal to steel-CFRP-steel-sandwich-parts in one process step. As forming and joining must be executed at temperatures above the melting point of the thermoplastic while the part removal must take place beneath this temperature, a heating concept for drawing tools was developed to enable short production cycles. In order to ensure an economic industrial production a fast heating and cooling of the tool is essential. Afterwards optimal impregnation and joining process parameters for short cycle times were determined with planar samplings. The influence of the process parameters on part quality was investigated microscopically. Based on this research, a forming tool was constructed and hat profiles of steel-FRP-steel sandwiches were drawn successfully. Subsequently, the impregnation quality was investigated based on the process parameter tool temperature. Furthermore, the geometrical deviation of formed hat profiles was investigated.

Peer-review under responsibility of the organizing committee of SHEMET17

Keywords: Variotherm Forming, Fiber-Reinforced Thermoplastics, Metal

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Peer-review under responsibility of the organizing committee of SHEMET17
doi:10.1016/j.proeng.2017.04.026

1. Introduction

Metals are used widely in engineering due to their outstanding processing and component properties. In particular, the processes for the production of sheet metal parts are characterized by a high productivity and therefore they are presently predominant in large-scale production. In contrast, fibre-reinforced thermoplastics are characterized by great potential for lightweight design but inefficient manufacturing processes. Although the forming effects and forming characteristics of both materials differ considerably, the forming processes of sheet metal and fibre-reinforced thermoplastic sheets themselves do resemble. In sheet metal forming tools consisting of punch, die and, if necessary, blank holder are used to manufacture efficiently. Based on this efficient forming technology, a new technology was to be developed to form steel-FRP-steel sandwich parts using common forming facilities.

2. Process Development

2.1. Design of the steel-FRP-bond

In [1] and [2] a hybrid demonstrator component, which is similar to a roof cross rail, has been developed and evaluated in terms of lightweight potential towards conventional steel components. One solution with a great lightweight potential is a sandwich structure consisting of cover sheet metals from steel and unidirectional carbon fibre reinforced plastic in between. The scope of this investigation is the development of a manufacturing technology, which allows producing such a component. Since there are no semi-finished products meeting this layer setup, an already impregnated and consolidated semi-finished product has been used in previous investigations for the FRP centre. This organic sheet has been heated with the cover sheet metals above the melting point of the thermoplastic and then been joined and formed simultaneously in a tool. The resulting process chain consists therefore only of the process steps heating and forming, which is very short and cost-saving [3].

An evaluation of the whole process chain regarding the manufacturing of the organic sheets too shows, that this chain is not designed optimally. Since the partially impregnated tapes (prepregs) of the thermoplastic and the fibres are stacked, heated, pressurized to impregnate and consolidate and cooled to get the mentioned organic sheet. Subsequently, the cover sheet metals and the organic sheet are stacked again, heated, pressurized to allow forming and the final consolidation and cooled again. So the FRP passes very similar process steps several times. For further investigations, the process chain has been shortened to an impregnation, consolidation and forming in one tool step only. The resulting process chain is stacking the prepregs and sheet metals, heating, pressurizing (forming, impregnating and consolidating) and cooling. Figure 1 shows the setup of the applied semi-finished products and their stacking order.

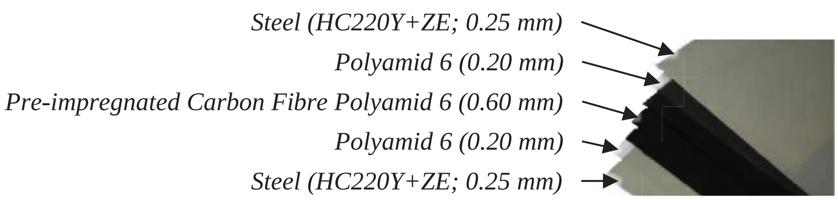

Fig. 1. Stacked semi-finished materials

The additional PA6 layers between the cover sheet metals and the actual FRP have been used to increase the adhesive joint between the cover sheet metals and the FRP. The adhesive bond between thermoplastic and sheet metals is enabled by the adhesive properties of the polyamide and it may be a potential weakness of the bond. This issue is increased during forming, if fibres push towards the sheet metal surface and thus reduce the adhesive area. A buffer layer of PA6 hinders the fibres getting to the surface. Furthermore, there is a risk of contact corrosion if fibres and sheet metal contact. The PA6 buffer layer prevents such a contact, too.