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Experimental Studies on Laser-based Hot-melt Bonding of thermosetting Composites and Thermoplastics

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Abstract

This paper presents experimental results of joining carbon fiber (CF) reinforced thermosetting composites (TSC) to thermoplastics (TP) by means of laser-based hot-melt bonding. First of all the influence of different laser systems ($\lambda = 355$ nm and $\lambda = 1064$ nm) on the ablation of the thermosetting matrix (epoxy) with preferably little damage to the CF is analyzed by means of microscopy. Afterwards the laser-based joining process of TSC and TP is carried out. Finally the joining connections are characterized by tensile shear tests. Thereby the influence of the surface treatment and the used thermoplastic (PC/ABS, PA66 or PA66-GF30) on the tensile shear strength is investigated.

Keywords: laser joining; hot-melt bonding; lightweight design; thermosetting composite; carbon fiber reinforced plastic; thermoplastic

1. Introduction

In recent years lightweight design by means of carbon fiber reinforced plastic (CFRP) became a focus in the construction of automobiles, wind power plants and aircrafts due to the scarcity of raw materials and the increasing environmental awareness [1]. As matrix which impregnates the fibers (e.g. carbon or glass fibers) mostly thermosetting resins (e.g. epoxy or polyester resins) are used because of their better wetting of the fibers and their simple processing in comparison to thermoplastic matrices. 40 years ago the mass fraction of carbon fiber (CF) structures in aircrafts like the Airbus A300 was only 5% whereas an A380 built 2005 already consists of 22% CFRP. The new status symbol from Boeing, the so-called Dreamliner (Boeing 787), has already a CF mass fraction of about 60% [2]. In the past few years in the automotive industry a lot of steel components are substituted by aluminum parts to reduce the car weight for lower fuel consumption and emission. The modern lightweight design by means of CFRP allows a further reduction of weight whereby the technological progress of CFRP is still increasing (see Figure 1). As a result of their versatile applicability and their outstanding technical properties CFRP will be used in future even more in various industrial products. However in all industries, the lightweight potential and product-specific requirements can only be fulfilled by an optimal and intelligent integration of different

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materials and suitable joining technologies [3]. According to the current state of the art the joining of thermosetting composite (TSC) to thermoplastic (TP) is limited by the available joining techniques (see Figure 2).

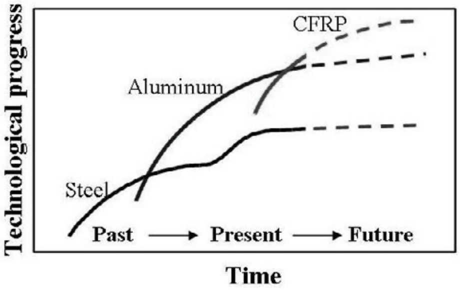

Figure 1: Comparison between the technological progress of steel, aluminum and CFRP [according to 4]

Thermosetting plastics can not be molten because their macromolecules are cross-linked so that welding is only possible for thermoplastic matrix composites (TPC) [5]. Dissimilar materials such as thermoplastic and thermosetting plastics can be joined by means of bonding. However a major disadvantage of bonding is the time-consuming and complex surface preparation and the long curing time which can vary by product and type of adhesive between several minutes and several hours [6]. As an alternative to bonding integral design can be used. Thereby the TSC is coated with a thermoplastic layer to make the composite weldable. The coating can be realized by a thermoplastic hybrid interlayer or a thermoplastic film co-cure. Both processes are directly linked to the manufacturing process of the TSC. A subsequent application of the TP layer on the TSC after the curing process is not possible and makes these techniques inflexible [7]. For a mechanical linkage with rivets or bolts holes have to be drilled into the composite whereby the fibers are cut through and the flux of force in the CFRP is significantly influenced. This has to be considered in the component design. Besides the fact that mechanical linkage is not "fiber-friendly" the joining elements limit the lightweight design and the visual appearance [8].

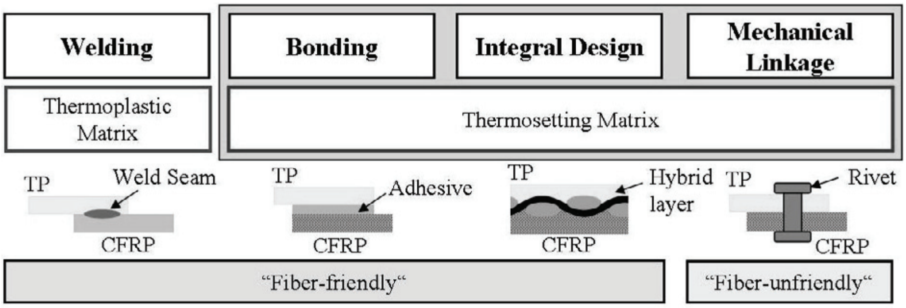

Figure 2: Current joining techniques for CFRP and TP

2. Laser-based hot-melt bonding of thermosetting composites and thermoplastics

Motivated by the described deficits of available joining techniques an innovative approach for joining thermosetting composites to thermoplastics by means of laser-based hot-melt bonding is presented in this paper. The new joining technique can be divided into (see also Figure 3):

- the laser-based surface treatment of the thermosetting composite and
- the laser-based joining process of the thermosetting composite and the thermoplastic.

The laser-based surface treatment is used to ablate the thermosetting matrix from the fibers to enlarge the effective joining area. This laser ablation causes a rough surface with micro undercuts (see Figure 3 a) which is important for the interlocking between the joining partners that takes place in the following joining process (see