JOINING ALUMINIUM AND FLAME-RETARDED POLYAMIDE BY LASER BEAM

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Main message

The laser joining of aluminium and polymer materials has been a hot topic in recent years. However, it has not yet been investigated how frequently used additives, such as flame retardants added to the polymer influence the properties of a laser-joined metal-polymer structure. In this poster publication, the results of experiments carried out on laser-joined aluminium and flame-retarded polyamide specimens are presented.

Keywords: laser joining, flame-retarded polyamide, aluminium.

Introduction

The use of flame-retarded polymers in vehicles is increasing each year, as constantly improved safety standards and the initiative to decrease the weight of the vehicles require lighter materials, such as polymers and polymer composites [1]. The joining of polymeric structures to the load-carrying metal structure of the vehicles is still dominated by conventional joining techniques, such as adhesive bonding and mechanical fastening [2, 3]. In recent years, numerous publications investigated the applicability of a laser-based technique in the joining of aluminium and polyamide structures [e.g. 4, 5]. However, none of these publications examined how a flame retardant additive, effectively always used in vehicular components made of polyamide, influences the joining process and the properties of the metal-polymer joint.

Experimental

A Trumpf TruDiode 151-type laser welding machine (max. power output: 150 W) was used to join AA6082-type aluminium to natural and flame-retarded polyamide specimens. As reference, two commercially available, unfilled PA6 materials ("A27" manufactured by Grupa Azoty S.A., Poland and "MV13" manufactured by LyondellBasell Industries Holding B.V., The Netherlands) were adopted. Besides these, an in-situ polymerised (caprolactame-based) PA6, and a PA6 based on the "A27" base material, containing flame-retardant ("T27-V0", manufactured by Grupa Azoty S.A., Poland) were also used. The fire performance of all polyamide materials were measured with standardised mass loss type cone calorimetry (MLC, 50 kW/m^2 heat flux), limited oxygen index and UL-94 measurements.

The effect of laser-engraved grooves (machined on the surface of the aluminium specimens) on the load-bearing capacity of the joints was also investigated. For the laser engraving, an SPI impulse laser with 10 W average power was used. The specimens were joined together in an overlapped configuration, using the direct laser joining method, so that only the aluminium specimen was irradiated with the laser beam. The load-bearing capacity of the joints was measured with a Zwick Z005-type universal testing machine, with 2 mm·s^{-1} measurement speed under quasi-static shear loading, in accordance with ISO 4587.

Results and Discussion

Based on the MLC results, all investigated materials had certain disadvantages regarding safety issues. The unfilled base materials had similar total heat release (THR) values, while "MV13" started to burn earlier and had a higher peak heat release rate (pHRR) compared to "A27". The in-situ polymerised PA (is-PA) started to burn even faster, which means that in case of a fire, evacuation time (which is in correlation with ignition time) is decreased by a third compared to the other, unfilled base materials. The total heat release during the burning of this material was also considerably higher, however, the peak heat release rate was lower and was reached after a longer period of time. This caprolactame-based, in-situ polymerised polyamide is a relatively new material, thus further investigations towards flame-retardation may promise considerable results.

The flame-retarded PA6 material ("T27-V0") had similar peak heat release rate and time to peak heat release rate compared to "A27", on which it was based. Its ignition time and total heat release was slightly lower (it probably contains a gas-phase flame retardant), and some residue also remained after the burning.

The unfilled base materials produced burning droplets during the UL-94 measurements, but the specimens did not burn through (V-2 classification); the in-situ polymerised polyamide got an HB classification, which may be caused by remaining oligomers and short chain molecules containing carbon atoms in the material; while the flame-retarded PA6 got a V-0 classification which complied with the documentation provided by its manufacturer.

The results of the laser joined aluminium-polyamide structures under shear load are going to be presented on the poster at the conference.

TABLE 1. Selected properties of natural and flame-retarded polyamide samples

Sample name	TTI [s]	pHRR [kW/m^2]	Time to pHRR [s]	THR [MJ/m^2]	Residue [mass%]	UL-94 [-]
Natural PA6 (A27)	51	847	156	81.2	0	V-2
Natural PA6 (MV13)	40	927	141	82.2	0	V-2
In-situ polymerised PA (is-PA)	32	730	260	195.6	0	HB (24 mm/min)
Flame-retarded PA6 (T27-V0)	47	854	142	71.5	4.5	V-0

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