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Experimental optimization and numerical modelling of laser welding parameters for PBT GF30 joint

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INTRODUCTION

The automotive industry is a major user of fiber-reinforced polymeric materials due to their advantageous combination of lightness, moldability, and strength. A key application involves encapsulating and sealing sensitive electronic circuits. To meet high-productivity demands, laser welding has emerged as the preferred joining technology for these components. This study focuses on optimizing the performance of a laser spot-welded fillet joint in PBT GF30, specifically by investigating the effects of various static welding parameters and providing a modelling methodology.

MATERIALS AND METHODOLOGY

The study was carried out on laser fillet welding, on 40x10x1 mm PBT GF 30 plates, with 20 mm overlap (Fig. 1a). An optically controlled manual process was used, as per the scheme of (Fig. 1b).

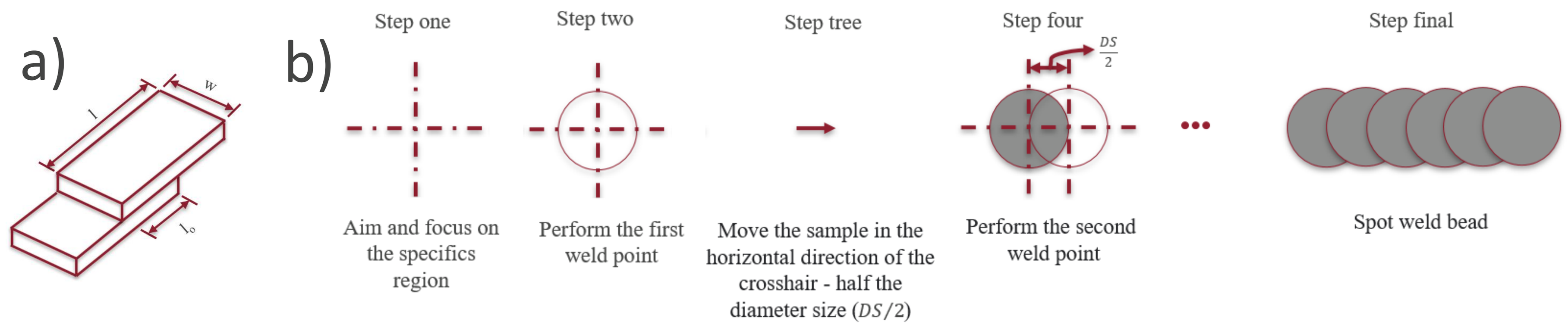

Figure 1 – a) Step-by-step procedures for the carring out of the advance on the spot weld bead.. b) Geometric joint configuration.

The joint is joined by a laser beam in a SISMA LM-D 180 machine, with a Nd:Yag 1064 nm type laser. The laser is focused on the upper edge of the overlapped plate (Fig. 2a).

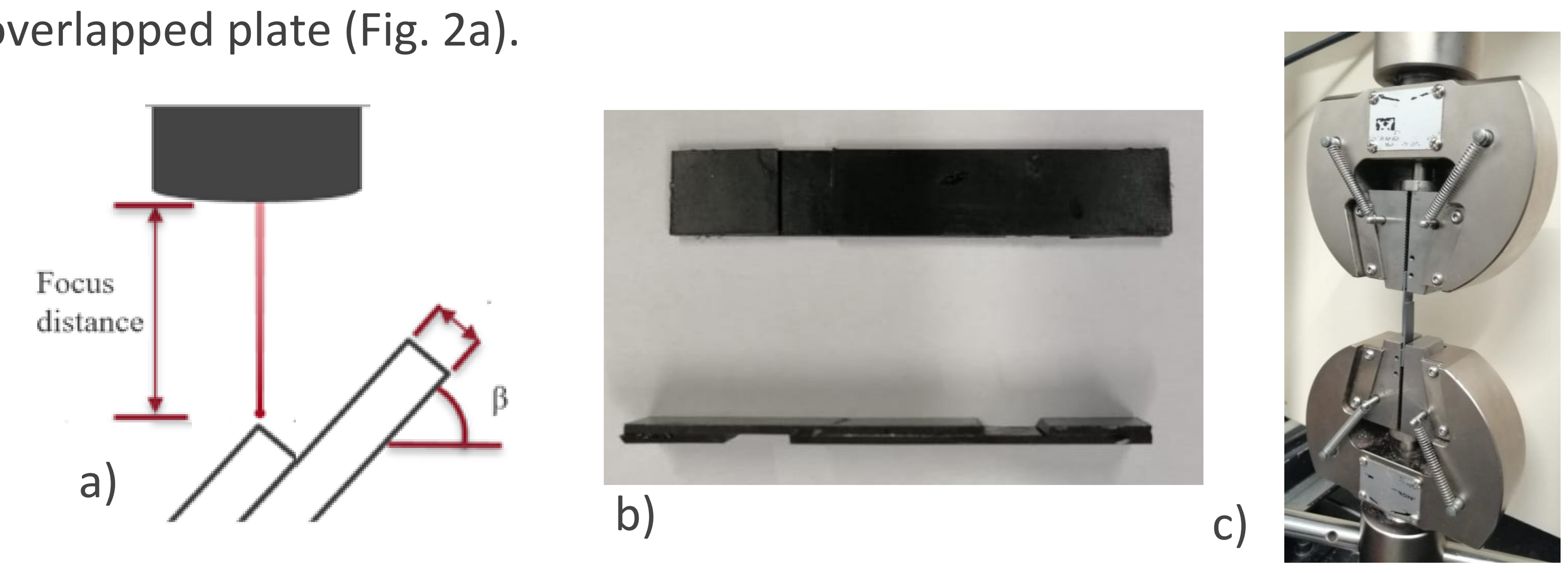

Figure 2– a) Laser incidence orientation. b) Double fillet lap joint showing tabs. c) Test setup

The parameters varied were the average laser power, the pulse time using a rectangular type pulse, the laser beam diameter, and the variation of the angle of incidence. To perform the joint strength tests, tabs were placed on the opposite sides of the joints (Fig. 2b) to align the fixture in the INSTRON® 3367 type universal testing machine (Fig. 2c).

RESULTS

initial parameters for testing consisted in a pulse time of 1.5 ms, laser beam diameter of 1.5 mm and the pulse frequency controlled manually. Fig. 3a points out that the best strength is achieved for 45° inclination, being proportional to the average power.

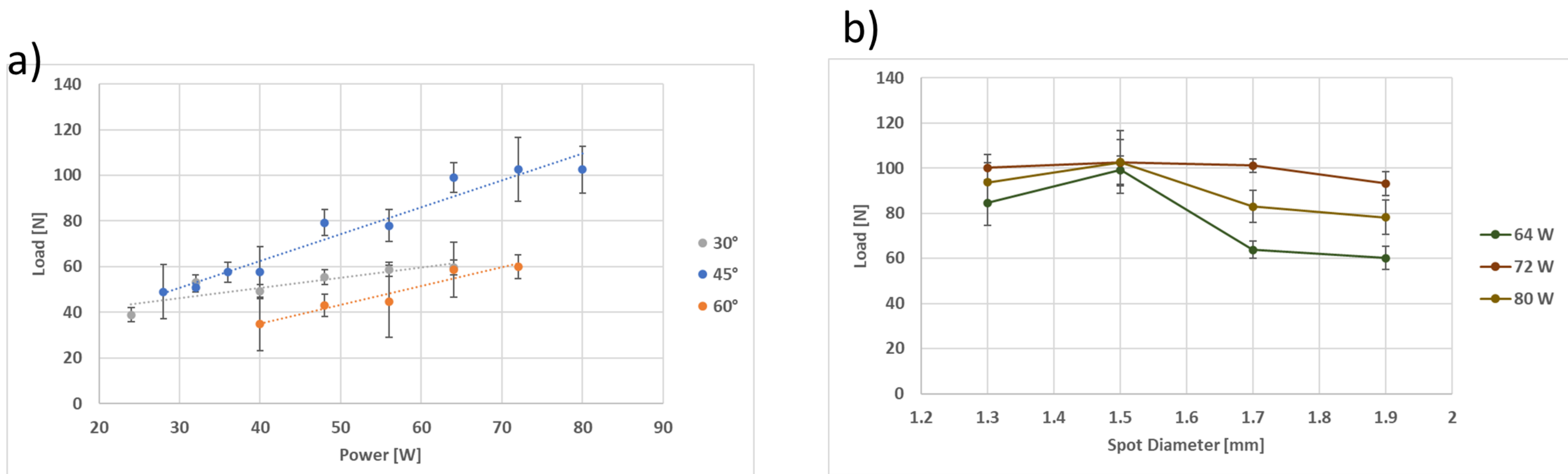

Figure 3 – a) Results of the failure load in relation to the angle of incidence and average power. b) Failure load study for 45º angles, with pulse time fixed in 1.5 ms varying the average power and the laser beam diameter.

An initial study varied only the laser diameter and a 1.5 ms laser pulse. As shown in Fig. 3b, the best result for the beam diameter was 1.5 mm. However, for the 72 and 80 W power levels, the substrate was perforated when the diameter was 1.3 mm. A secondary study followed, varying the laser pulse time, as shown in Figure 4a. It was observed that for a time of 3.5 ms, there was perforation of the sheet (Fig. 4b).

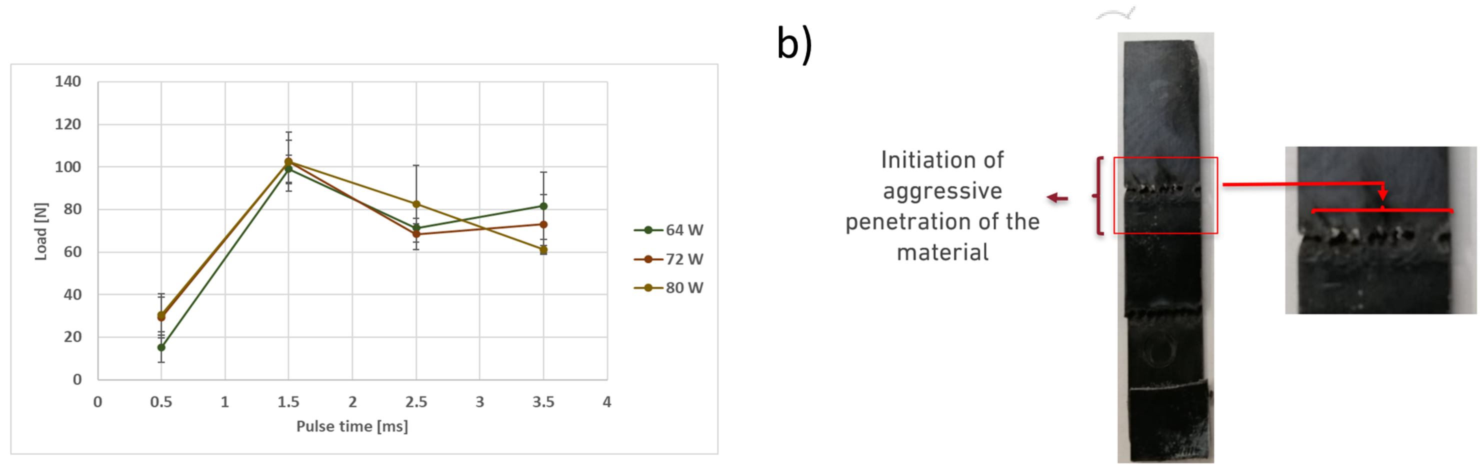

Figure 4 – a) Failure load study for 45º angles, with the optimized laser beam diameter (1.5 mm), varying the average power and the pulse time. b) Representative sample of the degradation caused by excessive power, pointing to the perforation of the GF30 PBT plate.

Such results limit the thermal flux density to 53 $W.m^2$ and energy flux density at 0.13 $J.mm^2$. Accordingly, optimization maps of the parameters can be made, shown in Fig. 5a and Fig. 5b.

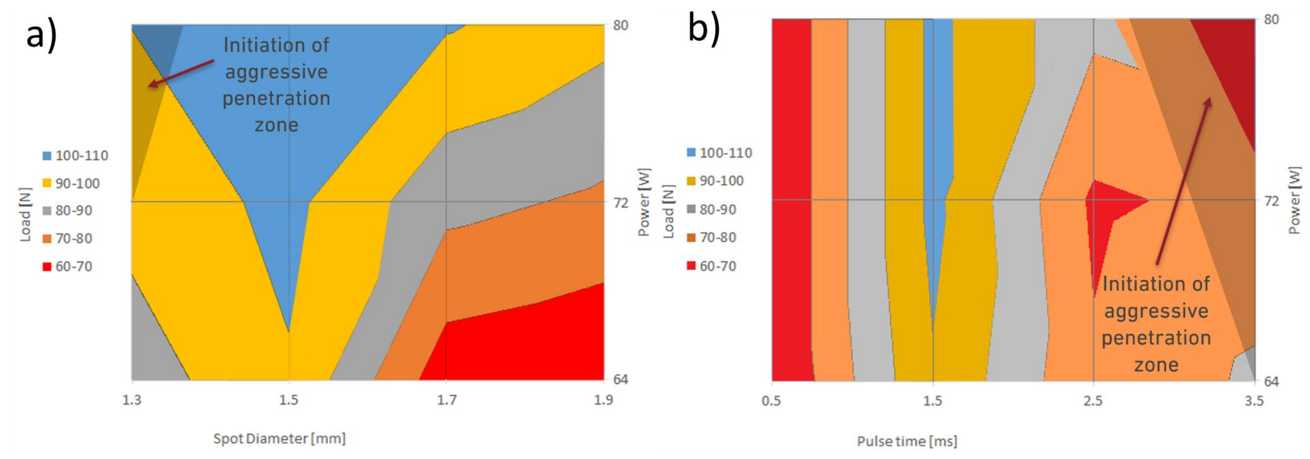

Figure 5 – a) Failure load map for 45º angles varying the average power and the laser beam diameter. b) Failure load map for 45° angles, varying the average power and time of the laser pulse.

NUMERICAL MODELLING

Modelling was carried out for a component representative of an actual application, as shown in Fig. 6a and material properties of the PBT were defined as a function of the thermal load the material was exposed to during welding (Fig. 6b).

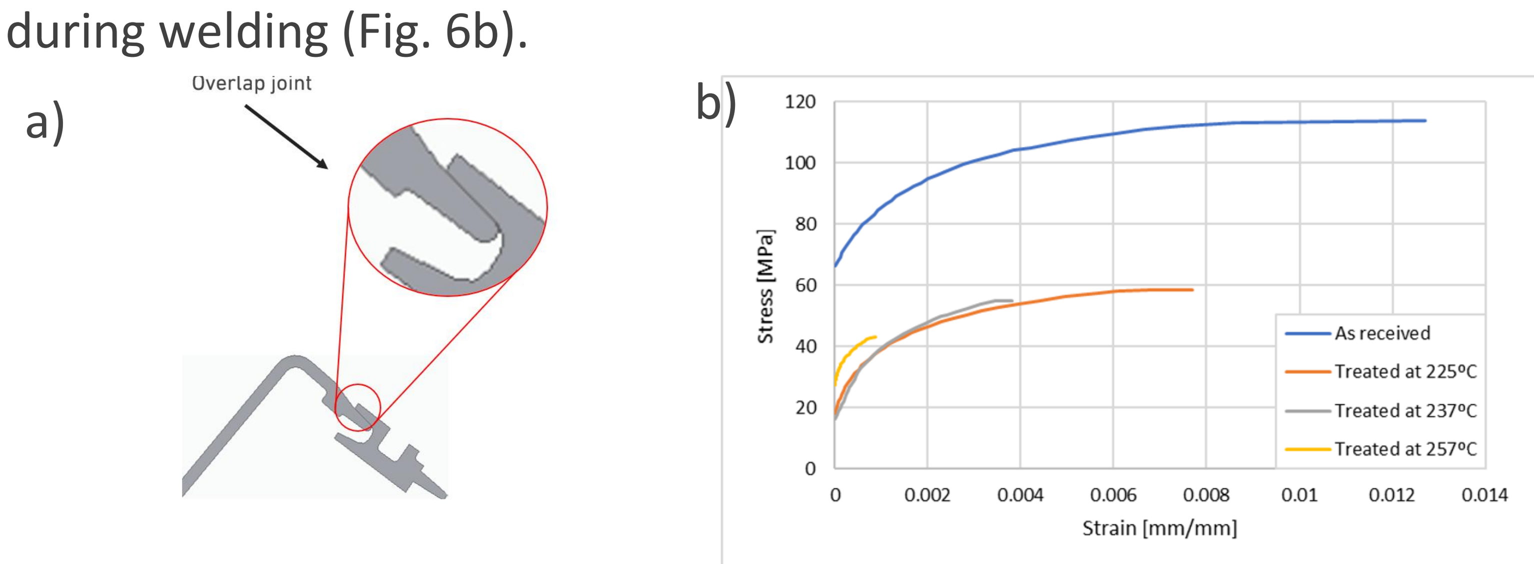

Figure 6 – a) Modelled overlap joint configuration b) Stress-strain curves of PBT-GF30 as a function of the heat exposure.

Using this approach, it was possible to model damage in critical joint locations (Fig 7a) and also extract a good prediction of the failure load (Fig 7b)

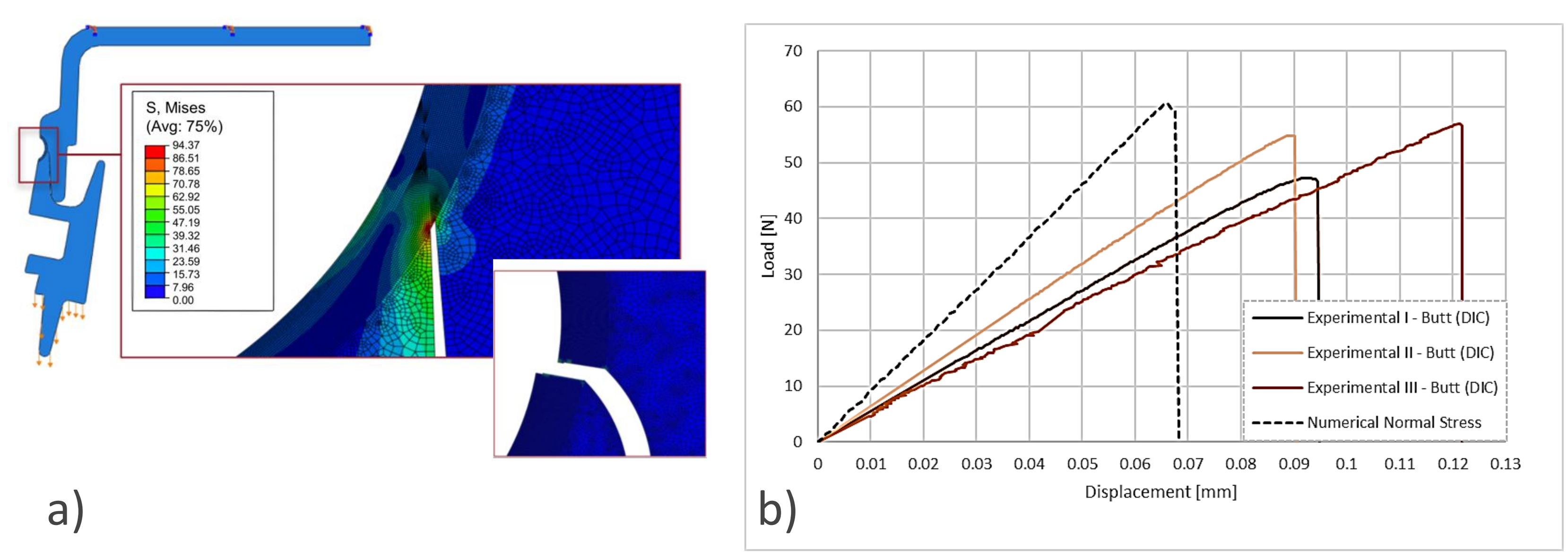

Figure 7 – Stress acting on model b) comparison between experimental and numerical data

Conclusion

Using a combined experimental and numerical approach, it was possible to define practical manufacturing parameters and also predict joint performance and failure mode.

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