Experimental study on the optimization of laser welding parameters in PBT GF30 joined by fillet joint

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Introduction

The automotive industry increases yearly the application of reinforced polymeric materials, searching for increased lightness, moldability and strength [1]. The main applications are in the protection of electronic circuits that need to be capsulated with good sealing. With the search of high productivity in the processes, the laser welding has occupied this market. Aiming to optimize the joining process of PBT GF30 in fillet type joint performed by laser spot welding, this work aims to study the static parameters to optimize the joint performance.

Experimental 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).

a) b)

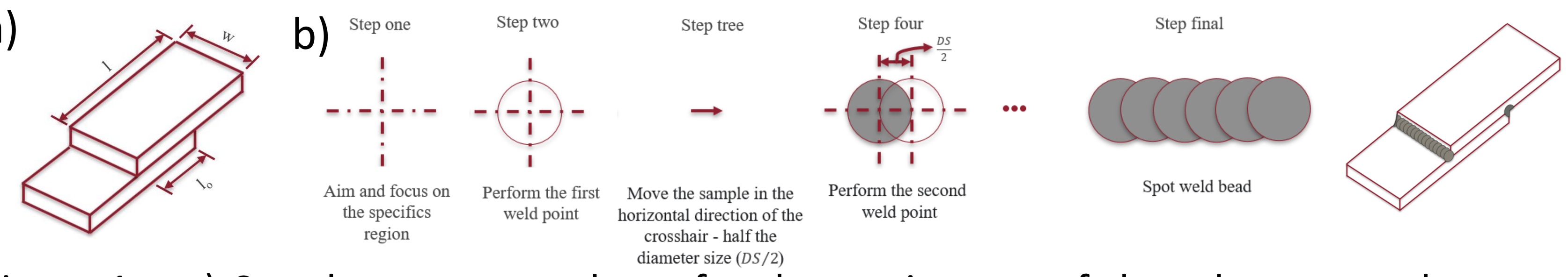
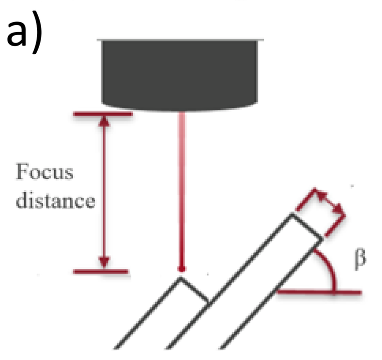


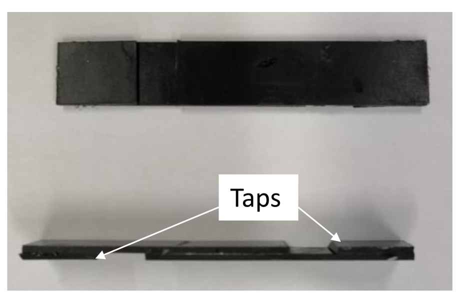
Figure 1 – a) Step-by-step procedures for the carring out of the advance on the spot weld bead.. b) Geometric joint configuration.

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).

a)



b)



c)

Figure 2– a) Incidence laser scheme. b) Double fillet lap joint showing the linearization taps. c) Test machine with the zoom on the specimens.

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).

Experimental results

The 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.

a) b)

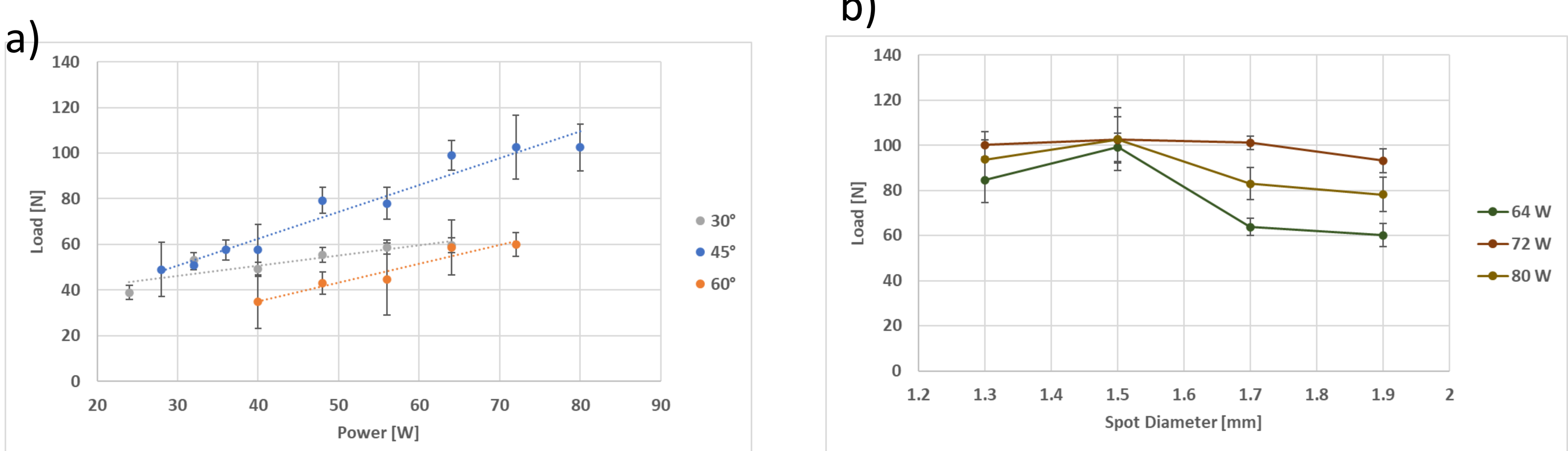


Figure 3 – a) Results of the failure load in relation to the angle of incidence and average power. b) Failure load study for 45º angles, with pulse time fixed in 1.5 ms varying the average power and the laser beam diameter.

From the three best results, for the 64, 72 and 80 W power levels, a primary study was carried out independently, varying only the laser diameter and keeping the laser pulse at 1.5 ms. According to Fig. 3b, the best result for the laser 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.

Based on the optimized laser beam diameter of 1.5 mm, a secondary study was performed varying the laser pulse time, as shown in Figure 4a. Similar to the analysis performed for the laser diameter study, it was observed that for a time of 3.5 ms, at both power levels, there was perforation of the sheet (Fig. 4b).

a) b)

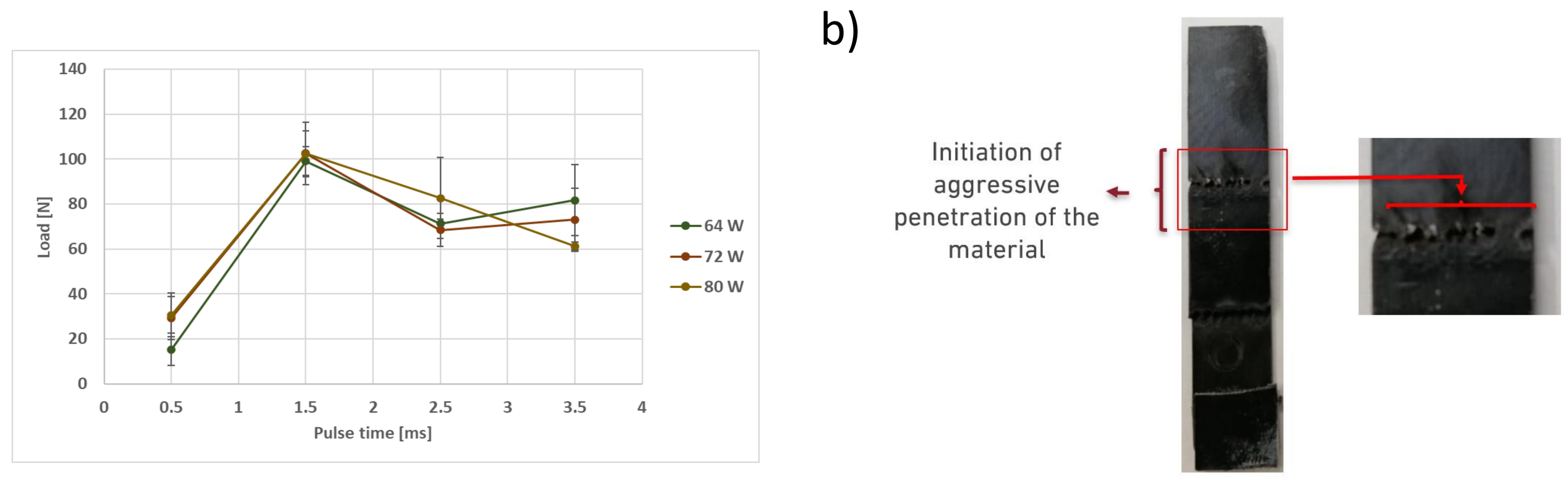


Figure 4 – a) Failure load study for 45º angles, with the optimized laser beam diameter (1.5 mm), varying the average power and the pulse time. b) Representative sample of the degradation caused by excessive power, pointing to the perforation of the GF30 PBT plate.

Taking the parameters that cause perforation in the plates as a basis, for the lowest critical energy situation, the optimization of the laser diameter is calculated by the thermal flux density to be limited at 53 W.mm^{-2} and also by the pulse time as energy flux density at 0.13 J.mm^{-2}. Accordingly, optimization maps of the parameters can be made, represented in Fig. 5a and Fig. 5b.

a) b)

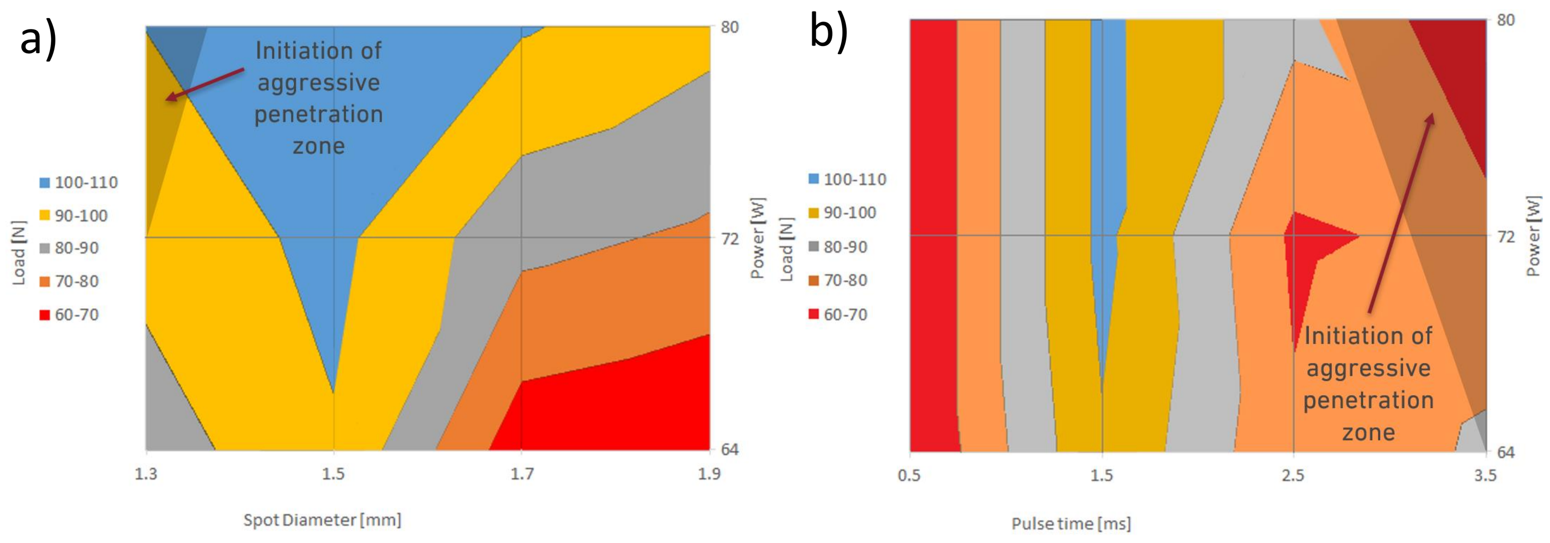


Figure 5 – a) Failure load map for 45º angles varying the average power and the laser beam diameter. b) Failure load map for 45° angles, varying the average power and time of the laser pulse.

Figures 3a, 5a and 5a, demonstrate that highest welding strength (in manual pulse frequency) is obtained when welding at 45°, with a pulse time of 1.5 ms, a diameter of 1.5 mm and 64 W of power.

Conclusions

In this work, a detailed parametrization of the study of the mean power maximum, pulse time, incidence laser angle and laser beam diameter was carried out, aiming at the determination of an efficient configuration for high strength spot laser welding of PBT in double lap fillet joints.

- The angle of laser incidence directly affects the joint resistance, especially for the 45° angle, which returns better mechanical performance.
- It can also be observed that the joint resistance is proportional to the maximum average power.
- The results also demonstrate that with a greater flow of energy or power, greater is the degradation of the material.
- It is noticeable that manual welding, in general, does not result in large strength values, making it necessary to study the dynamic parameters, such as frequency and speed of movement of the sample.

References

[1] Unterweger, C., O. Brüggemann, and C. Fürst, Synthetic fibers and thermoplastic short-fiber-reinforced polymers: Properties and characterization. Polymer Composites, 2014. 35(2): p. 227-236.

[2] Berger, S., F. Oefele, and M. Schmidt, Laser transmission welding of carbon fiber reinforced thermoplastic using filler material—A fundamental study. Journal of Laser Applications, 2015. 27(S2): p. S29009.

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