

Abstract

Through transmission laser welding (TTLW) method is an innovative plastic joining technology. It is used for its well-known advantages, such as non-contaminant, non-contact processes, ease of control, and automation. Moreover, this is a flexible joining process, has quicker processing times, and can provide quality, consistency and repeatability. The present study is based on transparent-to-transparent polymer (Acrylic and polycarbonate) welding by TTLW without any absorbent. The main objective of the present study is to find the optimum process parameters for obtaining good quality weld between Polycarbonate and Acrylic sheets in lap joint configuration, with Square and Circular contour using a Nd: YVO₄ laser beam. The input process parameters studied are Scanning speed (mm/s), Power(W) and laser frequency (kHz). The output parameters considered to evaluate weld quality are Weld width (WW), Heat Affected Zone (HAZ), Ultimate load (UL) and depth of penetration (DOP). Further, the experimental results are compared with simulation studies. A finite element model (FEM) is developed for the temperature contour for Weld width and depth of penetration analysis focusing on thermal modelling and structural analysis is done by modelling (LS-Dyna). 3D response surfaces and contour plots are generated by Response surface methodology (RSM) and Analysis of variance (ANOVA) is used to measure the combined effects of input parameters on responses. Confirmatory tests were conducted to validate the results of statistical optimisation resulted from desirability function analysis. Experimental results revealed that laser power initially increased weld width, but then it decreased, whereas the HAZ consistently increased. power and scanning speed showed negative effect on ultimate load but positive effected by frequency up to a threshold limit. Scanning speed decreased the weld width up to threshold limit and then increased. Relation between frequency and depth of penetration showed contradictory trend. Lower power with higher frequency and higher power with lower frequency gives higher depth of penetration, thus stronger weld. The results of ANOVA showed that scanning speed exhibited the maximum impact on weld width (89.34%) and HAZ (80.87%). FEM simulations aligned closely with experimental data, showing an average error of 8.09%. For plates of 0.5 mm thickness, maximum ultimate load is achieved is 372.60 N at 7.89 W power, 350 kHz frequency and 2.34 mm/s scanning speed. Whereas, the minimum ultimate load of 121.15 N was obtained using a laser power of 7.42 W, frequency of 300 kHz, and the scanning speed is at 1 mm/s. Structural modelling (LS-Dyna) of laser weld predicts similar load-displacement characteristics compared to that resulting from a physical test. When all of the responses are optimized in one setting, the parameter settings are: the power of 64.2014% of 12 W, frequency of 451.1340 kHz and a scanning speed of 0.6591 mm/s.