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Laser transmission welding of thermoplastic: experimental investigation using polycarbonate

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ABSTRACT

This paper investigates the effect of the laser welding parameters such as laser power, welding speed on weld strength. A 200W YAG laser with wavelength 1064nm has been used to weld transparent and absorbing Polycarbonate (PC) in lap weld configuration. The force at break of the lap welds was assessed on the Universal testing machine，weld fracture surfaces and weld cross-sections were also analyzed under microscope using reflected polarized light to qualitatively assess the weld quality.

KEYWORDS

Laser transmission welding;
Plastic welding;
Weld strength;
Polycarbonate.

INTRODUCTION

The use of lasers for joining plastics is growing. Several different approaches are being developed for laser welding of plastics. The main principle now used to laser-weld plastics is known as “transmission welding.” Transmission welding has demonstrated that precise, controllable heating and melting of low melting point thermoplastics can be produced at the interface between a transmissive and an absorptive plastic[1-8].

In the present research, an experimental investigation into laser welding of polycarbonate (PC) has been carried out. The force at break of the lap welds was assessed on the Universal testing machine，weld fracture surfaces and weld cross-sections were also analyzed under microscope using reflected polarized light to qualitatively assess the weld quality.

EXPERIMENTAL WORK

In order to study the effect of part thickness on weld quality, different thickness for transparent part was selected. The part thickness for transparent part varied between 1mm to 3.5 mm, and for absorbent part, a part thickness of 3 mm was selected. In order to manufacture both transparent part and absorbent part, a mold with different mold inserts was fabricated. The mould insert was used in an existing mould cavity in an injection moulding machine to produce the polycarbonate (PC) absorbent part and transparent part with different thickness, as shown in Figure 2.

The welding experiment were carried out using 200W Nd:YAG laser operating at 1064nm wavelength equipped with a 3-axes CNC work table, coordinated with the motion system and computer interface. A lap joint configuration was considered in the experiments, the laser-transparent part and the

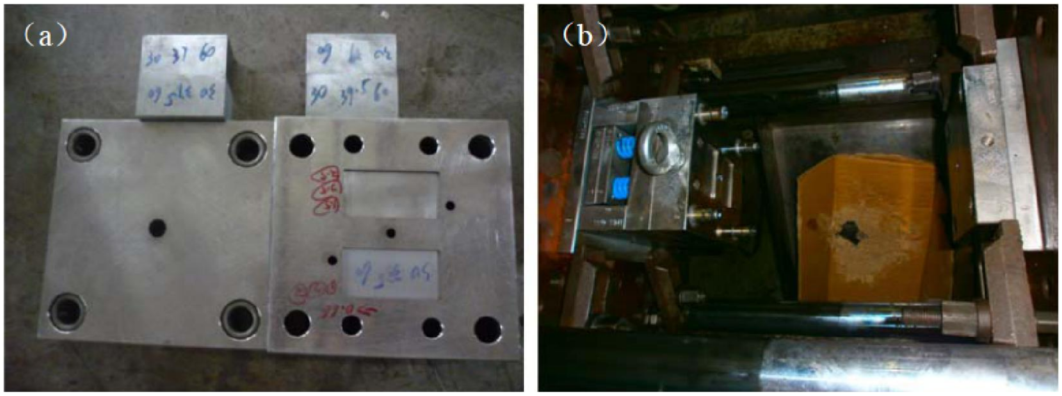

Figure 1 : (a) Mold with different mold insert; (b) Injection machine

Figure 2 : Injection molded of transparent and absorbent parts

Figure 3 : Laser welding process and welded samples

laser-absorbent part are welded together with a fixed overlap distance. The laser beam scans over the assembly at the specified power and speed to join the two parts together Figure 3. The effects of laser power, and welding speed on weld strength and microstructure were assessed. A shear lap tensile test with the weld line arranged perpendicular to the test pull direction was used to evaluate the weld quality of specimens.

EFFECT OF PARAMETERS ON WELD STRENGTH

Optical properties of transmitting part

In this section, the optical properties of the PC materials are investigated; the transmission measurement results are summarized in TABLE 1. The data shows that the transmittance varied with material thickness, which is approximately between 91%~94.5%. A 1 mm thick polycarbonate (PC) part has a transmittance of 94.5, and 3.5 mm thick PC has a transmittance of 91%. These results shows that for laser-transparent parts made of amorphous polymers such as PC, the part thickness usually has little

TABLE 1 : Transmission for different thickness of transparent part

Thickness of transparent part (mm)	Transmission (%)
1	94.5
1.5	94
2	93
2.5	92
3	91.7
3.5	91

Figure 5 : welding 20~30mm/s, laser power 40W, slight degradation of the weld joint occur

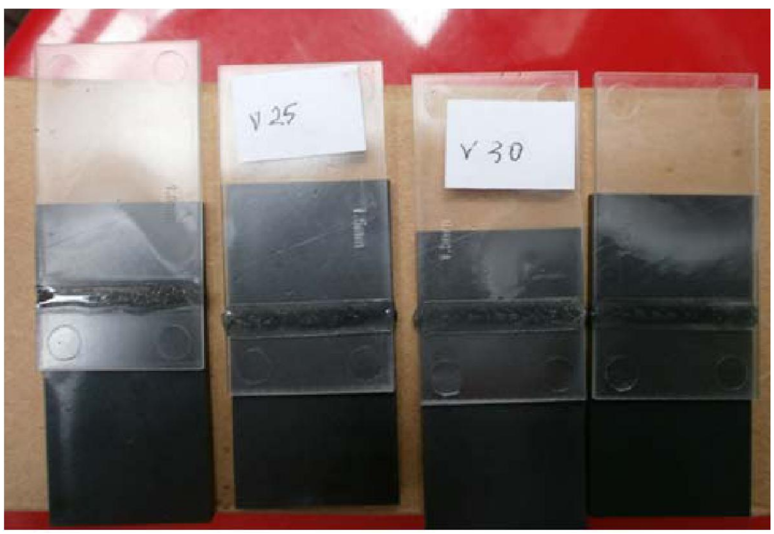

Figure 4 : welding 10mm/s, laser power 40W, overheating degradation of the weld joint occur

influence on transmittance[8].

Influence of welding speed on weld strength

At welding speed 10mm /s, laser power 40W, and transparent part thickness 1~1.5mm range, serious overheating degradation of the weld is observed. At low welding speed, longer laser irradiation time cause overheating degradation of the plastic part, thereby damaging the surface of the weld and plastic parts Figure 4.

At welding speed between 20~30mm/s, laser power 40 W, and transparent part thickness 1~1.5mm range, the PC welding process may be subject to thermal stress effect and lead to lower relative molecular diffusion, causing slight degradation or decomposition, thereby affecting performance of plastic parts and surface quality, as consequences shortened service life expectancy of the welded part Figure 5.

In Figure (6) the results indicate that the welding speed is the most important factor affecting the welded zone width. An increase in welding speed

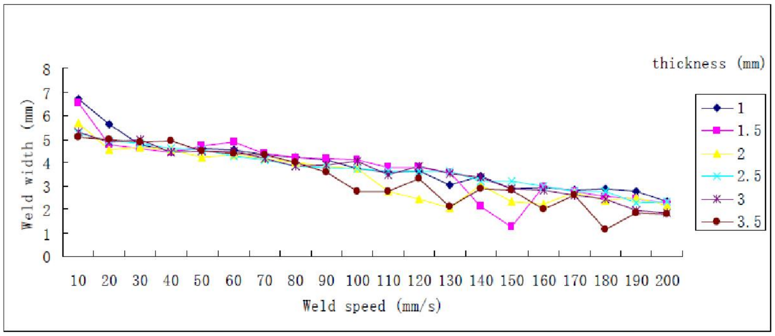

Figure 6 : Laser power 40W, weld width as function of weld speed

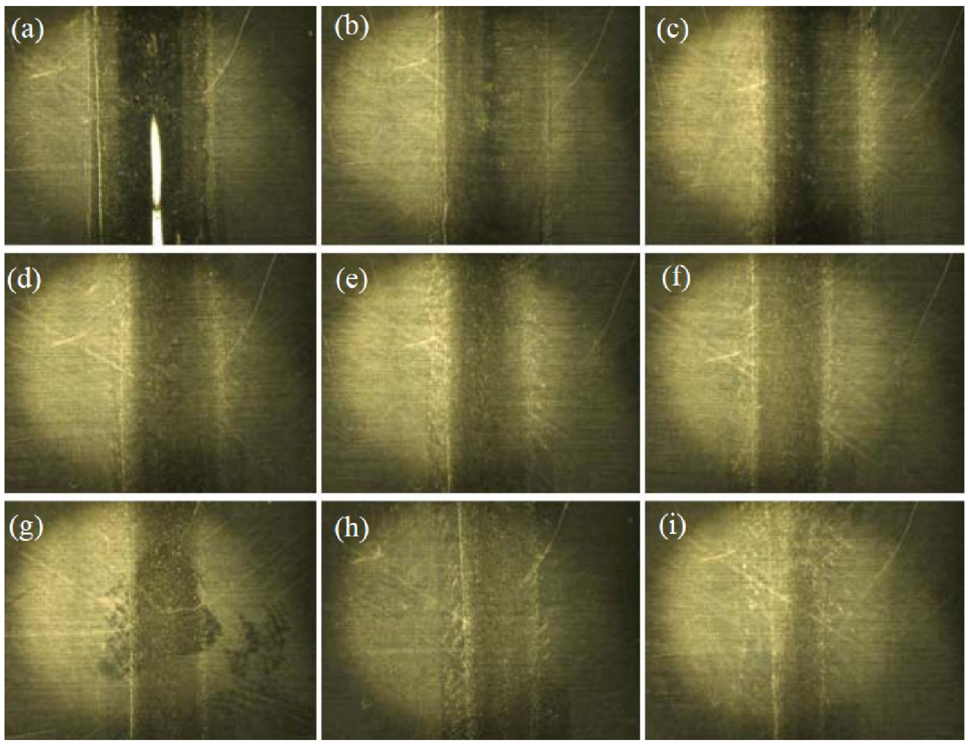

Figure 7 : Effect of welding speed to weld width, laser power 40W, transparent part thickness 1mm; (a) 40mm/s; (b) 50mm/s, (c) 60mm/s, (d)70mm/s; (e)80mm/s; (f) 100mm/s; (g)110mm/s; (h)120mm/s; (i)160mm/s

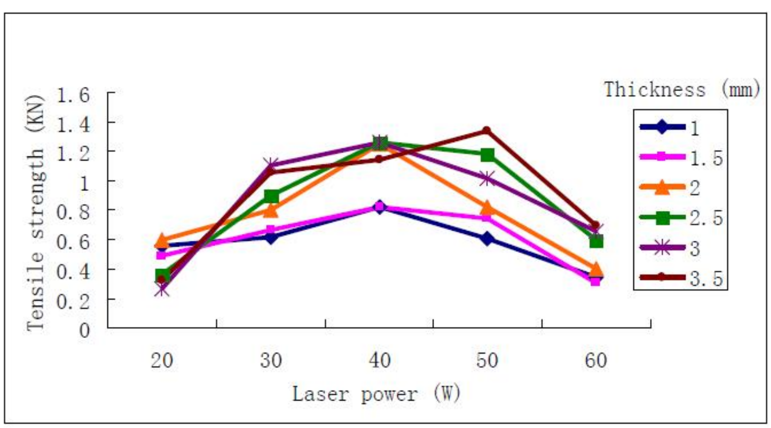

Figure 8 : Influence of laser power on weld strength

leads to a decrease in welded zone width. This is due to the laser beam travelling at high speed over the welding line when welding speed is increased. Therefore the heat input decreases leading to less

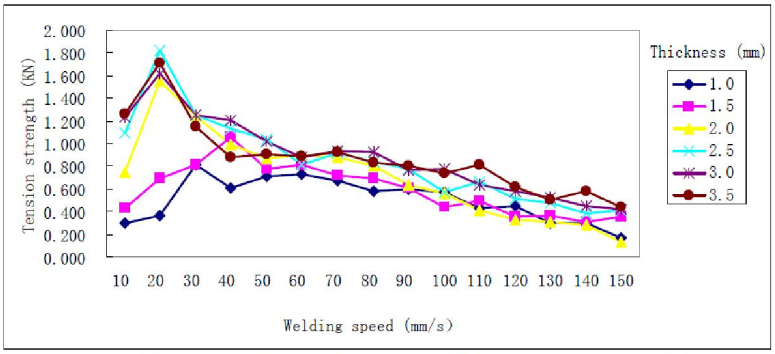

Figure 9 : The maximum load as a function of welding speed, laser power=40W

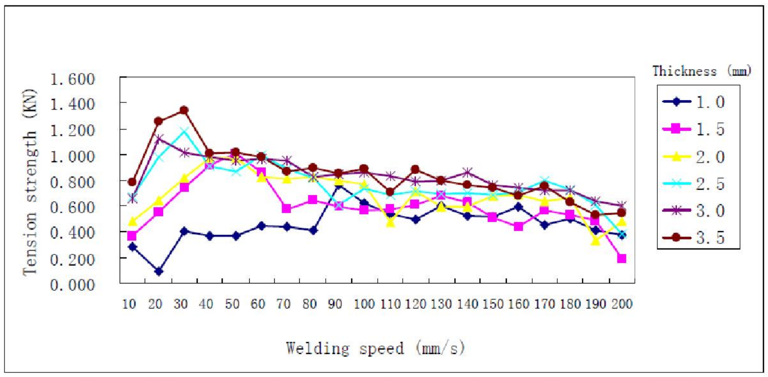

Figure 10 : The maximum load as a function of welding speed, laser power=50W

volume of the material being melted, consequently the width of the welded zone decreases. Moreover, the results shows also that laser power contribute secondary effect in the weld zone width dimensions. An increase in laser power results in slightly increases in the weld zone width, because of the increase in the power density. The main factor influencing the width of HAZ is the welding speed as the results indicated. This is due to the fact that at low welding speed the heat input will be greater.

Influence of laser power on weld strength

Figure 8 shows the force at break as a function of power for PC. It is observed that, the load-at-break increases with power and then starts to levels off or decrease as power is increased further. This is due to polymer degradation at the weld because of too high temperature caused by high laser power.

For PC, a minimum laser power of approximately 20 W is required for the two parts to bond together. Once the crystalline melting temperature is reached, the molten material is able to diffuse and form a weld. At this power setting, the load-at-break is low, these lower load are caused by low temperatures the weld zone.

For the applied laser power range 30 Wˆÿ40 W, the load approaches a maximum, these increase in load with power are caused by higher temperatures and wider heated zone at the weld seam.

For the applied laser power range 40 Wˆÿ60 W, the maximum load then starts to decrease as power is increased further. These changes in maximum load with power are caused by higher temperatures at the weld seam. This higher temperature caused by high laser power lead to polymer degradation at the weld zone.

An increase of the specimen thickness also resulted in increase of the weld strength (Figure 9 and Figure 10). It is possible that better performance of the thicker specimens is due to higher rigidity, which reduces bending of the lap joint during the tensile test.

The microscopic images of weld are shown in Figure 11-12 at a magnification of 20 X. From Figure 11 and Figure 12 it can be clearly seen that further increase of the laser power lead to degradation or burning of the weld joint area. Consequently, the high levels of the laser power caused degradation of the material at the center of the weld seam, reducing mechanical performance of the joint.

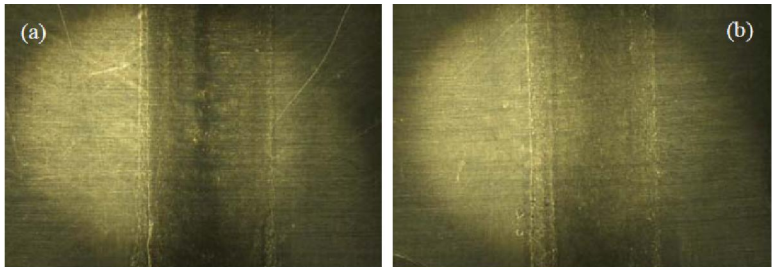

Figure 11 : Weld interface for PC with laser power 40 W, welding speed of 50mm/s; (a) transparent thickness 1mm; magnification 20 X; (b) transparent thickness 1.5mm; magnification 20 X

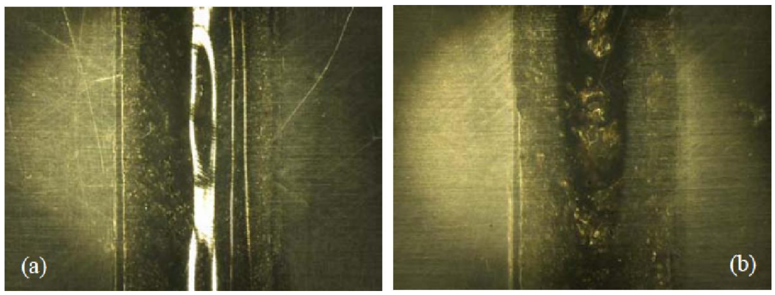

Figure 12 : Weld interface for PC with laser power 50W, welding speed of 50mm/sÿmagnification 20 X(a) transparent thickness 1mm and(b) transparent thickness 1.5mm; magnification 20 X

CONCLUSIONS

We can conclude that the weld strength is limited by very high welding speed in one hand, in the other hands the weld strength is limited by very high heat input, which causes overheating and partial decomposition of the material, and a very low heat input results in lack of fusion.

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