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Effect of processing parameters on meltdown in quasi-simultaneous laser transmission welding

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ABSTRACT

Meltdown is the term used to describe the collapse of two thermoplastic parts during welding. It is a critical process parameter in the laser-transmission welding of thermoplastics. This study examines the effect of quasi-simultaneous (QS) laser transmission welding (LTW) processing parameters including input power (P), number of passes (N), scan speed (V), total scan length (L_S) and weld pressure on the meltdown behavior of polycarbonate (PC) and polypropylene (PP), using a T-shaped test assembly. The total meltdown is shown to depend linearly on the total line energy (LE_T) defined as the product of P and N divided by V. Increasing L_S increases the critical LE_T for meltdown to begin. A simple model is presented that captures the main elements of meltdown in this thermoplastic welding process.

1. Introduction

Laser transmission welding (LTW) is a relatively new technique used to join thermoplastic components. In its most common form, a laser-transparent (L-Tr) and laser-absorbent (L-Ab) parts are clamped under pressure. A laser beam passes through the L-Tr part and is absorbed by laser-absorbing pigments or chemicals in the L-Ab component. The absorbed energy is transformed into heat and conducted further into both parts. Polymer melts and potentially flows under pressure from the weld interface, causing molecular diffusion to occur. Polymer flow from the weld interface (referred to as flash) causes the two parts to move towards each other. The distance of the collapse is referred to as meltdown. Meltdown can only occur if the entire contact area between the two parts is molten and if external pressure is applied.

LTW can be performed in three different ways: (*i*) contour, (*ii*) simultaneous and (*iii*) quasi-simultaneous. In contour welding, the laser moves at a relatively slow speed (speeds of the order of mm/s) and scans the weld area only once. Since only a fraction of the total weld line is generally molten at any time, there is no meltdown in contour welding. In simultaneous welding, the entire weld line is exposed to laser irradiation at the same time, using an array of laser beams. The interface temperature increases uniformly and meltdown can occur once the melting temperature is reached. In quasi-simultaneous (QS) welding, the laser repeatedly scans the weld line at relatively high scan speeds (of the order of m/s). The temperature in the weld rises in a saw-tooth manner and, after a period referred to as the induction time, the weld interface melts and steady state meltdown can begin.

The literature on LTW of thermoplastics can be classified into three major categories: (i) studies examining the effects of material properties such as glass fiber content and crystallinity, carbon black level, additives, and part thickness on light transmission and scattering [1–4]; (ii) research examining the effects of welding conditions on assembly properties such as surface damage of L-Tr part, degradation at weld interface, residual stress, microstructure, and mechanical strength of the joint [5–14]; and (iii) mathematical modelling to predict heat transfer and temperature profiles, mechanical behavior, molten area or light scattering [15–23].

Relatively few of these studies have been conducted on QS welding of thermoplastics. It has been shown that weld strength remained nearly constant during steady state meltdown [24]. A finite element analysis suggested that, at a given input power and scan length, the temperature-time profile does not change with speed [25]. Pressure profiling during LTW showed a positive impact on tensile strength of PP [26]. Finally, weld strength was found to be higher at low line energy (low power and high scan speed) [27].

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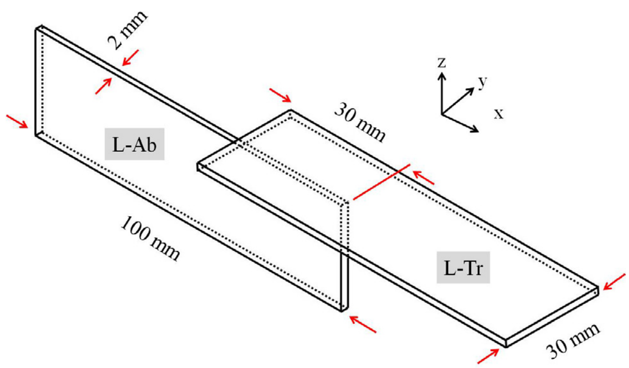

Fig. 1. Schematic of T-weld specimen (L-Tr part as flange and L-Ab part as web). Weld length was kept constant at 30 mm for all tests.

The literature contains limited experimental data on the effect of QS welding conditions on meltdown. This work is the first attempt to experimentally investigate the systematic effect of processing parameters on meltdown during QS welding. Meltdown is an important process output for those designing and welding industrial assemblies. QS laser welded assemblies are often designed with flash-traps that will enclose the flash when a specific target meltdown is reached. It is therefore important to understand the effect of process parameters on meltdown.

2. Experimental

2.1. Materials

Most of the work was performed using L-Tr parts composed of polycarbonate (PC) (Epitec 900F supplied by Osterman). 10 wt.% of a masterbatch (Monarch 880 supplied by Cabot) containing 2.5 wt.% carbon black (CB) (polyethylene as carrier polymer) was diluted in the PC matrix to obtain L-Ab parts with ca. 0.25 wt.% CB. Some studies were also conducted using polypropylene (PP) (Pro-fax 6323, from LyondellBasell). The PP L-Ab part was made using the same masterbatch and CB level as PC.

2.2. Sample preparation

The as-received PC and colorant masterbatch were injection molded into a series of 100 × 100 × 2 mm (length, width, thickness) plaques using an Engel 55 ton press. PC pellets were dried overnight in an oven at 110 °C. Colorant masterbatch was dry mixed with PC and then fed into the injection molding machine. Injection molding was conducted with a nozzle to feeder temperature profile of 290, 290, 280, 260 °C. The mold temperature was 70 °C and the injection, hold and cooling times were 1, 10 and 20 s, respectively. Injection speed and hydraulic hold pressure were 50 mm/s and 8 MPa, respectively. PP samples were prepared in a similar manner.

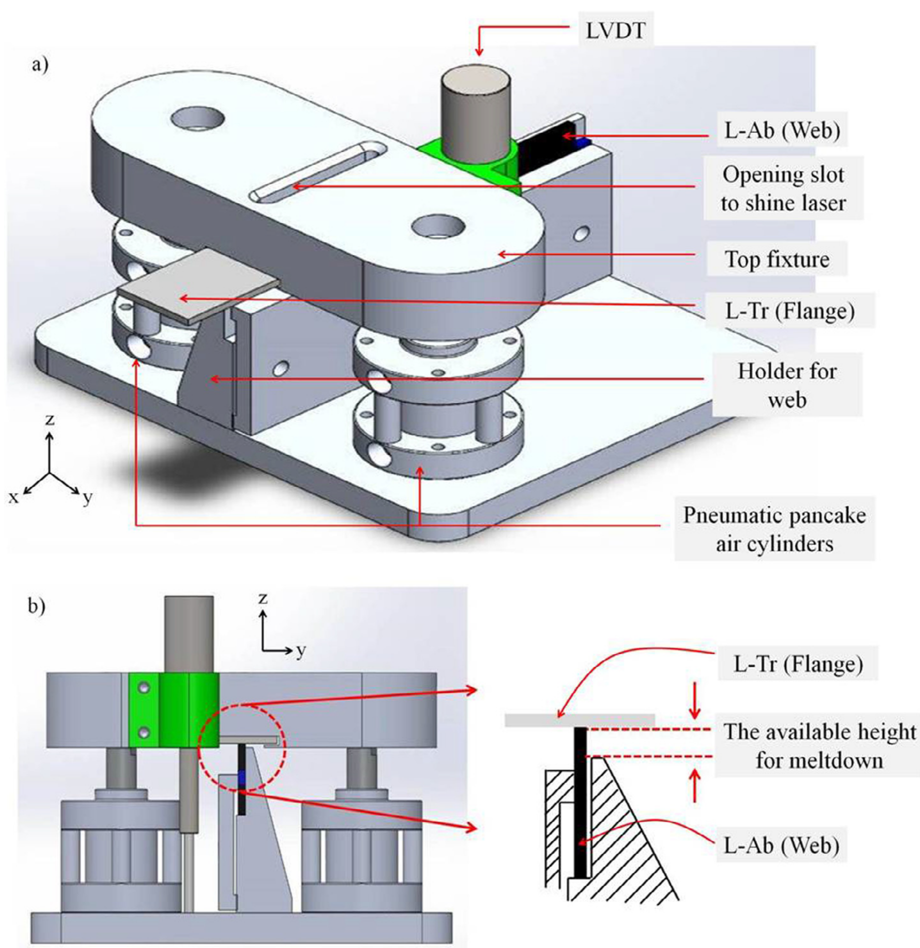

Fig. 2. (a) Schematic of T-weld fixture, (b) rear view (the available height for meltdown was ca. 2.4 mm).