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WELDING OF POLYMER FILMS BY LOW POWER LASERS

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The technology of laser welding by a transmission method allows welding overlapping polymeric films and sheets of various thickness. Welding of polyvinyl chloride films using a solid-state diode-pumped laser (DPSS) of 10 W power, which generates green radiation with wavelength of 532 nm, was performed in the developed experimental equipment. Application of this method made it possible to weld transparent multilayer medical films Wipak. Experiments have shown that with the help of such a laser it is possible to form a high-quality joint of Wipak medical film with paper. 9 Ref., 5 Figures.

Keywords: welded joints, polymer films, transmission laser welding, diode lasers

Versatility and adaptability to environmental conditions allows laser welding to be used even in the field conditions, where the question of welding fabrication productivity is the most relevant. More over, high intensity and monochromatic nature of the laser beam allow reaching high values of power and density of the energy flow that makes it fundamentally different from other heat sources in the welding technology. As laser radiation is an inertialess object, the time of the beam switching on and off, the change of its energy properties, as well as the direction of its movement relative to the treated part, are determined exclusively by the speed of laser radiation source, and the system of radiation transport and radiation control devices. The thermal cycle is determined by the accepted welding mode, which depends on radiation power, welding speed, conditions of beam position relative to the part being welded, cooling conditions, as well as thermophysical properties of the material. Thus, application of laser radiation and high productivity of laser welding at correct weld formation enable reaching a high level of welding process automation.

Laser welding is a radiation welding process with heating of the surfaces that are joined due to conversion of electromagnetic radiation energy into heat [1]. Laser designs can be divided into four main types (Figure 1), differing by radiation wave length and other parameters, and they can be used for welding of plastics [2, 3].

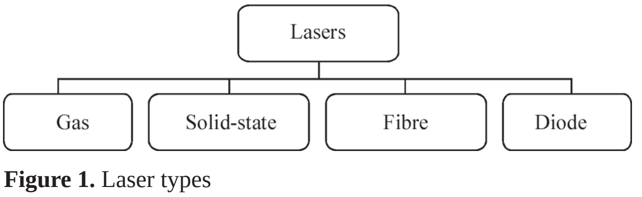

Figure 1. Laser types

Carbon dioxide (CO_2) gas laser generates continuous radiation with wave length of 10.6 μm. As such an IR radiation is readily absorbed by practically all kinds of plastics, powerful CO_2 lasers are applied for cutting and welding of polymer materials [4].

An active medium of solid-state lasers are dielectric crystals, activated by ions of rare-earth elements [5]. The most powerful of the solid-state devices is yttrium-aluminium neodymium laser (Nd:YAG), which generates radiation with 1.064 μm wavelength in the pulsed mode with the periodicity of less than a nanosecond. Such lasers are widely used in medicine and for treatment of engineering materials, in particular welding of plastics.

Fibre lasers use optical wave guide with fibres, alloyed by rare-earth elements, as active media. They form a sharply directed beam, which can be easily focused into a spot of very small dimensions. This laser type is convenient by that it can be readily combined with fibre optic lines for radiation transmission [6].

Diode (semiconductor) lasers are also solid-state ones, but unlike the above-mentioned lasers they have a different operation principle. An active medium in such lasers are semi-conductors, based on gallium and indium. Power of semiconductor lasers is smaller, but they are simple and compact, and can generate radiation in the optical, near and middle IR range. Therefore, semiconductor lasers are extensively used for treatment and welding of polymer materials [7, 8].

Development and mass industrial production of solid-state lasers greatly expanded the technological capabilities of laser welding of plastics. The most ex-

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tensively used now is overlap laser welding of sheet polymer materials by the transmission method. In this case, laser radiation of optical and near IR range passes through the transparent upper part of the welded joints, and is absorbed with heat evolution on the contact surface of parts. Such a method is often used to weld polymer films or sheet billets, which are semitransparent for laser radiation. Therefore, a possible variant is when the radiation is partially absorbed by both the billets, heating the welding zone [9].

Laser welding is believed to be costly from the view point of capital costs. At application of low power inexpensive lasers, however, this welding method can be more convenient, compared to other methods in manufacture of products from polymers films. It is believed that practically all the thermoplastics, such as polyethylene, polyvinylchloride, polypropylene, polystyrene, polycarbonate, ABS, polyamides, polymethyl methacrylate, as well as thermoplastic elastomers, are suitable for laser welding.

In our previous works we showed that 1 W laser is enough for film welding in the thickness range of 0.015–0.1 mm. A more powerful energy source is required for welding thicker material. Moreover, application of slides often does not allow accurately guiding the laser beam to the joint line, and following the progress of welding. Therefore, in this work a series of technology studies was conducted, using a more powerful long-focus source.

In this work, a 10 W diode-pumped solid-state laser was mounted on a carriage with regulated electromechanical drive (Figure 2). This laser uses a powerful diode with radiation wavelength of 808 nm, which is subjected to a series of transformations and eventually a green-coloured laser beam with 532 nm wavelength forms at the output. This radiation passes readily through transparent polymer materials, is less reflected from their surface and is readily absorbed by darkened materials. The laser is fitted with a system of lenses to form the beam, which allows focusing the radiation at 120 mm distance from the front edge of the case, or defocusing it to reduce energy concentration in the heated spot. Minimum diameter of laser radiation spot was 1.1 mm.

Laser case was fastened in a metal cylinder, which was able to move along a vertical guide with fixing at different distances from the plane of the parts being welded. During experiments, laser power remained unchanged, specific radiation energy was varied by adjustment of welding speed and distance from the laser to the part. Increase of laser power enabled welding thicker films from PVC. In welding the film was fixed by glass plates to ensure the required pressure and prevent joint deformation.

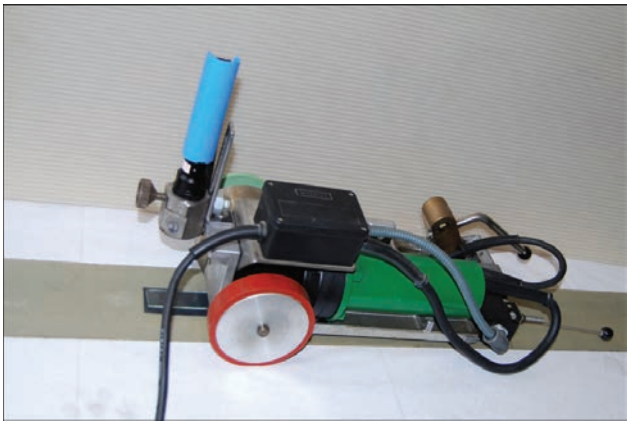

Figure 2. Experimental equipment for transmission laser welding of polymer film by a long-focus laser

Figure 3 shows the transverse section of an overlap weld of two PVC films 0.1 and 0.3 mm thick. At optimally selected welding mode, due to sufficient preheating of the lower film material, the upper film melts more than by half of its thickness that promotes formation of a sound welded joint.

Also studied was the weldability of special multilayer polymer film for medical packaging of Wipak Company. The widest application of this film is for manufacturing flat bags for medical instruments, where the film is bonded around the outer perimeter to a sheet of special paper by thermal welding. The film is completely transparent, so it poorly absorbs the laser radiation. Experiments showed that laser application enables forming a joint of the film with paper. For this purpose, it is necessary to apply additional pressure to the weld zone by special loading of the glass plate. In this case, adhesion of the film lower layers to the paper is achieved by heating the paper (Figure 4).

On the whole, for sufficient heating of the transparent polymer film, it is necessary to add to the weld zone dyes of black or dark colours, which promote active absorption of laser radiation and do not lower the mechanical characteristics of the joint material. Such dyes can be the traditional soot or graphite or fine polyethylene powder.

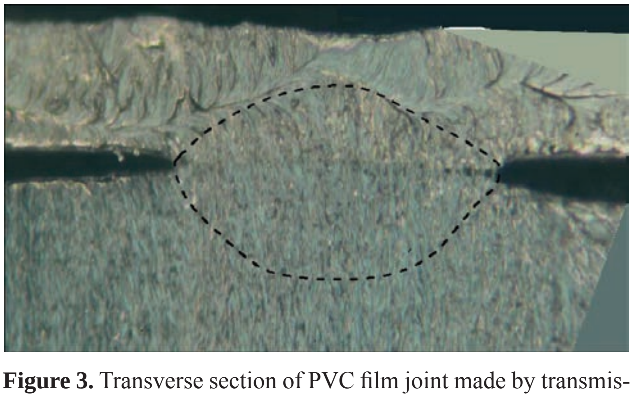

Figure 3. Transverse section of PVC film joint made by transmission laser welding. Dashed line marks the weld contours (×200)

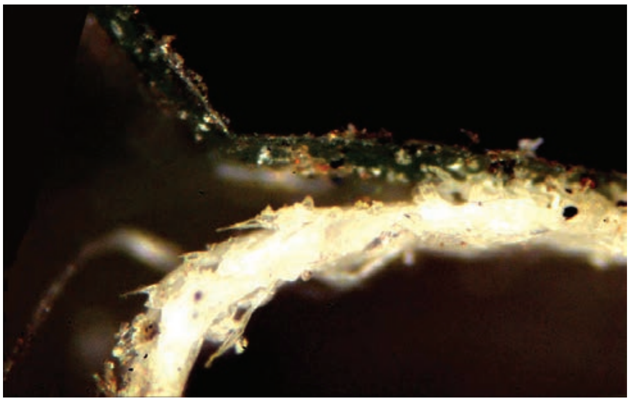

Figure 4. Joint of Wipak multilayer film to paper (×100)

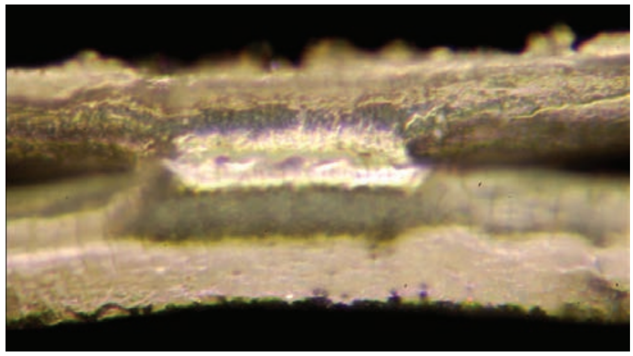

Figure 5. Optimum shape of the weld of polyethylene film 0.1 and 0.15 mm thick made by transmission laser welding (×200)

As a result of technological studies, the optimum parameters of transmission laser welding of polymer films were determined by the results of assessment of the weld appearance, studying their transverse sections under the microscope, as well as by the results of mechanical testing of film weld samples, in keeping with the requirements of the valid normative documents. At optimum parameters of the welding mode pores, blowholes, cracks or other defects are absent on the weld outer surface, on the weld transverse section uniform penetration is observed (Figure 5), which is somewhat increased for the lower film. Mechanical strength of such welds is on base material level. Investigation results were the base for development of recommendations on transmission laser welding of polymer films of different kinds, using low-power lasers of optical range.

Conclusions

Experimental studies of the impact of the main parameters of laser welding process on the morphology and service properties of the joints of polymer films and sheets were conducted. Rationality of application of low-power solid-state (diode) lasers of optical range was substantiated. Experimental equipment for laser transmission welding of polymer films was developed and manufactured. Technological recommendations were elaborated on laser welding of thin polymer materials that can be an alternative for joining polymer films by a heated tool.

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