Laser Welding Transparent Parts

Wide Area of Application. Up until now, laser-welding of clear-transparent components was not possible, because these materials did not absorb the laser beam. A new method involving the application of a special dispersion yields almost invisible welding seams.

GARETH MCGRATH

In plastics processing there are a variety of methods for joining plastics, including mechanical and chemical joining methods and welding. Each method has its own advantages and disadvantages, depending upon the intended application. Bonds created by welding are the result of intermolecular diffusion at the joint interface. Energy is applied to the materials, softening them at the joint interface and promoting this diffusion.

Welding techniques are categorized into three groups according to the means by which heat is applied: mechanical friction, thermal heating and electromagnetic radiation. Friction welding, including spin and ultrasonic, converts mechanical energy to heat through intermolecular friction. Thermal welding, on the other hand, involves the use of an external heat source, which is transferred to the surfaces through conduction or convection. Typical examples include hot-gas and hot-plate welding. In electromagnetic welding, the energy is converted to heat. In radio frequency (RF) welding, for example, the energy causes dipole vibration which generates heat. In transmission laser welding, the energy is absorbed and converted into heat.

Transmission laser welding uses a beam of high-density electromagnetic energy that passes through an infrared (IR)-transmissive substrate until it reaches an IR-absorbing substrate. Here the laser light is absorbed and localized heating of the substrates occurs at the joint interface, resulting in an instant weld. Controlling factors in the process are the power of the laser, the size of the laser beam, welding speed, intimate contact and properties of the material at the interface. Typically carbon black pigment is used as an additive to enhance absorption of the bottom substrate.

First used in the mid-1980s for welding automotive components, laser welding offers a number of distinct advantages compared with other plastics joining techniques. Because it does not involve vibration, it does not impart mechanical damage to a part or generate particulates, making it especially suitable for electronic and medical applications. Moreover, it yields bond strengths that are comparable or superior to other joining techniques, such as hot plate and ultrasonic, without visible markings or weld flash. It accommodates preassembly and high weld speeds, permits 3-D contour joint lines and facilitates rapid changeover to different products.

In addition, process parameters can be controlled precisely, and low heat input reduces the risk of thermal distortion. The process can be used for both polar and non-polar materials. The principal disadvantage of laser welding has been the need to use carbon black as an absorbent, posing a limitation in applications where colour and appearance are important.

Laser Welding for a Broad Field of Application

Recently, however, a revolutionary new process has been developed that offers all the advantages of conventional laser welding without the use of opaque materials or the addition of unwanted colour (Fig. 1). The process can be used to join a wide range of rigid and flexible plastics, both clear and coloured, making it ideal for assembling electronic, medical, automotive and consumer products, as well as packaging.

Materials can be developed for use with a wide range of materials (Table 1). The welding of dissimilar materials and some thermosets is also possible.

The process uses near-infrared-absorbing material systems to convert laser energy into heat. A thin layer of these materials applied at the interface of two pieces of plastic to be joined absorbs the light, acting as a focal point for the laser. Localized heating of the substrates occurs at the joint interface, producing clean, optically clear joints with no particulates or visible colour. Called Clearweld, the process was invented by TWI, a U.K.-based industrial research and development organization that specializes in materials joining, and has been developed for commercial use by Gentex Corporation, Cambridge/UK. It is patented in Europe and Australia with additional patents pending.

Tailormade Dispersion Systems

A series of materials has been developed, capable of powerful absorption in the near-IR spectrum, while remaining virtually colourless. Based on this, material systems were designed for use in a variety of production processes. The effectiveness of these material systems depends upon their compatibility with specific process parameters. These systems are custom-formulated, taking into account substrate materials, part design and process requirements, and are tested and certified for use with specific delivery methods. Intially these methods are limited to liquid dispensing and industrial ink jet printing, but may be expanded to include other printing methods. The process depends upon accurate and repeatable application of the near-IR absorbent at the localized joint interface.

Another important factor is intimate contact between the surfaces to be joined to ensure sufficient melt flow to produce a strong bond.

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Material	Abbreviation
Acrylnitrile butadiene styrene	ABS
Cellulose acetate	CA
Ethylene vinyl acetate copolymer	EVA
high-impact polystyrene	HIPS
Polyamide	PA
Polycarbonate	PC
1,4-cyclohexan-dimethylen-terephthalate	PCTG
Polyethylene	PE
Polyether ether ketone	PEEK
Polyether imide	PEI
Polyethylene naphthalate	PEN
Polyethylene terephthalate	PET
Polyethylene terephthalate, glycol-modified	PETG
Polymethyl methacrylate	PMMA
Polypropylene	PP
Polyphenylene oxide	PPO
Polystyrene	PS
Polysulphone	PSU
Polyvinyl chloride	PVC
Polyvinyl idenfluoride	PVDF
Acetal	
Polyurethane	PUR
Polyester	

Table 1. The system is suitable for a wide range of plastics

To obtain intimate contact of the substrates at the weld interface, a certain amount of clamping pressure is required. The amount of pressure depends upon the materials being joined and their surface conditions at the weld interface. Also critical is heat generation. High-power diode lasers provide the electromagnetic energy necessary for generating heat. The typical wavelengths employed range from 940 nm to 1000 nm (Fig. 2). Depending upon specific application requirements, a variety of power levels and configurations may be considered. It is critical, however, that the laser wavelength match the wavelength at which the material system is designed to absorb (Fig. 3).

Flexible Process Realisation

Due to their small size and weight, diode lasers can be used in a number of different ways in the Clearweld process. The choice and configuration of equipment for a given application will depend on a number of factors, including the size and weight of the component being welded, the rigidity of the material, whether it is film-based or moulded and the number of components that are required in a given design.

In a fixed laser, moving workpiece configuration, the equipment generally operates as a single-pass process, with the joint heated as the workpiece passes beneath the laser source.

It may be used with a dual-axis flat bed table to weld small- to medium-sized flexible components with 2-D joint lines or in the form of a continuously moving substrate for welding thin films for packaging applications, for example.

In a moving laser, fixed workpiece arrangement, the equipment operates as a single-pass process with the joint heated as the laser beam passes over the workpiece. The laser may be manipulated by a robot for 3-D processing or attached to a moving gantry over a flat bed for 2-D processing. This type of equipment is best suited to large, relatively flexible components.

In a fixed diode array, fixed workpiece scenario, the laser diodes are mounted in a frame designed to match the shape of the component being welded, rather than being put into a single laser source. The process operates with the entire joint being irradiated for a given time.

This procedure is suitable for small rigid moulded components that may not fit precisely at the joint line. Welding time is set to heat and soften the weld line, which will flow under clamping pressure and close any slight gaps.

Yet another equipment configuration is a scanning beam and fixed workpiece, whereby mirrors are programmed to move the laser beam around the joint line of the fixed component. The beam moves very quickly scanning the joint many times per second. This effectively heats the entire joint line simultaneously in the same manner as a laser diode array, making it suitable for small, rigid moulded components. This equipment has the added advantage of easily altering the weld line profile by simply loading a different program into the scanning unit.

Key to ensuring a successful process implementation are optimisation of laser power, weld speed and absorption of the custom material system. Fine-tuning these parameters can help produce weld strengths in excess of the parent materials and processing speeds equal to or greater than alternative joining techniques. ■

THE AUTHOR

DR. GARETH MCGRATH is European business development manager, Gentex Corporation, Cambridge/UK; gmcgrath@gentexcorp.com

Fig. 1. Applying a thin layer of the material system at the interface of two pieces of plastic concentrates laser energy at the interface. A localized melt of the substrates results in an instant weld, requiring no cure time and with no particulates or visible color

Fig. 2. Area of operations: The laser wavelength must match the wavelength at which the material system is designed to absorb. The Clearweld process is designed for use with lasers in the 940 to 1000 nm range Kunststoff vor dem Verschweißen = Plastic before welding; Absorbiersystem = Absorbing system; Kunststoff nach dem Verschweißen = Plastic after welding; Wellenlänge = Wavelength

Fig. 3. The thermal model left shows localized heating of the substrates only at the joint interface. The effect of this precise heating generated from optimized parameters produces a very small weld line and heat-affected zone, resulting in superior weld strength Wärmeeinfluss-Zone = Heat-affected zone; Schweißnaht = Weld line; Wärmemodell = Heating model; lokale Schmelze = localised melt; Substrat = substrate