Improving productivity and quality with laser seaming of fabrics

TWI's Ian Jones says that greater automation, increased productivity and higher quality will all result from the use of laser welding to replace traditional processes for seaming fabrics. Manufacturers of a wide range of textile-based products will benefit.

Fabric is most commonly joined by stitching, a highly labour-intensive process which that renders production cost-prohibitive in many parts of the world. It also makes holes in the fabric, which can impair the strength and sealing performance of the resulting seam. Recent studies show that laser welding offers the opportunity to increase the automation of the seaming process, while also providing good performance and appearance.

In searching for automated processes for seaming of fabrics, companies have looked to welding and adhesive bonding, particularly for synthetic fabrics. Laser welding offers the potential for both automation and improved seam performance. Principal advantages of this method include:

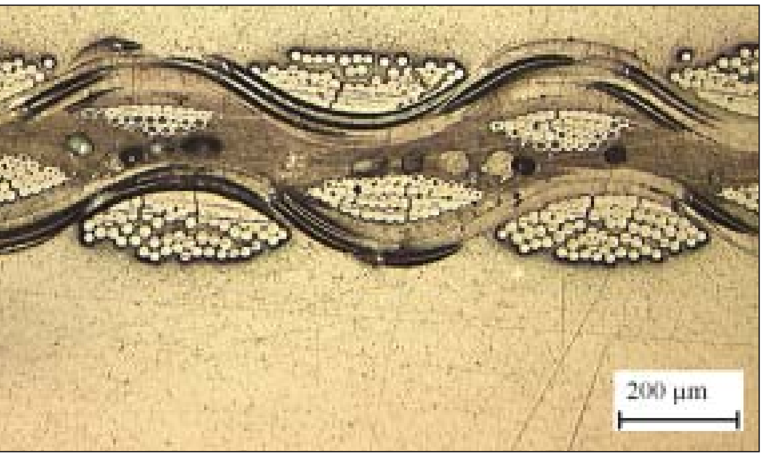
- high welding rates;
- restriction of heating to joint surfaces without affecting external texture;
- single-sided access, so welds can be performed beneath other layers of fabric;
- retention of seam flexibility;
- gas- or water-sealed seams where required;
- robotic or gantry manipulation of the laser for automated joining.

Two recent pilot projects have focused on the development of the welding process for applications such as airbag construction, bed assembly, medical furniture and protective clothing. Subsequent testing indicated the seams were as good as those produced by stitching and met the performance requirements of the applications. It should be noted, however, that challenges remain related to the mechanized positioning of the fabrics and support of curved surfaces during welding.

Currently furniture upholstery is produced using manually operated sewing machines and specialized quilting machines, with limited mechanization. Two types of stitches are commonly used—the lockstitch and the over-edge stitch. The main advantage of the conventional lockstitch process is that it readily produces a strong seam in which the stitching itself has low elongation and gape under stress. The over-edge stitch is used for joining removable or detachable covers, and is prevalent in the healthcare industry, for instance, where easy cleaning and improved infection control are required.

Coated fabric for waterproof applications is often thermally bonded using heat-sealing or dielectric welding. Staples are

Robotic manipulation of diode laser welding upholstery to polyvinyl chloride-coated wooden divan drawer.



Microstructure of laser-welded nylon 66 fabrics showing the horizontal melt line at the centre and, above and below this, cross-sections through the warp and weft fibres.

commonly used to attach fabrics to wooden or wood laminate furniture. And airbags typically have stitched seams or are woven in one piece on specialized looms.

Laser welding can be used to produce joints in either lap or peel configurations, depending on the design and required appearance. The procedure used for textiles is based on the Clearweld® method of transmission laser welding, which employs special materials to absorb infra-red radiation, instead of carbon black. The process localizes the laser energy, converting it to heat and melting the material at the joint.

In their natural state, thermoplastics, including man-made fibres, transmit near-infra-red (NIR) energy. To weld fabrics, radiation from a NIR laser must be absorbed at the joint.

Healthcare seat with laser-welded cover.

This is typically achieved by adding an infra-red absorber, either by dispersing it throughout the lower layer or applying a thin layer of it at the joint interface.

Traditional broad-spectrum absorbers such as carbon black add colour to the joint, which severely restricts the use of transmission laser welding in applications where appearance is important. Clearweld is used to weld clear, coloured and opaque plastics where welds need to be made without the addition of unwanted colour. Invented by TWI, the process has been commercialized by Gentex Corp of Carbondale, Pennsylvania, USA.

Trials showed that the infra-red absorber could be applied by spraying it directly on the fabric surface or on a polymer film, which was then positioned between two pieces of fabric. The fabric was then placed on a flatbed or on a more complicated three-dimensional support. After initial positioning of the pieces to be joined, with respect to each other and to the laser manipulation system, no further jigging was required.

In more complicated applications, significant development work remains to be done to design flexible jigging for various component shapes. Issues such as tensioning the fabric, asymmetrical upholstery shapes, gathering around corners, folds/tucks and welding through multiple layers of fabric will be addressed in the future.

Pressure was applied at the seam using a ring-shaped clamp sliding over a transparent cover sheet on top of the fabric. The laser irradiated the weld through the hole in the ring. Alternatively a vacuum table was used to apply clamping pressure.

Various NIR lasers can be used to produce welds with the Clearweld process, including:

- direct or fibre-coupled diode lasers, which typically operate at wavelengths of 808 nm or 940 nm;
- neodymium-doped yttrium aluminium garnet (Nd:YAG) lasers, operating at 1064 nm;
- fibre lasers operating at wavelengths between 1050 nm and 1500 nm.

Commercially available Clearweld absorbers have been shown to weld effectively at wavelengths between 800 nm and 1100 nm, absorbing laser radiation most efficiently at about 940 nm. For this reason, a 940 nm direct-diode laser with output power in the 150–600 W range and a beam width of 3–10 mm was selected for the project.

The laser was manipulated using either a gantry or robotic unit. In a typical robotic system, the laser is mounted on a robot arm and can be manipulated in three dimensions over a complicated form supporting the fabrics. If a direct-diode laser is used, the robot carries the entire laser head. With a fibre-delivered laser, the robot carries only the laser optics. A flatbed gantry system also can be considered if only two-dimensional weld seams are required.

Divan bed with laser-welded components.

The fabrics were laid flat in the proper position for welding, a cover sheet was placed over the weld region, and pressure was applied via a clamp attached below the laser, or by vacuum through the flatbed. The joint line was then traced by moving the laser with respect to the flatbed.

Based on a survey of current practice, the following fabrics were selected for the laser welding trials:

- flat, woven nylon 66, of a medium weight for airbag use;
- nylon, polyester or cotton coated with polyvinyl chloride (PVC) or polyurethane (PU) for medical furniture;
- patterned flat-woven damask in various blends of polyester, polypropylene, viscose and cotton for upholstery;
- nonwoven nylon or polyester for divan upholstery;
- wood laminates (both PVC-coated and paper foil-coated) for the divan drawer demonstrators.

Following laser transmission measurements on more than 50 fabrics, it was shown that the additives and colorants were important in defining whether the fabric could be welded. The polymer fibre and fabric types were less important. Fabrics with transmission values of more than 10% were found to be viable for use as the upper layer in welding. Transmission of the laser through the lower layer is of little consequence.

Welding was performed at speeds of 3–10 $m.min^{-1}$, depending on the laser power and the type of fabric. Joints were evaluated for basic slippage, distortion, strength and durability. Additionally, the seams in the PU-coated fabric were assessed for waterproof properties. We tested the airbags by measuring their leak rates under a range of static pressure conditions.

Seams as strong as the parent material were achieved in the lighter-weight woven materials. However, weld strength in the heavier airbag nylon was less than that of the parent material or a stitched seam. Seam strengths of between 40–100% of the parent material were achieved for most thermoplastic fabrics and laminates. This resulted in welds of the required strength and fatigue resistance for upholstery

Side-curtain airbag. Image courtesy of Autoliv.

applications. In addition to resisting unsightly gape at the seam, laser welding provided high performance where air or liquid sealing is required.

The strength of the seam was closely linked to the microstructure of the welds, which in turn is controlled by the laser energy input. Too little energy does not melt enough material to yield a strong weld. Too much energy melts the fabrics completely, creating a line of weakness at the edge of the weld and reducing its strength. The optimum energy input controls the melting for maximum weld strength and retention of the outward appearance of the fabric.

Pilot applications

A chair supplied by UK-based Knightsbridge Furniture Productions Ltd featured a waterproof cover of PU-coated polyester fabric. The back pad of the chair was a two-dimensional envelope that was welded inside out, turned, and pulled over the chair back to provide a sealed seam. The healthcare industry requires hermetically sealed seams to decrease bacterial penetration to the seat interior, reducing the risk of contamination and transfer of infection. The covers were successfully welded with acceptable appearance, and a durability test simulating a year of service was then performed on the finished chair with no significant damage. The seams also passed hydrostatic pressure leak tests.

Silentnight Beds, also from the UK, selected three separate bed-manufacturing operations as the bed-set pilot. These included attaching the mattress information label, producing a welded joint in the mattress side-panel border in quilted fabric, and welding the fabric on the PVC-coated wooden drawer front of a divan. All of these applications were successfully welded and subjected to industry standard testing with no visible deterioration of the seams. In all three cases, significant time-savings were realized compared with current methods. Replacement of manual stapling for the fabric-to-wood attachment for the drawer also can eliminate repetitive strain injuries.

Airbags are an important application for the nylon 66 fibre produced by Invista of Gloucester, UK. Recent developments in automotive safety have led to the introduction of airbags mounted in the sides of the seats and in the roof above the doors (curtain airbags; see also, *Technical Textiles International*, *Side-curtain airbags—a fresh challenge for yarn producers*, March 2002, pages 19–23). These provide protection from side impacts and during multiple rollovers, which require the curtain bags to remain inflated for at least 10 s to offer effective protection. This requirement adds extra steps to the manufacturing process.

Laser welding can provide a rapid, automated method for sealing a seam against gas or fluid leakage, and airbag samples were prepared and tested. The results from these trials were promising with the welded seams showing leak against pressure performance within the range achieved using conventionally sealed seams. Moreover, the highly automated welding procedure offers the potential for cost savings by reducing the time and number of steps involved in airbag manufacture.

Summary

Laser welding of fabrics can lead to greater automation, increased productivity and improved quality, offering manufacturers a competitive advantage and reducing the incentive to relocate production to regions with low labour costs. Producing finished goods close to where they are sold also reduces shipping costs. Additionally, the process reduces noise levels and injuries in the workplace.

Further developments in material handling, clamping and fabric selection promise even greater benefits in terms of process speed, automation and quality improvements. Laser welding is already being used successfully in some simple applications, and it is expected that ever more complicated articles will be manufactured using this technique.

Further information

Ian Jones is in the advanced materials and processes department of TWI Ltd, a UK-based industrial research and development organization that specializes in material joining. He has worked in the area of laser welding development for 15 years covering a wide range of materials and application areas.

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