EC CONTRACT COOP-CT-2005-017614

Automated Laser Welding for Textiles

Horizontal Research Activities Involving SME's Co-operative Research (CRAFT)

Publishable Final Activity Report

Date of preparation: 21 December 2007   Revision 1

Start date of Project: 15 November 2005   Duration: 2 years 1 month

Project co-ordinator: Ian Jones
Project co-ordinator organisation: TWI Ltd, Granta Park, Gt Abington, Cambridge, CB21 6AL UK.

Contents

1 Project Execution

1.1 Project objectives

- Preparation of textile barrier structures for protective garments and development of laser welding procedures to meet the performance requirements of garment and bed manufacturing applications.
- Development of a reconfigurable support system to hold fabrics during the joining procedure using novel surface generation strategies from 2D pattern geometries to create 2D and 3D seam shapes.
- Development of a laser welding head and laser carrier system to provide joining and consolidation of the joint to achieve the mechanical performance described above.
- Demonstration of laser welding procedures in the fabrication of applications in protective garment making and mattress construction.

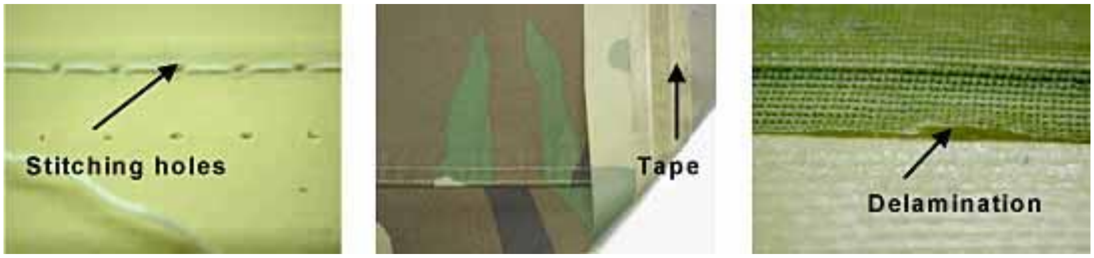
1.2 List of contractors

Akatex - Poland
Arlen Spólka Akcyjna - Poland
D'Appolonia SpA - Italy
Dorimi Srl - Italy
Frizza SpA - Italy
Grado Zero Espace Srl - Italy
HighfTech Engineering Srl - Italy
Monarch Textiles Ltd - UK
PIL Membranes Ltd - UK
Prolas GmbH - Germany
Silentnight Beds Ltd - UK
TWI Ltd - UK (Project manager)

1.3 Introduction

In Europe several tens of millions of workers operate in dangerous environments and require protective clothing. Additionally there is a large market for outdoor waterproof sports and leisure wear.

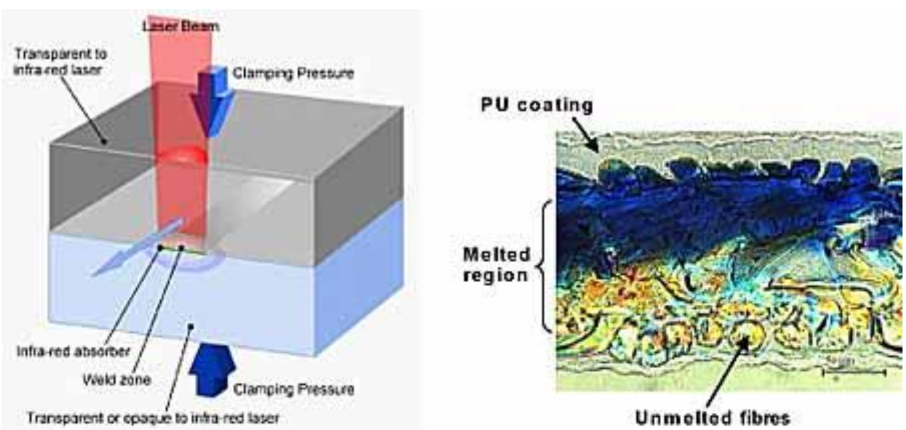
Fig.1. Typical sealing characteristics



In these applications highly engineered fabrics provide a barrier to particles, liquids or gases. The main limitation however is the joining of these fabrics as sewing penetrates the material and resealing is required in a second taping process. Alternative sealing methods using hot melt adhesive tape are emerging, but these all use an additional layer between the fabrics at the seam. The current procedures are time consuming, highly labour intensive and the use of tape is limited in applications using complex 3D seams. Additionally, because of the limited peel strength of taped seams and the continuous bending of the joints during use as well as maintenance and washing, the sealed seam often delaminates (see *Fig.1*).

Laser welding offers a method of making sealed seams without using additional film at the joint. The process melts a thin layer of the fabrics without affecting the outer surfaces by transmitting the laser energy through the outer fibres. The process is also suitable for automation. This results in a joint that has a greater flexibility and softer feel than is made with other welding methods. The outer texture of the fabric is also retained.

Fig.2. Laser welding uses transmission of energy to weld without melting the outer surfaces



Laser welding achieves this by applying a well-controlled amount of heat, just to the contacting surfaces of the fabrics. This selective heating is achieved by introducing a low visibility laser absorbing fluid, such as Clearweld®, onto one or both of the fabric surfaces usually by spraying in advance. The laser energy passes through the fabric, heats the absorber and generates a weld which seals the interface. Resulting beneficial features of the process include:

- Control of melt volume and hence seam flexibility
- Sealed seams in one operation, avoiding use of tapes - curved seams become possible
- Potential for high speed seaming and automation
- A novel appearance to the seam - new design opportunities
- Welding may be achieved through several layers, so closed products with internal welded structures are possible

The aims of this project were to develop equipment, textiles and procedures for manufacturing textile products based on recent laser welding process innovations. Laser welding allows sealed seams to be made for applications such as outdoor clothing, with the potential for a reduced number of process steps and improved reliability, consistency and security compared to alternative techniques. The process is also suited to automation and would potentially fit into a fully automated production line for garment or other textile product manufacture such as bed manufacture.

1.4 Work performed

1.4.1 Fabric development

Existing fabrics for waterproof applications have been tested and new fabrics developed to provide improvements in performance and laser processing capability. The fabrics tested included three-layer laminated materials with polyester face, nylon back and a breathable membrane, polyurethane coated materials and bi-adhesive laminated materials. The results have shown that high integrity seams can be made which exceed the current industry requirements for resistance to water penetration (at least 200cm water head required to ISO 811), and survive a 50 cycle wash test without detriment (to ISO 105-C01/89). The seam strengths are also very good with many existing fabrics easily meeting the 120N industry requirement (to ASTM D1683-04).

A summary of the results of tests on seam strength and resistance to water penetration are shown in the *Table 1*. The results for a single layer fabric, similar to that used in the biadhesive material, are shown for comparison. This fabric shows higher strength than the others (it was not designed to be waterproof), and serves to demonstrate that the seam strengths in the laminated materials were limited by the lamination strength in the parent fabrics. This result was further reinforced by examination of the failure mechanisms for the tensile tests.

This work identified alterations that could be made to the fabrics to provide further improvements to the performance and weldability using the laser seaming process. New barrier fabrics have been specified specifically for laser welding applications, and examples have been prepared. These have the same polymer on both faces and laminated layers with good transmission of the laser beam.

Table 1 Laser welded seam performance for different fabric groups

Material	Seam Strength Lap seam ASTM D1683-04			Resistance to Water Penetration ISO 811
Industry Requirement	**120N**			**200cm**
	FF	**FB**	**BB**	
Nylon with polyurethane transfer coating, 222g/m^2	274N	278N	289N	>200cm
3-layer laminate, polyester/PTFE/nylon, 190g/m^2	447N	247N	243N	>200cm
2 layer polyester laminated with 14% PU biadhesive, 240g/m^2	256N	245N	100N	>200cm
Single layer polyester/lycra, Teflon coated, 250g/m^2	547N			33cm

Notes: FF = face to face lap joint, FB = face to back, BB = back to back

1.4.2 Equipment development

The other aspect of the project was to develop equipment to allow construction of complex textile products in a wide range of sizes and designs. A reconfigurable table to support the fabric parts in the required location and shape has been made. This has been integrated with a laser beam delivery unit to provide controlled laser heating and pressure application along the textile seams. The diode laser is delivered by a fibre optic and the head is manipulated with 6-axis robot to provide a functioning laser welding workstation.

The final welding head incorporates sensors to monitor the weld temperature and provide continuous control of the laser power allowing very high weld consistency at all times. This work has already resulted in a patent application. Two support systems have been developed to deal with either 2D or 3D seaming procedures. The reconfigurable table assembly for 2D procedures uses driven rollers that can operate jointly with the air suction system to ensure no wrinkle or crease formation on fabric. For 3D seams the curved shape of the seam may be defined by a shaped substrate. The feasibility of welding a curved 3D seam has been demonstrated on a rigid mould, and a small scale prototype equipment has been made with a rubber membrane and actuated pin elements able to precisely reproduce 3D shape required. This indicates a route forward to a fully flexible system.

The robotic laser welding equipment has been constructed and integrated and a simulation model (see next section) for the integration of the welding unit into a fully automated textile product factory has been developed. The equipment is shown below.

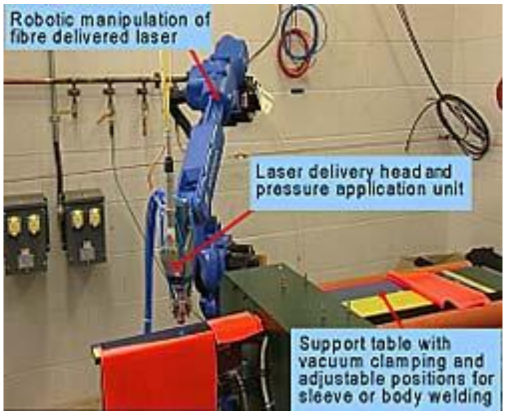


Fig.3. Automated laser welding equipment

1.4.3 Application demonstrations

Waterproof jacket and 3D hood
An existing jacket design was modified to have seam designs and forms more suited to a laser welding fabrication. Additionally the total number of seams was reduced. A series of fabrication steps was developed starting from a pattern for the trunk followed by attachment of cuffs, pockets, collar and lapels. The welds were completed at a speed of 3m/min using a laser power of around 75W.

Fig.4. Laser welded waterproof jacket

The equipment was also evaluated for the manufacturing of 3D seams. The hood for the waterproof jacket was chosen to demonstrate 3D processing as shown in *Figure 5*.

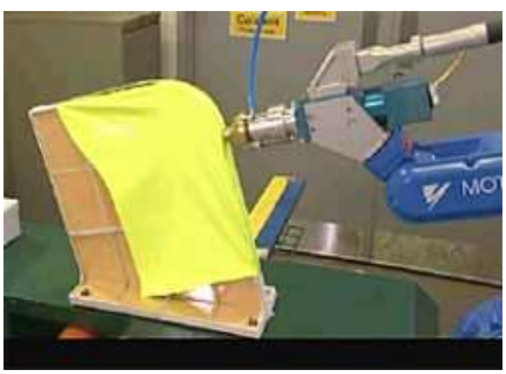


Fig.5. 3D processing for a hood seam

Mattress border
The second demonstration consisted of welding the border of a mattress. The border of a bed mattress has one vertical seam to make it into a loop and is made from quilted fabric with a woven polyester/polypropylene face, polyester wadding and a non-woven polyethylene support backing layer. Currently, the border seam has to be

completed off the mattress, and this leads to problems matching the dimensions of the component parts. Laser welding is expected to improve production rate and reproducibility as the mattress border can be joined in-situ on the mattress.

Suitable jigging was prepared to support the ends of the border in a peel joint configuration such that both free ends of the fabric were hidden on the inside of the border. The weld obtained was strong and allowed positioning of the border around the mattress without any difficulties. It was made at 3m/min using a laser power of around 100W.

Fig.6. Application tested in mattress construction

1.4.4 Project achievements and dissemination

This activity has shown that laser welding of textile could be used for the manufacturing of simple or complex shapes, if the appropriate clamping and support systems are used. Automated welding has been demonstrated in specific application areas. However, to take full advantage of the automated procedures to provide time and labour savings, the equipment needs to be integrated with an automated production line that would include preparation and handling of the fabrics. We could imagine that preparation of the fabrics such as cutting, spraying of absorber and positioning could be done automatically using a combination of flat-bed tables and robots. The laser could also be coupled to several fibres so that welding of several jackets, for example, could be made simultaneously.

A simulated automated manufacturing environment is shown in *Figure 7.*

Fig.7. Simulated example of automation using laser welding of textiles

It is estimated that the laser welding operation of the jacket would take around 10 minutes compared to 45 minutes for the manual stitching and taping process. Therefore, an automated procedure would provide a higher production rate per manufacturing unit, whilst also providing a higher quality product.

The exploitation plan has been completed. Future plans taking advantage of all the major results obtained in the project have been considered:

- laser welding procedures for textiles
- characteristics of the fabrics suited to laser welding
- type of barrier layer and lamination procedures
- design of laser welding head and pressure application suited to textiles
- design of the support table, fabric holding and automation methods
- garment or bed design and manufacturing methods using laser welding.

Dissemination activities will continue for the ALTEX project, using following instruments:

- National and Regional Workshops, Exhibitions, Posters and Public Conference.
- Use of WEB platform.
- Direct contacts with high level textiles companies.

Routes to further development of the automated methods are being explored, in both national and European arenas, including links to the LEAPFROG European Integrated Project on development of garment manufacturing and discussions with individual companies.

1.4.5 Impact on the textile product manufacturing industry

This project has examined the use of laser welding in the fabrication of textile products, specifically protective garments and mattresses.

Existing waterproof textiles have been welded and the seams meet the industry requirements for strength and water resistance. Textiles more suitable for laser welding have been specified with suitable laser transmission and polymer compatibility properties.

A prototype automated textile welding station has been built. A fibre delivered diode laser was integrated with a 6-axis robot and a reconfigurable table to provide regions for different 2D and 3D seaming requirements. The system also used weld temperature monitoring and laser power control to maintain a consistent seam quality.

The use of laser welding and the prototype welding station for the manufacture of garments and bed mattresses has been successfully demonstrated in the following applications:

- The body of a waterproof jacket with seams sealed in one welding operation instead of stitching and taping
- The hood of the waterproof jacket, demonstrating the shaping of a 3D shaped seam form using a moulded support
- The border of a mattress allowing the weld to be made in-situ on the mattress, and solving the problems of matching the size of the border to the mattress

Further developments are being considered to integrate the automated laser welding station into a garment prototype production line.

2 Dissemination and Use

The following table provides an overview of the exploitable products of the project and indicates the main partners in the project who will proceed with the exploitation.

Exploitable Knowledge (description)	Exploitable product(s) or measure(s)	Sector(s) of application	Timetable for commercial use	Patents or other IPR protection	Owner & Other Partner(s) involved
1. Laser welding procedures for fabrics	Fabric support Absorber application Welding method Quality control	Garments Furniture Automotive Aerospace Construction Medical R&D	2010 on	Existing	TWI GZE Prolas D'Appolonia
2. Fabrics with characteristics suited to laser welding	Production of barrier and other fabrics	Garments Furniture Automotive Aerospace Construction Medical R&D	2010 on	Expected	Frizza Arlen GZE
3. Barrier layer and lamination procedures	Supply of barrier layer and laminated	Garments Furniture	2009 on	Expected	PIL Arlen

suited to welding	or coated fabrics	Automotive Aerospace Construction Medical R&D			Frizza GZE
4. Design of laser welding head and pressure application suited to textiles	Beam profile Beam manipulation Pressure application equipment	Garments Furniture Automotive Aerospace Construction Medical R&D	2009 on	Application filed	Prolas TWI
5. Design of support table, fabric holding and automation methods	Manufacture of table Fabric holding system 3D seaming modules	Garments Furniture Automotive Aerospace Construction Medical R&D	2010 on	Expected	Highftech D'Appolonia
6. Garment design and manufacturing methods using laser welding	Protective and other garments Seam and part design Automation	Corporate Leisure Medical	2010 on	Expected	Monarch Arlen Akatex Dorimi
7. Bed design and manufacture methods using laser welding	Manufacturing procedures and automation	Furniture	2010 on	Expected	Silentnight