Laser Welding of Textiles: A creative approach to technology through a reflective craft practice

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Abstract

In an increasingly digital age of manufacture the role of the craft practitioner and particularly hand making processes has had to be reconsidered. There are those that would argue the depletion of goods made by hand simply negates the need for making skills in the development of new products; however, there is an emerging argument that places more value in the potential benefit of craft practice, and particularly making, to bridge between scientific knowledge and the needs of industry.
This paper calls upon the research of Dr. Kate Goldsworthy and Helen Paine, who have utilised laser-welding equipment to explore the benefits of a 'craft approach' in assisting the development of an emerging technology for decorative and functional textile finishing applications. Goldsworthy first worked with the technology in 2008 during her doctoral research, and has used it to develop unique surface finishes for textiles that preserve material purity and can be recycled within a closed-loop system. The inventors of the technology, TWI, fund Paine's current doctoral research, and wrote the original brief for the project that is essentially technologically driven; from which Paine has chosen to investigate new aesthetic and functional opportunities for stretch textiles offered by the equipment.
Despite the disparate contexts for the research of Goldsworthy and Paine, their shared background in textile design has led them both to follow a familiar practice-led approach. In this unified approach they have been able to collectively recognise the benefits of working in a hands-on way with the technology. This paper will explore techniques undertaken by both researchers during their investigations and share their insights from working with the laser welding equipment, made available to them by TWI. More widely, the paper will demonstrate the benefit of an intuitive craft approach in the development of an emerging technology.

Keywords: *Technology, craft, textile finishing, laser welding, tacit knowledge, creative problem solving.*

Introduction

Goldsworthy and Paine have both developed practice-based doctoral projects using laser technology based at The Welding Institute (TWI), in Cambridge. Goldsworthy first worked with the technology in 2008 and has used it to develop unique surface finishes for textiles that preserve material purity and can be recycled within a closed-loop system. The inventors of the technology, TWI, subsequently funded Paine's current doctoral research project, which began in 2012. Paine is investigating new aesthetic and functional opportunities for stretch textiles offered by the equipment. Both doctoral projects have resulted in new IP being considered for industry exploitation.

Despite different research contexts for the technology both have a background in traditional textile design; Goldsworthy in printed textiles and Paine in knit, and have adopted practice-led approaches that reflect these specific skills and experiences.

This paper will outline their collective insights through working with laser welding during their doctoral practice, illustrated with specific examples of their experiences of developing a craft practice using a digitally driven and lab-based technology. In particular, their approaches to overcoming the manifold barriers created by the nature of the process are explored and discussed in order to demonstrate the benefits of a craft approach in the development of such emerging technologies.

A Brief History of Laser Welding Technology (Transmission Laser welding)

Laser welding of textiles was first developed at TWI during the mid 1990s. The process was first demonstrated to join plastic materials and could only be applied, before TWI's developments, to join materials of a dissimilar colour. The nature of the process relies on the transmittance of the laser through the top material and the absorbance of the laser in a lower material. Dyes in the materials have a direct effect on the transmittance of the laser and TWI developed a laser absorbing dye, which could be placed at the interface of the materials to be joined. This made joining materials of the same colour possible for the first time. TWI has successfully demonstrated feasibility for the technology to be used in various seaming applications as varied as clothing, furniture, medical devices and airships. Seams, in some cases, have exceeded strengths achieved using traditional stitched seam methods. Other benefits offered by the technology over alternative methods include increased manufacturing speed, an ability to produce waterproof seams in a one-step process and an almost invisible appearance on the outer surface of the material.

New Applications of the Technology Developed by Goldsworthy and Paine

Goldsworthy's doctoral project (2005–2012) first demonstrated potential for new applications of transmission laser welding for textile finishing and creation of composite fabrics by using it as a tool to transform polyester fabrics into varied and complex designs that were monomaterial in composition to enable repeat recycling within a closed loop system. Material limitations and faults in the welding process, such as melted and marked surfaces, that are considered undesirable for welding in other applications, were employed to useful effect in creating these varied decorative finishing techniques.

Helen joined TWI in 2012 to undertake a PhD project to further develop an understanding and capability for this advanced method of joining textiles. Responding to this technology driven brief she chose to take a practice-led approach in pursuit of new opportunities. There was an interest in exploring the aesthetic opportunities enabled by the technology and the research has centred on the development of seaming and surfacing techniques for stretchy fabrics.

Coming from a background in textile design both researchers have developed a familiarity, and preference for, a hands-on and intuitive way of working that is combined with a methodical research approach. Their understanding of the technology has been developed largely by taking a playful and intuitive approach of trial and error; to first gain an understanding of the equipment's established capabilities, but also to seek new opportunities for its development based on a tacit understanding of the materials in use.

> *It is not craft as handcraft that defines contemporary craftsmanship: it is craft as knowledge that empowers a maker to take charge of technology. (Dormer, 1997)*

This paper will discuss the particular barriers of working with the laser welding equipment, which have been identified through the practical investigations of both Goldsworthy and Paine; some of which are specific to the craft practitioner and others that are more generally applicable. Through their joint investigations the researchers have been able to devise solutions to these barriers, some of which are only temporary, but others that could be more influential in the wider development of this emerging technology.

> *Today's quiet revolution of craft is most obviously about technological change: about makers raiding the creative potential of digital technologies for new processes, media and creative strategies. (Press, 2007)*

Image 1

Image 1. Paine operating the laser from the workstation outside of the lab, 2013.

During the researcher's time working with the laser, several barriers and opportunities relating to the new technology were explored. The following sections review the challenges encountered by the researchers and the solutions found. It is divided into three main sections:

- Physical barriers between maker and machine
- System barriers between maker and software
- Material barriers between maker and material

These barriers are described and examples given of solutions that were informed by the particular craft knowledge of the maker during a period of reflective craft practice.

Physical Barriers Between Maker & Machine

This first set of challenges relates to the physical set up of the technology and overcoming an imposed *remoteness* from the tools of making. The challenge facing makers exploring production processes that rely wholly on CAD/CAM is described by Philpott (2010) as a 'removal of the intimacy of touch from the design process'.

Barrier: Remoteness from process

Due to the nature of the process it is necessary for the equipment to be set up in a separate and sealed environment to which the operator can only gain access when the laser is turned off. The computer control workstation is located outside of where the process is controlled and managed, meaning the user needs to view the material through a camera linked to the equipment. Whilst this interface allows the user to see if there is a problem with the equipment itself, it is not possible to see the effect on the material without stopping the machine, going into the room and removing the material from the flatbed. This results in a very *broken* and disjointed process which needs to constantly be stopped and started, with a certain amount of guesswork needed in order to make decisions about the settings and their effects. If the material is completely taken off the machine it would be impossible to replace it without creating a gap in the design.

'In the making process the hand becomes intellectual, enabling the simultaneous creation and analysis of work' (Philpott, 2010). However, in this case the physical distance between the maker and the machine during the process causes a *distancing* not usually experienced during traditional *hands-on* processes. The usual continuous opportunity to oversee or manipulate the material during the manufacturing process is removed. It is true to say that this dependence on the presence of the maker can vary to a greater or lesser degree in traditional making methods; however, there is rarely an occasion when the maker would be completely removed from the activity of transformation to this extent.

Solution: Creating moments of pause for 'reflection in action'

Through a cycle of trial and error with the unfamiliar set up it was discovered that by pausing the equipment during a cycle the researchers could go back into the room and make visual assessments without creating any negative effects on the material. This was not a function that the scientists in the department used during their experiments and therefore had not been originally known to be possible. Although this did not give the full detail that taking the material off the machine would have done, it did at least allow major faults or incorrect settings to be picked up through the protective barrier.

> *If the maker scrutinizes and assess their actions as they make this can advance the practice as they can respond rapidly to insights gained whilst making and amend their actions as necessary. (Philpott, 2013)*

This solution also had a secondary benefit of creating a method for hand-marking the materials through the physical interruption of any program during its cycle.

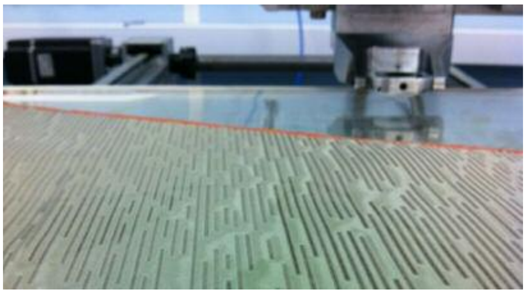

Image 2

Image 3

Image 2. Manually operated marking technique, Goldsworthy, 2011.

Image 3. Lab set up, including laser welding equipment and working area, 2012.

Image 4. Goldsworthy using hand-processes during laser-processing, 2014.

Image 4

Schon (1983) advocates that *good designers* should reflect upon their action both during and after practice in order to move from exploration to 'commitment' as they recognise the implications of each material situation. In working with the laser from outside the lab it was difficult to reflect upon the work during progress. Using the pause button did help to some extent to imitate *normal* working practices which were in so many ways lost working with this unfamiliar set up.

Barrier: Lack of creative space

The spaces themselves are set up very much as a scientific *lab* and not a design studio. This element is usually a vital part of what it means to be a maker – surrounding a space with visual elements and materials in order to analyse and review samples during the process. In practical terms, there was little surface area on which to work and *lay-out* design work for review during the process. This was extremely difficult in such a utility space with no surfaces to work on.

Solution: Creating a temporary studio set-up

Without the space in the lab to pin work up and reflect upon it during the creative process of making, mount boards were used by both researchers as a sort of transportable alternative. Finding ways to mock-up familiar studio environments where possible assisted in getting in to the *zone* for creative work.

Barrier: Removal of the hand & the 'reveal'

This removal of the maker's hand in the process creates a barrier to tactile understanding. The laser works its magic separate from the maker who loses the haptic feedback of working directly with materials. This creates a moment of *reveal* when you remove the materials off the laser once the process is complete and you see for the first time the effect that it had created.

In response to these challenges, the researchers employed various tactics in order to negate the negative impacts of the distancing between themselves and the machine (tool).

Solution: Integration of hand before and after laser processing

The removal of the hand at the point of production does not mean that there were no hand-manipulated processes at all. It was found that by manipulating the materials before, and sometimes after laser processing new and interesting effects could be achieved. Paine found that by stretching out fabrics using an embroidery hoop before they were processed using the laser, fabrics were set into new positions creating a three dimensional surface effect.

Goldsworthy often built up designs in layers, each responding to the previous results. By combining physical manipulation techniques such as pleating, creasing and gathering of particular layers, controllable variation of 3D effects could be achieved.

System barriers between maker & software

The software which runs the robotic axis of the flat-bed system also creates a language barrier between the maker and the tool. The challenge is how these input systems can be navigated and controlled most directly from design to realisation.

Barrier: Unfamiliar 'machine language' driven by coding

The unfamiliarity of the software, a *machine language* driven purely by coding, makes the usually instinctive translation of imagery and line from the hand-drawn to the digital almost impossible. Every movement of the laser head has to be programmed as coordinates, a kind of dot-to-dot process, making anything more complex than a series of repeating lines almost impossible to make. For designers used to using design driven software, such as Adobe, this is an agonising process, and completely counter-intuitive.

> *What is of particular interest is the way in which artists, applied or otherwise, wisely, wilfully, tend to do low-tech things with high tech technology.* *(Harrod, 2007)*

Solution: Integration of familiar craft practices

Both Goldsworthy and Paine relied on tacit knowledge from their own specialism (knit and print) in order to find a solution to this barrier. In particular, using mark-making methods as a way to reveal the programming directly through the laser movement. Paine attached a pen to the laser head and ran existing programs stored in its memory. This enabled the program to be seen *in action* and to produce a physical full-scale *map* of each one for reference.

A second technique involved using black photocopy paper (simply laser-printed black sheets) as a *carbon copy* to reveal where the laser was working by fusing the carbon from the copy onto a clean sheet and thus reveal the movement.

Solution: Creating raster patterns through bypassing the software

As a print designer, Goldsworthy was interested not only in the seaming or stitch-like effects that the laser could produce through vector lines, but an all over patterning or image based finish in order to replicate the desired print based finishes. In order to do this she drew on experience as a print designer and developed

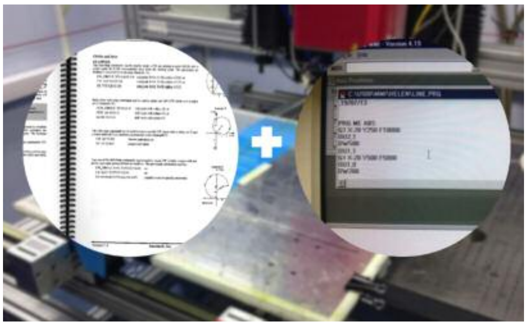

Image 5

Image 5. Overcoming coding barriers, through *hacking* software, Paine, 2014.

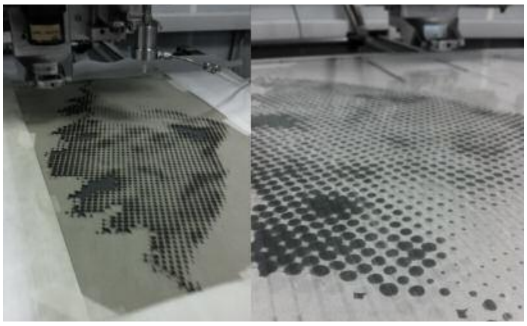

Image 6

Image 6. Overcoming coding barriers through stencilling, Goldsworthy, 2012.

a stencilling process (based on traditional screen-printing methods for all-over surface effects) to mask the laser so that it only effected the desired parts of the material. The more detailed the stencil the more *photographic* the effect. This was a breakthrough in the creation of the number of finishes that could be replicated with a very simple laser-programme. Flocking, devore, gloss-coating, and printing effects could all be replicated, as well as some more complex composite materials if the laser was used to laminate multiple layers together. This was the first time the technology had been used for anything other than seaming, and it opened up a vast array of potential manufacturing opportunities, which could be achieved without the need to change the laser programme during production.

Working with an all-over raster pattern to create surface effects in this way can be a slow process as the laser is focussed to a point that is less than 1cm wide. This has to travel across the whole surface of the material. Goldsworthy devised a system of creating multiple samples at once that explore a variety of processing conditions and material lay-ups. By adopting a systematic and methodical approach to the technology, she was able to maximise her material investigations in a restricted time frame. Once the desired effect had been achieved, laser settings could be adjusted to prioritise the speed of production without negating the material and aesthetic results.

Solution: Copy and pasting bits of existing programs together- hacker mentality

Using visual methods to *map out* the movement of the laser, Paine found it was possible to isolate parts from existing programmes on the system and copy and paste them into new programme files. Hashing various parts of different programmes together it was possible to build new designs without a thorough understanding of all the coding instructions. This process of *borrowing* elements from pre-existing patterns to build your own designs can be compared to the process of designing knitted textile patterns or collage. Working with a range of established stitch patterns new designs can be developed by combining these patterns in different sequences and varying proportions.

Material Barriers Between Maker & Material

Material restrictions are complex and depend on knowledge that cannot be ascertained from information often provided by retailers of textile materials. A detailed understanding of material behaviours was developed through the hands-on experience of reflective practice with the technology.

Barrier: Understanding material limitations

Material suitability for laser welding depends on a number of factors not usually necessary for a maker to consider. It is understood that materials must have a high level of theroplastic content so that they melt when heated. Familiar synthetic textile materials, such as polyester and nylon, can be used for the process; however, it also relies on the material being able to transmit a high proportion of the laser energy. This material property is unlikely to be known even by the manufacturers as it is only relevant for this particular technology. Mostly, all coloured synthetic materials are suitable; however, some additives such as colourants and binders that may not be listed by the manufacturers can be problematic to the process causing unpredictable results that mark the top surface of the material or create undesired effects. Any new materials need to be first tested for suitability before being used even if fibre content is known. The construction, colour, finish and hidden additional materials may also effect its response to the process.

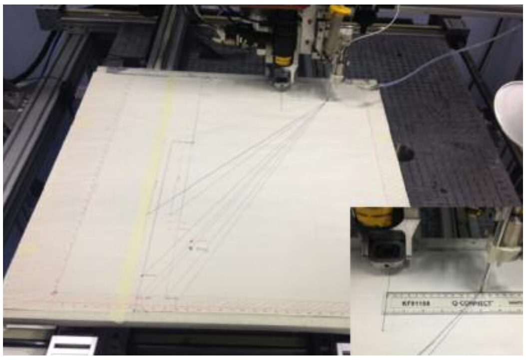

Image 7

Image 8

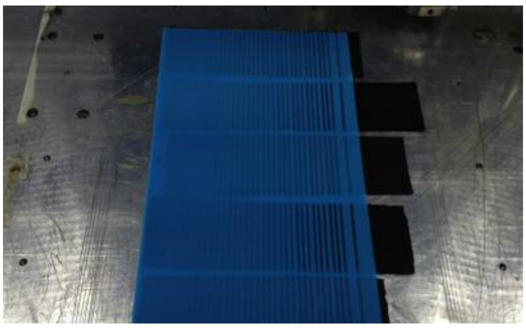

Image 9

Image 7.
Plotting existing software on flat-bed, Paine, 2014.

Image 8.
Material testing and post-sampling reflection, Goldsworthy, 2014.

Image 9.
Exploring settings to increase surface effects, Paine, 2014.

Solution: Using restrictions as an opportunity

For laser welding the top material must be transparent to the laser so that the energy can pass through and form the weld at the material interface. Working from an intuitive craft approach, exploring new visual opportunities for the technology, these material restrictions could sometimes create unplanned surface changes which it might be possible for a designer to exploit to useful effect.

> *Designers are often seen playing around with ideas, tossing up possibilities (proposals) in what may look like a hit and miss process. What they are in fact doing is trying out and thinking through many possibilities, thus building up a repertoire of experiences that help them develop an intuition of what will work in the problematic situation. (Dorst, 2010, p.133)*

At TWI, Paine was shown how to test the transparency of a material to the laser using an energy meter. A 2 J pulse of laser energy is passed through the material and then re-measured on the underside to see how much energy has been absorbed. Any material that absorbs more than 80% of the laser energy will not be suitable for using as the top surface in laser welding. Using this scientific method Paine was able to develop further insight into how transparent a particular material was to the laser. However, in a quest to explore alternative decorative mark-making opportunities the researchers played about with material configuration, exploring the effect of different material lay-ups on the visual quality of the weld. As the investigations in the beginning were not concerned with weld strength there was freedom to explore the visual impact of material lay up without considering the strength of the weld.

Barrier: Process depends heavily on machine parameters and not factors that are controllable by memory through the hand

The laser welding process is controlled by a number of variables that have to be programmed into the machine. Repetition of effects depends on the interrelationship between these variables. Once a new technique has been developed the process, including machine parameters has to be fully documented if effects are to be repeated. Work produced by textile designers, although likely to be dependant on some machine settings, can also be reliant on hand-manipulated processes that cannot be recorded in the same way. Effects are repeated by applying the memory of how they were achieved before. This process is not concerned with remembering specific numerical settings, but more about finding a familiar *feeling* through the hand, which is cast in the memory of the maker from previous experience.

Solution: Adapting record-keeping methods
Pre-preparing methods for recording brought a more systematic framework to the process of making, that was rigorous yet minimally invasive to the intuitive craft approach. This rigorous recording of the making process can disturb the intuitive craft practice through repeated breaks. The intuitive process of making can seem oppositional to the rigorous scientific methods of record keeping required for laser welding. It was therefore necessary to devise techniques for recording that minimised disruption that might disturb creative trains of thought.

With the aim of keeping track of the parameters and processes that were linked to different effects, sketchbooks became more like technical journals. Spec-sheets were pre-prepared ahead of making with spaces for all the relevant variables to be recorded. As each sample was produced it was attached to the relevant spec sheet and immediately stored in a file. Photographs were also used as a way of documenting any parts of the process that were particularly unique or vital to a particular effect. It also became increasingly important to date any work in sketchbooks or notebooks so that textural and photographic records could be connected and reflected upon together retrospectively.

> *The representations of problems and solutions (in words and sketches, sometimes using quite sophisticated visualisation techniques) is important because it allows the designer to develop their ideas in conversation with their representation. (Dorst, 2010, p.133)*

The act of methodically recording results and parameters became part of the creative process and allowed reflection to continue before and after continued experimentation.

Conclusion / Insights
Following the analysis of the examples presented in this paper there were several points considered as useful for further investigation and consideration. Insights from the combined experience of Goldsworthy and Paine in their approach to the technology is summarised below.

Image 10

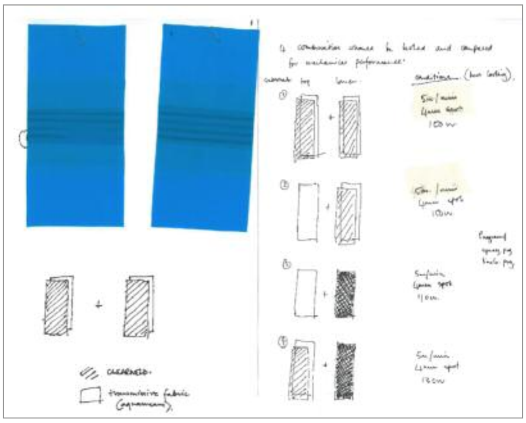

Image 11

Image 10. Sketchbook and technical records, Goldsworthy, 2012.

Image 11. Sketchbook and technical records, Paine, 2014.

- Cheating the technology: Using tacit knowledge from their embedded print and knit craft knowledge in order to find ways to control the system in order to achieve desired results.
- Understanding material behaviour: It is not possible to choose materials for aesthetic and tactile properties alone when using such transformative technologies. The behaviour of fibres under the conditions of the process become the leading feature of the selection process.
- Creating moments of reflection: Digital technologies are not often designed with *experimentation of process* in mind. Designers need to find ways to get closer to the process in action in order to reflect and evolve their practice.
- Embracing new tools and scientific methods: Often new skills borrowed from a scientific field become essential to deepening understanding and developing a new techno-craft approach.
- Developing ways to record and analyse results before, during and after processing: Complex processing parameters including technical, material and craft methods need to be carefully recorded in order to make results repeatable and transferable.

When working with such an unfamiliar production technology, both textile makers used these tactics to control the process and ultimately find new techniques and applications that continue to develop through their current practice.

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Helen Paine *is a Doctoral student funded by TWI and based at the Royal College of Art London. Coming from a background in textile design her research has followed a practice-led approach working closely with industry to seek new functional and aesthetic opportunities for existing advanced joining technologies.*