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Development of Fabric Seaming for Clothing Using Ultrasonic Sealing Technique

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Knowledge generated in this project will be presented in the thesis. Successful techniques will provide an alternative method of manufacturing clothing. This has an environmental effect in that it reduces the significant amount of waste that we produce every year in garment manufacturing. Furthermore, recycling of garments will be easier

because no foreign matter (thread) is introduced into the garment when ultrasonic seaming is used. The research conducted will provide information on advanced textile technology since this project involves recent developments in textile construction.

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DEVELOPMENT OF FABRIC SEAMING FOR CLOTHING USING ULTRASONIC SEALING TECHNIQUE

By

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Professor Subhas Ghosh Ph. D.

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The scope of my thesis was to develop fabric seam using synthetic or a blend of natural and synthetic fabric by an ultrasonic sewing machine. This fabric will be tested for usual seam quality.

The methodology that was used is the utilization of the ultrasonic sewing machine. The intended seam was used to sew polyester and polyester cotton fabric to produce women's blouses. Using the same fabric, traditional seam with needle and thread was prepared. Seam strength and stiffness were measured using ASTM standard methods.

Knowledge generated in this project will be presented in the thesis. Successful techniques will provide an alternative method of manufacturing clothing. This has an environmental effect in that it reduces the significant amount of waste that we produce every year in garment manufacturing. Furthermore, recycling of garments will be easier because no foreign matter (thread) is introduced into the garment when ultrasonic seaming is used. The research conducted will provide information on advanced textile technology since this project involves recent developments in textile construction.

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Introduction

Sewing remains the most common method of joining fabrics in the textile industry today. Industrial 301 Lockstitch machines are used in most factories that produce garments, household goods and other soft materials in spite of perforated seams, thread deterioration, waste and speed limitation. A more recent alternative to sewing is ultrasonic seaming. This innovation can be used on fabrics that contain a significant amount of thermoplastic fibers; at least 60 percent. This technique is less wasteful in that it does not require needles, thread, solvents, adhesives or mechanical fasteners. There is no limitation on speed and there is no need to worry about rethreading a bobbin or replacing a spool of thread. Ultrasonic sewing also conserves more energy and makes recycling simple due to the absence of foreign yarns (Ghosh and Reddy 2009).

Ultrasonic seaming is beneficial in the production of many products as well. Because an impermeable seam is created, clothing worn around a contaminated environment, such as in the medical or science field, shields the person from harm. This impermeable seam is also beneficial in the production of boat sails, parachutes and any other textile material that must endure and defend against strong winds.

This paper describes a study on the benefits of ultrasonic sewing. It also compares and contrasts the advantages and disadvantages of both ultrasonic and traditional sewing. Using tensile strength and seam stiffness machines, both methods will be tested on the same 100% polyester fabric. The results will indicate which method of sewing is not only stronger and more comfortable on a garment, it will also show which method is more environmentally friendly and overall beneficial to the world of garment production.

Literature Review

Ultrasonic is defined as acoustic frequencies above the range audible to the human ear, or above approximately 20,000 hertz. Ultrasonic waves (frequencies) are administered to the fabric from the horn of the FS-90 machine. This frequency generates heat within the fibers at the point of the joint site, causing the polymers to join and form a bond. This application is very valuable to the progression of the textile industry and is more efficient than standard sewing when utilizing synthetic fibers or synthetic blends that contain at least 40% synthetic fibers (Ibar 1998).

FS-90 Information

The Branson Model FS-90 Ultrasonic Fabric Sealing System bonds nonwoven and man-made thermoplastic materials without the use of a needle or thread. Materials are produced at the rates up to 50 surface feet per minute. With modifications, speeds up to 160 feet per minute can be achieved. This unit is a stand-alone system with a 1100-watt power supply (http://www.branson-plasticsjoin.com/pdf/PW-45_FS-90.pdf Date Accessed: 06/10/2009). In order to achieve successful seaming, thermoplastic fabrics, or fabric containing significant amount of thermoplastic materials must be used. 100% synthetics such as nylon, polyester, polypropylene, polyethylene, modified acrylics, some vinyls, urethane, and synthetic blends with up to 40% non-synthetic fiber content have been processed by other investigations (Ghosh and Reddy 2009). Garments that are typically made with the FS-90 include protective garments, disposable hospital gowns, shoe covers, face masks, infants' nursery garments, filters, bags, curtains, sails, and web splicing. Ultrasonic seaming is beneficial in the manufacturing of these items because the sealed edges and seams with no stitch holes provide no penetration by chemicals, liquids, blood-borne pathologens or other particles (Ghosh and Reddy 2009). With sails and parachutes, the seams are impermeable to wind, which creates a strong seam and less chance of hole development. This feature provides a benefit over conventional sewing, which is not impermeable due to stitch holes. Bulk in the seams is also reduced when utilizing the ultrasonic slitting option. This option creates a sealed edge as well as cuts off access fabric.

The sealing horn is what would perform the similar task as a needle on a standard sewing machine. The fabric is placed under the horn and the sealing wheels act as feed dogs, guiding the fabric through the machine.

Figure 1 Branson Model FS-90 Ultrasonic Sealing System (http://www.branson-plasticsjoin.com/pdf/PW-45_FS-90.pdf Date Accessed: 06/10/2009)

Standard Sewing vs. Ultrasonic Seaming

Sewing remains the most popular method of joining fabrics. The lockstitch machine is the standard method used for sewing. A bobbin sits in the middle of the shuttle, which is rotated in synch with the motion of the needle. The needle pulls a loop of thread through the fabric, rises, then reinserts into the fabric. The feed dogs are what move the fabric forward and through the machine. Instead of joining the different loops together as seen in chain stitching, the thread from the machine is joined with a separate spool of thread that is the bobbin. On the machine, a tension wheel is present. The tension must be at the appropriate setting in order for the stitch to form correctly. In a single inch of a seam there are usually 10 stitches per inch.

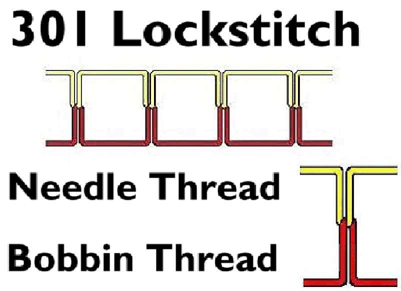

Figure 2 301 Lockstitch. Seam is only as strong as the bottom thread strength, so thread can't be downsized (www.amefird.com.cn/seam_engineering.htm 06/15/2009)

Figure 3 301 Lockstitch sewing machine (www.alibaba.com 06/15/2009)

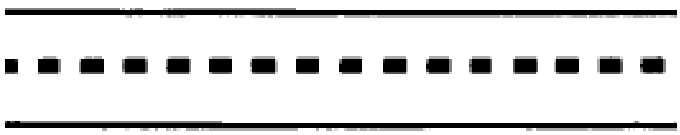

Figure 4 Single stitch pattern (Branson EDP. NO. 101-160-911)

Disadvantages with traditional sewing include discontinuous joints producing perforated seams, sewing thread deteriorating over time, and speed limitations.

Ultrasonic sealing, as defined above, has several advantages for joining fabrics made from thermoplastic polymers or those containing thermoplastic fibers. The FS-90 machine requires no needles. This significantly reduces on waste generated because in traditional sewing, needles frequently break, causing waste. More money is also spent on replacing the needles. The absence of thread in ultrasonic sealing is also extremely beneficial. Because there is no presence of thread in garments that have been welded ultrasonically, there is no threat of thread deterioration over time. A large amount of material and waste is also reduced when thread is not used. This can be very beneficial for the environment, making ultrasonic sealing a 'green' technology. The technique also requires no solvents, adhesives or mechanical fasteners when joining two fabrics together. Ultrasonic sealing differs from thermal bonding in the sense that fiber degradation is minimized because heat energy is generated within the fibers using ultrasonic energy (Tolunay, Dawson et al. 1983; Mao and Goswami 1997). In thermal bonding, the heat energy is applied to the fibers in order to melt them. Seams created with ultrasonic sealing are impermeable, making the garments produced ideal for medical clothing that can be worn around contamination, parachutes and other products, such as boat sails that must have impermeable seams in order to function (Benatar and Gutowski 1986; Benatar and Gutowski 1989). Ultrasonic sealing of non-woven thermoplastic fibers is based on the ultrasonic welding of metal that was first discovered in the 1960's. Although the materials joined are different, the same mechanisms of operation exist to create a bond.

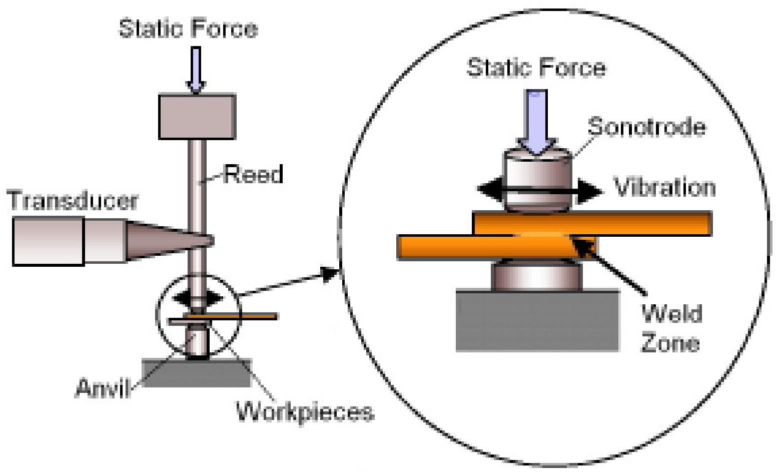

Figure 5 Overview of the workings of ultrasonic welding (Wright, Prangnell et al. 2009)

The process of ultrasonic welding involves 4 key components. The power supply converts a standard electrical signal into an ultrasonic frequency, usually of the order of 20 kHz. A transducer converts the electrical energy into mechanical vibratory energy, which is amplified and transmitted to the workpiece by a sonotrode. When a joint is made, a clamping force combined with vibration cause a localized heating affect at the interface of the 2 materials and a bond forms (Benatar and Gutowski 1986; Benatar and Gutowski 1989; Wright, Prangnell et al. 2009). The absence of heating elements, or the need for cooling and extremely low tooling costs make this process very cost effective when compared to other joining methods.

Experimental Methods and Results

Test Specimens

The specimens used in this thesis were synthetic material (PET). There are several advantages of synthetics. They are not exposed to the hazards of agriculture, such as extreme weather conditions, pesticides, disease and infestation. Therefore, they are produced indoor, year-round, thus creating more fabric. The manufacturing of synthetic fibers also benefits the Earth because pastures and other large pieces of land are not taken over for the development of the fibers. Because they are manufactured in a secure setting, they can be made to any length; staple or filament. The texture can be altered from smooth to coarse, as well as thickness alteration.

Synthetic fabrics are utilized in ultrasonic sewing because they have thermoplastic properties that allow them to soften and bond when subjected to ultrasonic energy. Fibers such as nylon and polyester are commonly used. Nylon is a good fiber choice due to its outstanding properties. It is a strong major fiber; it gives when stretch and has outstanding abrasion resistance. One disadvantage with nylon is that when it pills the balls of fibers cannot simply be brushed off. They must be cut off with a sharp blade. Polyester (PET) is the most-used synthetic fiber overall. PET stands for polyethylene terephthalate, which is the result of reacting and then polymerizing ethylene glycol and terephthalic acid. Polyester has similar properties to those of nylon. It has strength and abrasion resistance and takes a permanent heat set. It does not stretch as well as nylon, but it does remove moisture way from the skin better by wicking, dries faster, and is suppler in cold conditions.

The particular fabric that I have chosen for this study is 100% polyester (PET). The most common polyester is a PET fiber. This fiber is the same polymer used for many soft drink bottles and can also be recycled. PET is made by reacting ethylene glycol with either terephthalic acid or methyl ester of it in the presence of an antimony catalyst (www.fibersource.com/f-tutor/polyester 2008). Characteristics of polyester include strength, resistance to shrinkage and stretching, quick drying, resistance to chemicals, wrinkle and mildew resistant, washable and abrasion resistant, meaning the fabric can be abraded against another surface and never lose it's characteristics. Polyester also retains heat-set pleats.

Methods

Two types of tests were conducted utilizing traditional sewing and ultrasonic sealing. The first test that is conducted is the tensile strength test. The MTS Synergie 200 machine is used to test tensile strength and compression. The amount of force exerted on the fabric before it's breaking point is measured in Newtons or KiloNewtons. The breaking strength of all materials tested must not exceed 500 N to 5kN. The maximum load range on the Synergie 200 is 200 pounds or 1 kN. Sample pieces are cut with a width of 1" and a length of 6". The samples are then individually inserted into the top and bottom clamp. The sample pieces must be taut, but not pulled too tight. Using a computer that the MTS machine runs through, the required data is entered into the computer system and a start button is pressed to exert force onto the fabric, pulling it upward. The machine will automatically stop when the fabric rips or fully breaks. The force is exerted consistently and constantly in order to relate to elongation of the fabric. Once the machine stops, a reading in Newtons or kiloNewtons is provided on the computer. This process is to be completed four times with each sewing type and eight times with the original fabric, sans seams.

The second test conducted is the stiffness test. The Taber V-5 Stiffness Tester evaluates the stiffness and resilient qualities of laminated plastic, cardboard, paper, light metallic sheet, foil and wire. An initial reading called initial stiffness is recorded and a basic stiffness rating is to be obtained by averaging all of the readings together. Initial stiffness is indicated when the opaque line on the pendulum point moves from 0 and aligns with the 15 degree deflection line on the motor driven disc. This is done in the direction to the left and the right. The scale reading opposite the 0 mark is used and is measured in Taber Units. The two readings are averaged together and then multiplied by 0.098067 in order to convert the readings into millinewton meters (mNm).

Results

Using the stiffness test, eight samples of the polyester fabric were tested in order to determine the stiffness of the material.

Table 1 Polyester fabric stiffness results

Specimen	Left	Right	Average (Taber)	Stiffness (mNm)
Fab1	26.5	26	26.25	2.57
Fab2	25	26.5	25.75	2.53
Fab3	26	26	26	2.55
Fab4	26	26	26	2.55
Fab5	26	26.5	26.25	2.57
Fab6	26	26	26	2.55
Fab7	26	26	26	2.55
Fab8	26	25.5	25.75	2.53
Mean			**26**	**2.55**

As seen above, the average stiffness of the polyester fabric is 2.55 mNm. The samples were then cut and joined together by ultrasonic seaming and traditional sewing. Four samples of each were tested for stiffness.

Table 2 Traditionally sewn seam stiffness results

Specimen	Left	Right	Average (Taber)	Stiffness (mNm)
Traditional1	27	28	27.5	2.70
Traditional2	27	28	27.5	2.70
Traditional3	27	28	27.5	2.70
Traditional4	26.5	28	27.25	2.67
Mean			**27.4375**	**2.69**

In comparing the fabric before a traditional sewing seam was applied, the strength was 2.55 mNm. After the application of the seam, the strength increased by 0.14 mNm, giving the traditional seam a strength of 2.69 mNm.

Table 3 Ultrasonically welded seam stiffness results

Specimen	Left	Right	Average (Taber)	Stiffness (mNm)
USW1	28	30	29	2.84
USW2	28.5	29.5	29	2.84
USW3	27	30	28.5	2.79
USW4	27	29	28	2.75
Mean			**28.625**	**2.81**

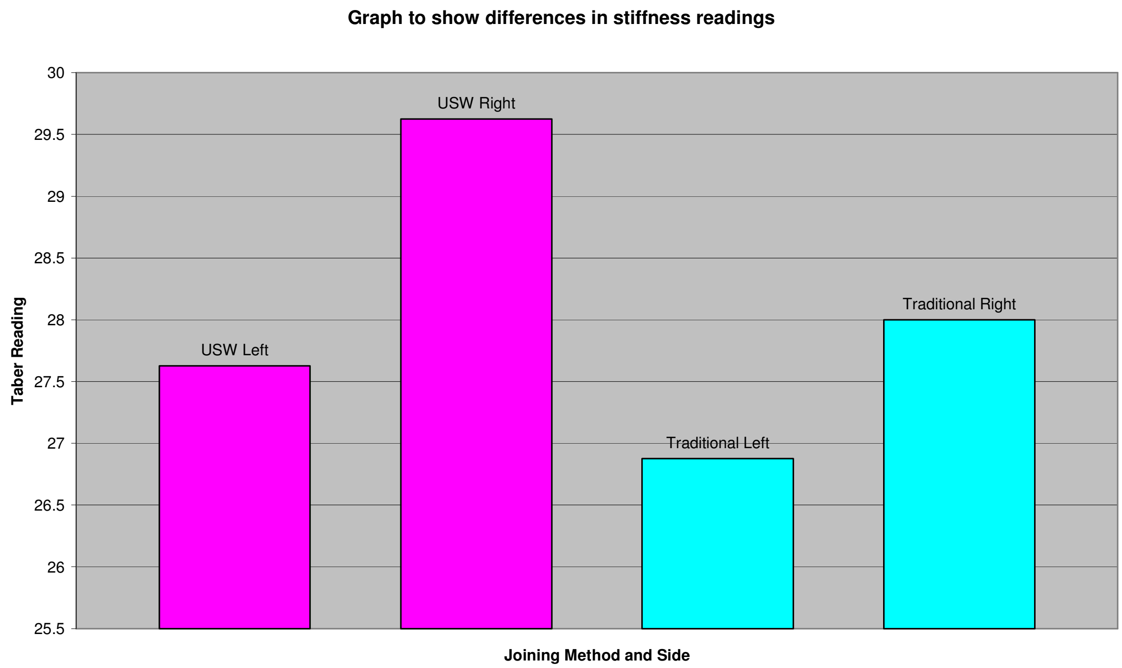

Figure 6 Graph highlighting the differences in readings taken directly from the Taber V-5 Stiffness Tester

Table 4 Tensile results of USW samples

Specimen	Peak Load (lbf)	Peak Stress (ksi)	Strain at Break (%)	Modulus (ksi)
USW1	19.574	0.1	20.335	0.422
USW2	20.394	0.1	22.42	0.418
USW3	20.492	0.1	23.053	0.408
USW4	18.241	0.1	18.607	0.403
USW5	17.307	0.1	18.175	0.403
USW6	17.325	0.1	17.084	0.432
USW7	16.143	0.1	58.446	0.391
USW9	15.267	0.1	45.394	0.366
65amp2	18.161	0.1	16.731	0.442
70amp1	19.955	0.1	19.607	0.435
65amp	22.049	0.1	20.837	0.452
Mean	18.628	0.1	25.51718182	0.415636364

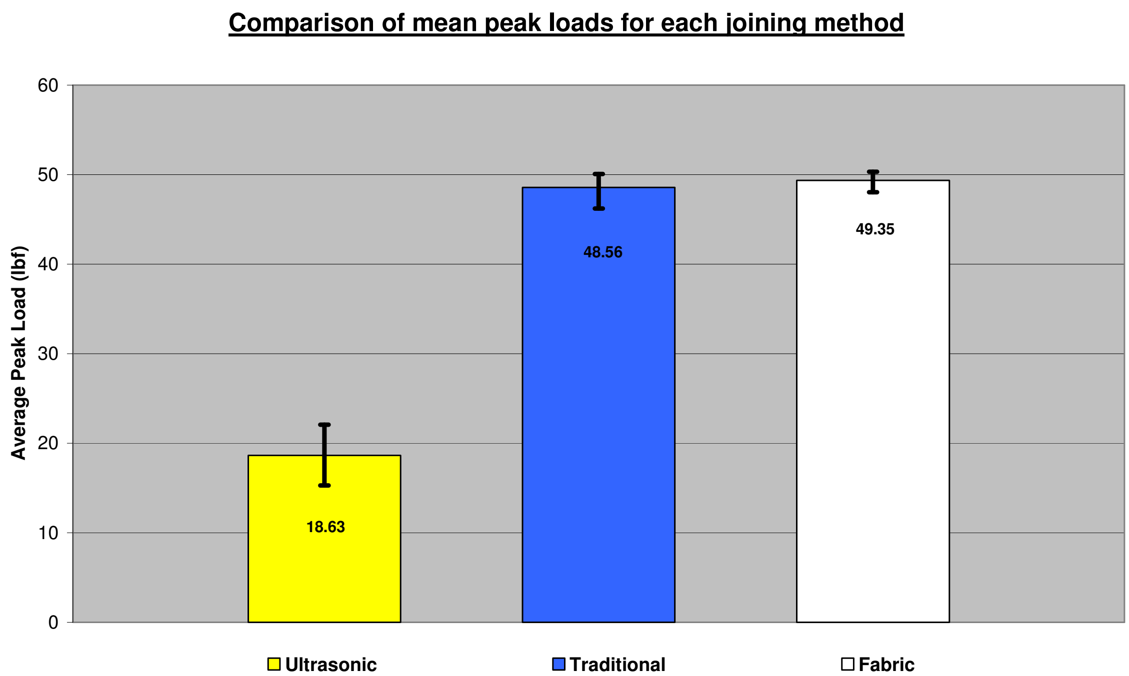

Figure 7 Comparison of mean peak loads for each joining method

Analysis and Conclusion

Strength Comparison

The strength results show the ultrasonic seams to be significantly lower in mean strength than the traditional alternative. The traditional seam has a mean strength 62% higher than ultrasonic seams. Any applications that are highly dependent on seam strength should not consider an ultrasonic method using this material, without further modification. There is also greater variation in the strengths generated by ultrasonic seams than other methods. The traditional sewing method strength is very close to the fabric in its natural condition and is a very positive result.

The results for stiffness show the ultrasonic seams to be stiffer by 4.3% when compared to the traditional seams. There is also a large degree of variation between the Taber stiffness's recorded on the right and left side of the seam. This could be explained by the vibrational input direction, which is driven by a one-sided transducer on the top surface. The top side of the material may be more agitated as a result, which could lead to these higher stiffness values on one side. The traditional lockstitch sewing method involves a different thread pattern between the top and bottom material that could account for the difference in stiffness between the right and left. However, the difference in pattern is not a substantial as the differences seen in ultrasonic seaming, given rise to the results seen above. As Ghosh and Reddy (Ghosh and Reddy 2009) shown that through parameter manipulation and addition of a thermoplastic ribbon at the location of the seam formation, the strength of the ultrasonic seam can be increased significantly.

Environmental Impact

The ultrasonic seaming method has a very low environmental impact compared to other fabric joining methods. The input energy levels are extremely low, and there is no need for any service supplies into the machine other than electrical power. The tool life is very high compared to other methods, which means better production times and lower tooling costs. There are also no consumables, which gives a process with zero wastage. A traditional sewing method by contrast has high consumable costs, due to the thread used in joining the material. There is also wastage associated with re-threading a machine, and this also contributes down time in an industrial situation, which costs a company money all the time a machine is stopped. This problem is not associated with ultrasonic joining methods.

Conclusion

The low strength shown by ultrasonic seaming makes it unsuitable for applications requiring high strength seams. The high stiffness that ultrasonic seams produce is also undesirable for many clothing applications although may be good for sporting goods, and sails. The latest swim suit technology uses ultrasonic joining methods to bond the different panels in a seamless way. Other possible applications could involve anything requiring an impermeable seam, or waterproofing. One question that still remains with ultrasonic seaming is strengths vary with the fabric being joined. Different polymers, and nylon contents may have different strengths. This remains an interesting area of further research, and one that could develop the findings of this report.

The traditional seam produces high strength, and low stiffness which makes it ideal for most common clothing applications. It is still the best overall method for joining garments, although it is still expensive compared to ultrasonic seaming. Further work would be helpful to asses the economic benefits of ultrasonic seaming compared to traditional joining methods.

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