Analyzing the Feasibility of Applying Ultrasonic Bonding in Basic T-Shirt Manufacturing

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I. INTRODUCTION

Ultrasonic bonding is a technique used to join synthetic and synthetic blends together. In ultrasonic bonding, normal-frequency electric power is converted into high-frequency electric power, which falls into the ultrasonic frequency range of 20- 40kHz [1]. The materials to be joined by ultrasonic bonding must be 100% synthetic or blend up to 60% synthetic materials[2]. Ultrasonic bonding was initially used in plastic welding and now has expanded its applications into the automotive, filtration, electronics, electrical, packaging, and apparel industries[3].

Traditional sewing methods are widely used in the apparel industry to combine fabric pieces. In traditional sewing, the needle penetrates through the fabric to create the stitches. Therefore, punch holes can be seen in sewn fabrics, and the seams are not continuous. Also, there are issues like thread unraveling, thread deterioration, thread breakage, and difficulties in matching the thread to the fabric's color. Though there are many benefits, ultrasonic seaming is not very popular in the apparel industry due to the lower tensile properties of ultrasonic bonded seams [2].

Currently, there are many published works on ultrasonic bonding of non-woven and how tensile properties vary when ultrasonic bonding parameters. However, only a few published works on ultrasonic bonding of woven and knitted fabrics are available. Though the researchers have considered the tensile properties of ultrasonic-bonded seams, they have not explored the possibility of replacing ultrasonic bonding for seams in garments. Therefore, this research is to discover possible areas in garments where ultrasonic bonding can be used to gain advantages of ultrasonic bonding, eliminating the issues in traditional sewing. This research focuses on how ultrasonic bonding can be used in different areas of a basic T-shirt and the possibility of making 100% Ultrasonic bonded T-shirts.

II. LITERATURE REVIEW

In Ultrasonic bonding the vibration is passed through the thermoplastic material surface to generate frictional heat at the interface to obtain sufficient temperature to melt the thermoplastic materials and bond them together. Ultrasonic bonding starts at the interface because the heat is generated at the interface. To apply the high-frequency vibration, the materials to be joined are fed in between a moving wheel and a vibrating ultrasonic horn [1].

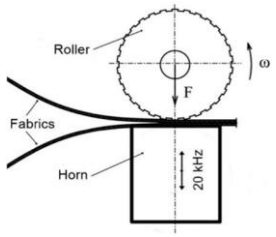

Fig 1. Schematic diagram of ultrasonic bonding
Adapted from [5]

Initially, ultrasonic bonding was used for plastic welding [6]. Ultrasonic bonding technology is currently used in many industries, such as the automotive industry, medical industry, covering and packaging, and filtration industry[4]. Also, at present, experiments are being done to find the feasibility of replacing sewing with ultrasonic bonding. Though ultrasonic bonding has not yet replaced sewing, some applications are being made using ultrasonic bonding in the textile and apparel industry. Ultrasonic bonding is used for cutting edges (mainly lace and elastic cutting), slitting and trimming fabrics, quilting, and embossing. Using ultrasonic bonding for these processes can avoid the need for materials such as glue, clips, and scissors. Also, most importantly, there will be a considerable time reduction due to the quick and easy process. Also, due to the impermeable nature of the seams

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created by ultrasonic bonding, ultrasonic bonding is used in medical clothing to protect from contamination and also in products like parachutes, sailboats which require impermeable seams to function [3]

In the 1970s, ultrasonic bonding technology evolved. The invention of Branson's ultrasonic sewing machine took place in the 1970s, and this was a revolutionary point in joining fabrics without using needles and threads [4]

A. *Advantages and disadvantages of ultrasonic bonding over traditional sewing*

Traditional sewing requires a needle and a thread. When using the needle, there will be needle punches in the fabric. These needle punches are eliminated in ultrasonic bonding. Also, problems related to thread unmatching, thread unraveling, and thread breakages are eliminated in ultrasonic bonding [6]. Unlike in traditional sewing, there is no need to replace the bobbing or threads and no speed limitation [3]. Unlike in thermal bonding, fiber degradation is minimized in ultrasonic bonding because heat is generated at the joining site [6].

Ultrasonic bonding techniques is economical because no additional materials are used, and also as well as the recycling process of ultrasonic-bonded fabrics will be easy due to the absence of foreign yarns [2]. Also, impermeable seams make ultrasonic bonding suitable for functional uses such as parachutes and medical clothing [3].

The disadvantage of ultrasonic bonding is that the seam tensile properties are not up to the desired level. This limits the applications of ultrasonic bonding the textile and apparel industry [4].

B. *Ultrasonic bonding machine*

Ultrasonic bonding machines mainly consist of a welding horn, convertor, stepped horn, and roller [5].

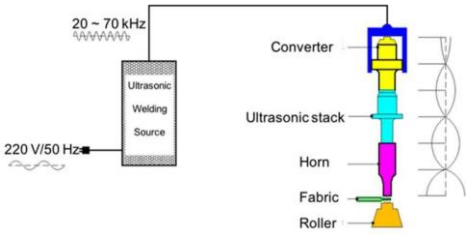

Fig 2. A schematic diagram of a common ultrasonic bonding machine
Adapted from [5]

In an ultrasonic bonding machine, the horn performs a role similar to that of the needle in a traditional sewing machine. The sealing wheels perform a role similar to the role of a feed dog in the traditional sewing machine [3]

C. *Factors affecting ultrasonic bonding.*

The main process variables of ultrasonic bonding are,

- Amplitude
- Pressure
- Time

Other than these three main parameters, there are some other factors affecting ultrasonic bonding, such as roller profile, weld area, and fiber type.

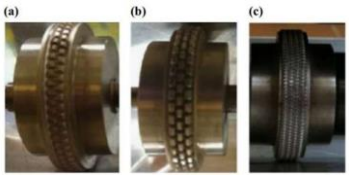

Fig 3. Roller profiles with two, three, four rows
Adapted from [2]

As per the previous studies, when the number of rows increases, the strength also increases. When comparing the above three rollers, roller (a) has 2 rows, roller (b) has three rows, and roller (c) has four rows. Roller (c) with the highest number of rows gave the highest seam strength [2].

III. MATERIALS AND METHODS

A. *Phase 1*

In a T-shirt, there are straight and curved seams.

- Straight seams – Side seams, shoulder seams, bottom hem
- Curved seams – Armhole, neckline

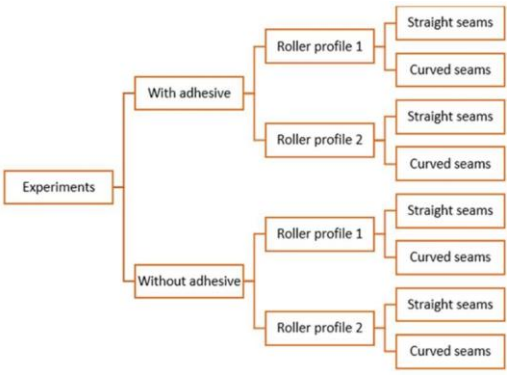

Fig 4. Experimental process

In this research, straight and curved ultrasonic bonding without adhesive and with adhesive tape was done using the optimum bonding parameters for both roller profile 1 and roller profile 2.

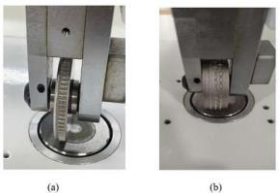

Fig 5. (a) Roller Profile 1 (b) Roller Profile 2

75% Nylon and 25% Spandex interlock fabric having a of GSM 240 was selected and below parameters were used.

- Pressure – 0.25 MPa
- Frequency – 35.09 kHz
- Speed – 1000 mm/min

B. Phase 2

Then, based on the results of phase 1 the roller profile with the highest seam strength (Roller profile 2) was selected, and four different variations of garments were made with different ultrasonic seam combinations.

TABLE I GARMENT VARIATIONS

Seam	with/without adhesive (Variation 1)	with/without adhesive (Variation 2)	with/without adhesive (Variation 3)	with/without adhesive (Variation 4)
Side seam	without	with	without	with
Shoulder seam	without	with	without	with
Armhole seam	without	with	with	without

IV. Results and Discussion

A. Phase 1

As per the results of the phase 1, the roller profile 2 with the highest seam strength values for both with adhesive and without adhesive scenarios was selected to continue with the phase 2.

TABLE II PHASE 1 RESULTS

Sample	Without adhesive		With adhesive	
	Straight	Curved	Straight	Curved
Average	144.31 N	90.15 N	207.69 N	173.64 N

B. Phase 2

Seams were not broken in any garment variation after wash. Curved seams without adhesive tape had small openings in the seams and the straight seams without adhesive tape did not had such openings. The curved seams with adhesive tape had a wrinkled appearance after washing.

After analyzing the appearance seam strength values after wash measured. The seam strength was lowered after washing, but the drop was considerably low.

V. Conclusion

When comparing the roller profile designs it was proven that the roller profile2 with horizontal bricked shape design gave the highest seam strength in both with adhesive and without adhesive scenarios. And the roller profile 2 was selected to continue with phase 2

As per the phase 2 results it was clear that the seam strength of ultrasonic bonded seams were slightly dropped after washing. When comparing the appearance none of the ultrasonic bonded seams were broken. But curved seams without adhesive tapes had slight openings in the seam and curved seams with adhesive tape had a wrinkled appearance in the tape after wash. The straight seams did not had considerable openings and a wrinkled appearance was not visible.

When analyzing the results garment Variation 3 (When the armhole seams secured with adhesive tape) gave the best results when comparing both quality wise and cost wise. Therefore, in conclusion it was proved that ultrasonically bonded t-shirts can be made. But the curved seams should be protected by using adhesive tapes.

References

[1] W. Shi and T. Little, “Mechanisms of ultrasonic joining of textile materials,” *Int. J. Cloth. Sci. Technol.*, vol. 12, no. 5, pp. 331–350, Dec. 2000, doi: 10.1108/09556220010377869.

[2] M. Kayar, S. I. Mistik, and D. Inan, “Analysing effect of the factors on ultrasonic seam tensile properties of nonwoven fabrics by Nested Anova Design,” *Int. J. Cloth. Sci. Technol.*, vol. 27, no. 6, pp. 803–817, Nov. 2015, doi: 10.1108/IJCST-05-2014-0066.

[3] C. K. Appleby, “Development of Fabric Seaming for Clothing Using Ultrasonic Sealing Technique”.

[4] M. Kayar, “Analysis of Ultrasonic Seam Tensile Properties of Thermal Bonded Nonwoven Fabrics,” *J. Eng. Fibers Fabr.*, vol. 9, no. 3, p. 155892501400900, Sep. 2014, doi: 10.1177/155892501400900302.

[5] T. Nguyen, L. Q. Thanh, N. H. Loc, M. N. Huu, and A. Nguyen Van, “Effects of Different Roller Profiles on the Microstructure and Peel Strength of the Ultrasonic Welding Joints of Nonwoven Fabrics,” *Appl. Sci.*, vol. 10, no. 12, p. 4101, Jun. 2020, doi: 10.3390/app10124101.

[6] N. Seram and D. Cabon, “Investigating the possibility of constructing different seam types for clothing using ultrasonic,” *Int. J. Cloth. Sci. Technol.*, vol. 25, no. 2, pp. 90–98, May 2013, doi: 10.1108/09556221311298583.