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Evaluation strength of ultrasonic sewing with two rollers and comparison with traditional sewing

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Abstract: In recent years ultrasonic seaming that is shown as an alternative method to conventional seaming has been investigated by many researchers. The scope of my thesis was to develop fabric seam using 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 polyamide fabric to produce Sportswear Using the same fabric, traditional seam with needle and thread was prezared. Seam strength, sewing elongation and appearance 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.

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1. Introduction

Apparel industry enhancing the added value of products is one of the sectors which have major importance. Various seaming methods are used in conversion into final product of different fabric surfaces produced by different methods. However, seaming process of some types of textile products which requires functional specifications is in need of alternative seaming methods besides conventional seaming methods. One of these alternative methods is ultrasonic seaming which have been used for almost 20 years (Boz and Erdoğan, 2011; Porav, 2013). Ultrasonic sewing also conserves more energy and makes recycling simple due to the absence of foreign yarn (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.

The ability of textiles to be welded ultrasonically depends on their thermoplastic content. The joint fabrics must have a minimum of 65% (Shishoo, 2012) thermoplastic content, which melts under mechanical vibration to a degree, enabling to join the textile components under determined pressure. In particular cases, the natural fabrics can also be welded using a hot melt adhesive film placed between layers before welding. (Shishoo, 2012)

The quality of welded joints depends on the composition of the work piece, the shape and type of a joint, as well as on welding parameters in all welding techniques (Jakubcˇioniene and Masteikaite, 2010; Eryu¨ru¨k et al 2014) There are a few studies in the literature related to ultrasonic welding of textiles (Popp, 2010) reported that parameters such as clamping force, vibration amplitude, and velocity of ultrasonic welding sonotrode directly influence the quality of the finished product (Vujasinovic et al., 2007). Analyzed ultrasonic sailcloth bonding as an alternative to classic sewing using an anvil wheel with appropriate engraving and optimal welding parameters such as speed and amplitude.

Also Hayes et al. (2007), compared ultrasonically welded seams, sewn and sewn/tape-sealed seams used for waterproof polyester fabric. The sewn/tape-sealed seam was found to withstand a higher load than the welded seam, probably because of the double mechanism of the sewn seam and tape in maintaining seam integrity. The sewn and tape-sealed seam had a longer bending length than the welded seam, making it less flexible. Welded seams were found to have a greater load-carrying capacity than sewn seams. Developed ultrasonic welding technology for the smart seams by incorporating optic fibers in military uniforms and examined the effects of ultrasonic welding pressure, welding time, and amplitude of vibration on the joint strength (Shi and Little, 2000)

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.

Context of the problem:

The research problem can be formulated through the following questions:

- What is the possibility of benefiting from ultrasonic sewing in enriching the functional aspect of clothing?
- How does ultrasonic sewing affect industrial materials?
- Is it possible to dispense with traditional sewing and replace it with ultrasonic knitting?

Research objectives:

The research aims mainly to know the ways to benefit from ultrasonic sewing to woven materials, through the following sub-goals;

1. Utilizing ultrasonic sewing to increase the efficiency and quality of garments with synthetic materials.
2. Showing the functional aspect of using ultrasound in clothes with industrial materials.

Information

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).

It is an important tool for sealing, welding, bonding, cutting and slitting without heat, adhesive or consumables. It has been utilized in automotive, electronics and electrical appliances, filtration, packaging, aerospace and apparel industries. Ultrasonic technology, even though initially used for plastic welding, at present is identified as an alternative method of seaming waterproof, breathable synthetic materials only for Straight seams in outdoor apparels, (www.sonobondultrasonics.com) One of the early uses of ultrasonic bonding in textiles was in the manufacturing of mattress pads and bedspreads, known as the Pin sonic process.(Flood, 1989), The first main fiber and fabric assembly application of this technology was performed in 1970s. Invention of Branson ultrasonic sewing machine was revolutionary in 1970s for the sewing of the fabrics without needle and yarn (Branson, 2014).

Kuttruff (1991) investigated the mechanism of the ultrasonic welding in 1991. A similar research was repeated by Abramov (1994). Material properties and material content of the ultrasonic sewing applications and ultrasonic sewing mechanism were investigated by Kuttruff (1994). Factors which effect the ultrasonic welding strength and placement of the optic fibers into the fabrics by using ultrasonic welding were investigated by Shi and Little (2000).

Several researchers have studied on ultrasonic welding technique focused on understanding the heating, welding time, welding force, welding pressure and bonding mechanisms and the effects of welding parameters on bond strength (Frankel and Wang, 1980).

A real image and a schematic diagram of ultrasonic welding equipment for bonding fabrics are shown in Figures 1 and 2. Generally, this equipment consists of a welding source, a stepped horn, an ultrasonic stack, a roller, and fabric (base material) Figure 1.

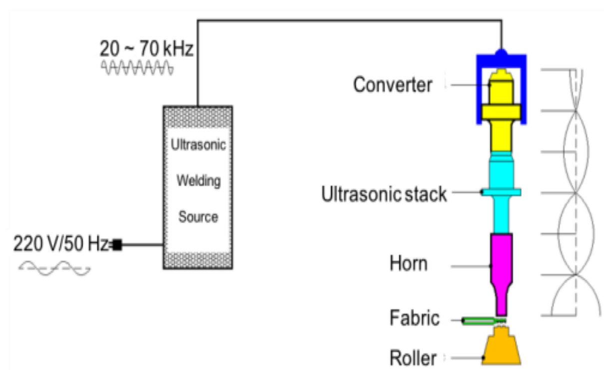
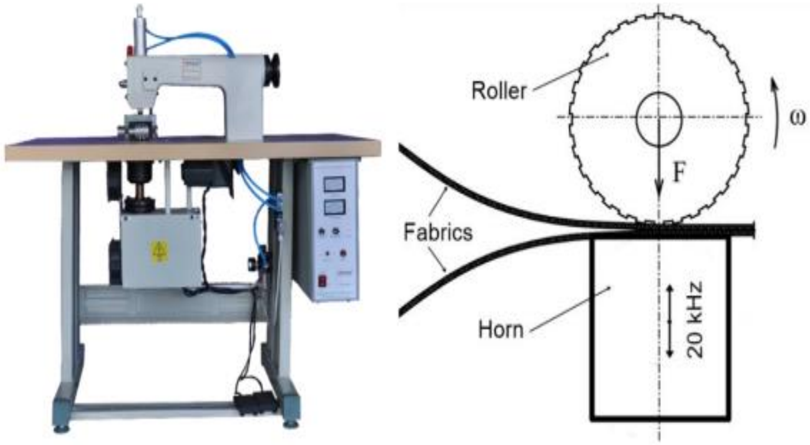


Figure 1) A schematic diagram of a common ultrasonic welding equipment (Nguyen, et al., 2020).



(a) Ultrasonic welding machine (b) Schematic diagram of ultrasonic welding

Figure 2. Ultrasonic welding equipment and schematic diagram. (a) Ultrasonic welding machine, (b) Schematic diagram of ultrasonic welding (Nguyen et al., 2020).

According to Devine (1994) there are advantages over traditional sewing since it eliminates needle punches and problems related to thread breakages and color matching and thread un-raveling and no threat of thread deterioration over time. As Flood (1989) notes fiber degradation is minimized because heat energy is generated within the fibers using ultrasonic energy at the point of the joint site, unlike thermal bonding where heat energy is conducted through the fibers to melt them. Moreover, 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 as Ghosh and Reddy (2009) believe (Figure 3,4)

(Figure3) Ultrasonic sewing machine parts

(Figure4) roller Ultrasonic sewing

Synthetic fabrics are utilized in ultrasonic sewing because they have thermoplastic properties that allow them to soften and bond when subjected to ultrasonic energy. The materials suitable for processing with the ultrasonic technology are already identified as 100 percent synthetics such as nylon, polyester, polypropylene, polyethylene, modified acrylics, acetates, spandex and some poly vinyl chlorides (PVC) and synthetic blends up to 40 percent non synthetic fibre contents (Devine, 1994). Therefore, the polyamide material was chosen to conduct the experiments of the current study on it .

When we look at the studies related to ultrasonic sewing, several researchers studied on welding parameters of ultrasonic sewing but very limited studies were performed on assembling of woven fabrics with ultrasonic sewing. Therefore effect of production methods of woven fabrics on the properties of ultrasonic sewing such as seam strength, appearance and elongation should be investigated.

2. Material and Method

In this study, conventional seam and ultrasonic seam were applied On polyamide material with three different weights, Applying conventional seam on the material 'over 4" and use two types of ultrasonic seams, Then, a comparison was made between conventional seam and ultrasonic seam by measuring the tensile strength of the seaming, elongation and the appearance of the seam, In the end, appropriate statistical treatments are conducted to find out the best raw material and the best quality of seaming.

The properties of fabrics and the seam parameters are characteristic in Table (1).

Table (1): It shows the specifications of the material used in the research

Fabric code	Weight in grams per square meter (g/m²)	Thickness (mm)	Raw material	Seam type	Roller/ velocity code	Sewn fabric code
F1	130	0.4	Polyamid	Ultrasonic seam	R1v1	F1r1v1
F1	130	0.4	Polyamid	Ultrasonic seam	R1v2	F1r1v2
F1	130	0.4	Polyamid	Ultrasonic seam	R2V1	F1r2v1
F1	130	0.4	Polyamid	Ultrasonic seam	R2V2	F1r2v2
F2	250	0.9	Polyamid	Ultrasonic seam	R1v1	F2r1v1
F2	250	0.9	Polyamid	Ultrasonic seam	R1v2	F2r1v2
F2	250	0.9	Polyamid	Ultrasonic seam	R2v1	F2r2v1
F2	250	0.9	Polyamid	Ultrasonic seam	R2v2	F2r2v2
F1	130	0.4	Polyamid	Convention seam	Over4	F1O1
F2	250	0.9	Polyamid	Convention seam	Over4	F3O2

Fabric samples were prepared along the warp directionو Ultrasonic seam process was performed by using HS-WL20 ultrasonic sewing machine as shown in Figure 5. Amplitude of the machine was 100% during the sewing process. Two different speeds were performed as 25 dm/min (v1) and 45 dm/min (v2), Two rollers were used HS-WL20R that across 4 mm (r1) and 12 mm (r2) which have the different pattern as shown in Figure 6, Conventional seam process was performed to woven fabrics by using overlock (O) Juki MO-6700, four-thread overlock machine as shown in Figure (7), Stitch length was 2 stitches/cm.

Figure(5): Ultrasonic sewing machine

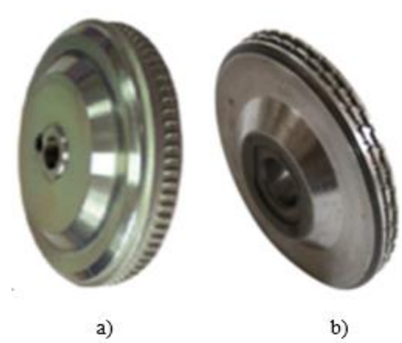


Figure (6): a) Roller r1 b) Roller r2.

Figure (7): Overlock machine

10 samples were prepared according to the specifications of the initial samples that were placed so that the sample is two layers of size 50 * 50 cm and sewn from one direction Some of the samples were sewn on an ultrasonic sewing machine at two speeds and by means of two rollers, and the rest of the samples were sewn on an overlock machine.

All of the sewn fabrics were tested for tensile strength and sewing appearance, seam strength test was performed according to the specification ASTMD5035-19995,sewing elongation according to the specification ASTMD5035-19995 As for the appearance, it was presented to the specialists in the field of ready-made garments to evaluate the appearance with numbers from 1:10 to take the highest degree in appearance No 10 and The lowest appearance score takes a No 1

Results:

Using the test of seam strength, elongation and appearance of sewing, the test was carried out for 10 samples of polyamide material to determine the seam strength and appearance which is higher in relation to ultrasonic sewing or traditional sewing.

Table 2 Results of tensile strength of polyamide

Fabric code	Weight in grams per square meter (g/m²)	Sewn fabric code	seam strength (kg/m)
F1	130	F1r1v1	45.35
F1	130	F1r1v2	72.11
F1	130	F1r2v1	85.41
F1	130	F1r2v2	99.01
F2	250	F2r1v1	50.7
F2	250	F2r1v2	23.57
F2	250	F2r2v1	66.58
F2	250	F2r2v2	27.28
F1	130	F1O1	40.58
F2	250	F3O2	39.51

Table 3 Results of sewing elongation of polyamide

Fabric code	Weight in grams per square meter (g/m²)	Sewn fabric code	sewing elongation %
F1	130	F1r1v1	125.25
F1	130	F1r1v2	127.34
F1	130	F1r2v1	128.64
F1	130	F1r2v2	140.58
F2	250	F2r1v1	85.36
F2	250	F2r1v2	64.25
F2	250	F2r2v1	90.65
F2	250	F2r2v2	89.25
F1	130	F1O1	67.58
F2	250	F3O2	69.12

Table 4 Results of sewing appearance of polyamide

Fabric code	Weight in grams per square meter (g/m²)	Sewn fabric code	sewing Appearance
F1	130	F1r1v1	7.4
F1	130	F1r1v2	6.9
F1	130	F1r2v1	8.2
F1	130	F1r2v2	9.1
F2	250	F2r1v1	6.5
F2	250	F2r1v2	6.01
F2	250	F2r2v1	6.7
F2	250	F2r2v2	7.2
F1	130	F1O1	5.2
F2	250	F3O2	5.6

Analysis and Conclusion

The tensile strength test:

It'is clear from the previous table that there are statistical differences in the tensile strength between (Roller1 & Roller2) for ultrasonic sewing for Roller2 (R2) on a polyamide fabric with light weight of 130 g / m2, and this is evident in the following figure 8.

It'is clear from the previous table that there are statistical differences in the tensile strength between (Roller1 & Roller2) for ultrasonic sewing for Roller2 (R2) on a polyamide fabric with heavy weight of 250 g / m2, and this is evident in the following figure (9).

The Elongation test:

It'is clear from the previous table that there are statistical differences in the sewing elongation between (Roller1 & Roller2) for ultrasonic sewing for Roller2 (R2) on a polyamide fabric with light weight of 130 g / m2, and this is evident in the following figure (10)

Table (5): Differences in the use of "R1 & R2" ultrasonic sewing in the tensile strength test of "polyamide" fabric with light weight of "130" g / m2

Variables		R1		R2		"T" Test	For (N=10)
		Mean	± SD	Mean	± SD		
Speed	**V1**	45.35	1.64	85.41	1.35	21.2*	**R2**
	V2	72.11	1.42	99.01	1.05	19.4*	**R2**

Tabular (T) value at a significant level (0.05) = 1.83

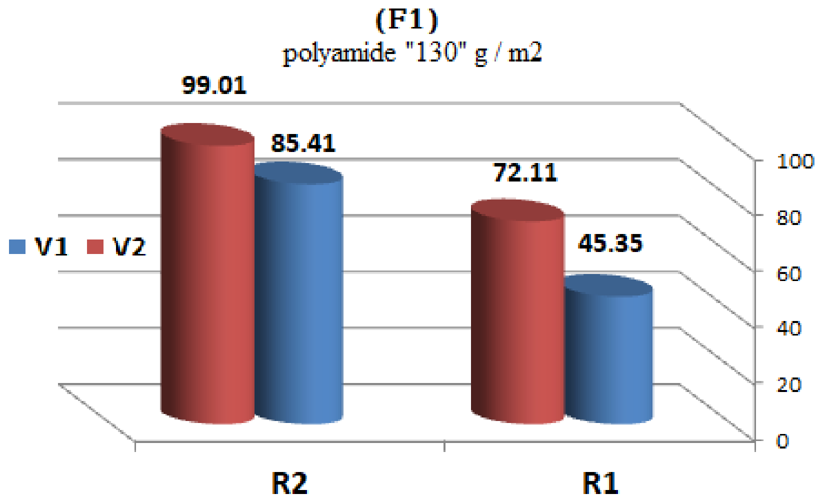


Figure (8): Differences in the use of "R1 & R2" ultrasonic sewing in the tensile strength test of "polyamide" fabric with light weight of "130" g / m2

Table (6): Differences in the use of "R1 & R2" ultrasonic sewing in the tensile strength test of "polyamide" fabric with heavy weight of "250" g / m2

Variables		**R1**		**R2**		**"T" Test**	**For (N=10)**
		Mean	± SD	Mean	± SD		
Speed	**V1**	50.07	3.54	66.58	2.67	11.2*	**R2**
	V2	23.57	2.98	27.28	3.45	2.44*	**R2**

Tabular (T) value at a significant level (0.05) = 1.83

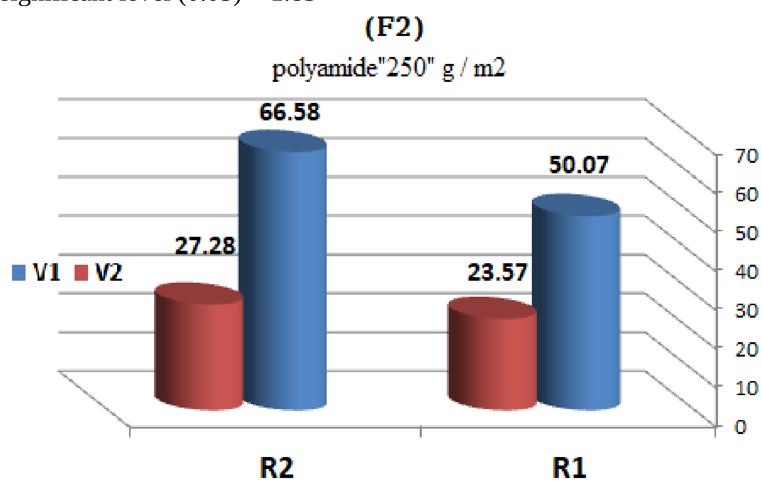


Figure (9): Differences in the use of "R1 & R2" ultrasonic sewing in the tensile strength test of "polyamide" fabric with heavy weight of "250" g / m2

Table (7): Differences in the use of "R1 & R2" ultrasonic sewing in elongation test of "polyamide" fabric with a light weight of "130"g/m2

Variables		**R1**		**R2**		**"T" Test**	**For (N=10)**
		Mean	± SD	Mean	± SD		
Speed	**V1**	125.25	1.65	128.64	1.89	4.05*	**R2**
	V2	127.34	2.84	140.58	3.54	8.75*	**R2**

Tabular (T) value at a significant level (0.05) = 1.83v

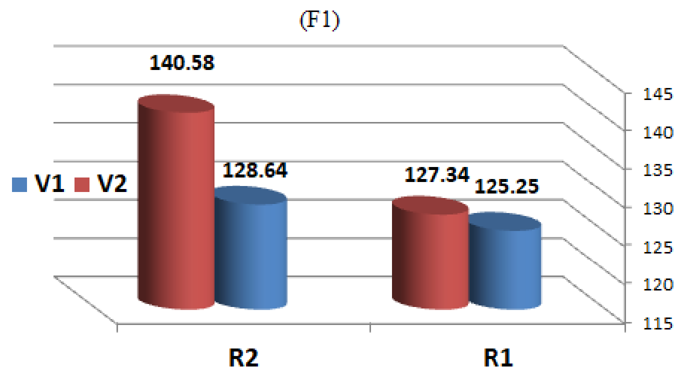


Figure (10): Differences in the use of "R1 & R2" ultrasonic sewing in elongation test of "polyamide" fabric with light weight of "130"g/m2

It'is clear from the previous table that there are statistical differences in the sewing elongation between (Roller1 & Roller2) for ultrasonic sewing for Roller2 (R2) on a polyamide fabric with heavy weight of 250 g / m2, and this is evident in the following figure

Table (8): Differences in the use of "R1 & R2" ultrasonic sewing in elongation test of "polyamide" fabric with heavy weight of "250"g/ m2

Variables		**R1**		**R2**		**"T" Test**	**For (N=10)**
		Mean	± SD	Mean	± SD		
Speed	**V1**	85.36	1.24	90.65	1.28	8.91*	**R2**
	V2	64.25	3.54	89.25	3.95	14.1*	**R2**

Tabular (T) value at a significant level (0.05) = 1.83

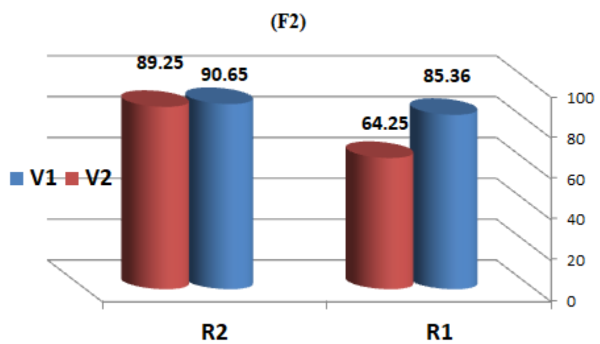


Figure (11): Differences in the use of "R1 & R2" ultrasonic sewing in elongation test of "polyamide" fabric with heavy weight of "250" g / m2

The Appearance test:

It'is clear from the previous table that there are statistical differences in the sewing appearance between (Roller1 & Roller2) for ultrasonic sewing for Roller2 (R2) on a polyamide fabric with light weight of 130 g / m2, and this is evident in the following figure 12

Table (9): Differences in the use of "R1 & R2" ultrasonic sewing in appearance test of "polyamide" fabric with light weight of "130"g /m2

Variables		**R1**		**R2**		**"T" Test**	**For (N=10)**
		Mean	± SD	Mean	± SD		
Speed	**V1**	7.4	1.05	8.2	0.31	2.19*	**R2**
	V2	6.9	0.45	9.1	1.22	5.08*	**R2**

Tabular (T) value at a significant level (0.05) = 1.83

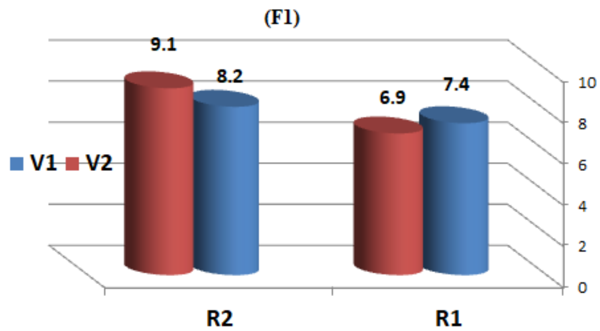


Figure (12): Differences in the use of "R1 & R2" ultrasonic sewing in the appearance test of "polyamide" fabric with light weight of "130" g / m2

It'is clear from the previous table that there are statistical differences in the sewing appearance between (Roller1 & Roller2) for ultrasonic sewing for Roller2 (R2) on a polyamide fabric with heavy weight of 250 g / m2, and this is evident in the following figure 13

Table (10): Differences in the use of "R1 & R2" ultrasonic sewing in the sewing appearance test of "polyamide" fabric with heavy weight of "250" g /m2

Variables		R1		R2		"T" Test	For (N=10)
		Mean	± SD	Mean	± SD		
Speed	**V1**	6.5	0.21	6.7	0.16	2.27*	**R2**
	V2	6.01	0.33	7.2	0.26	8.5*	**R2**

Tabular (T) value at a significant level (0.05) = 1.83

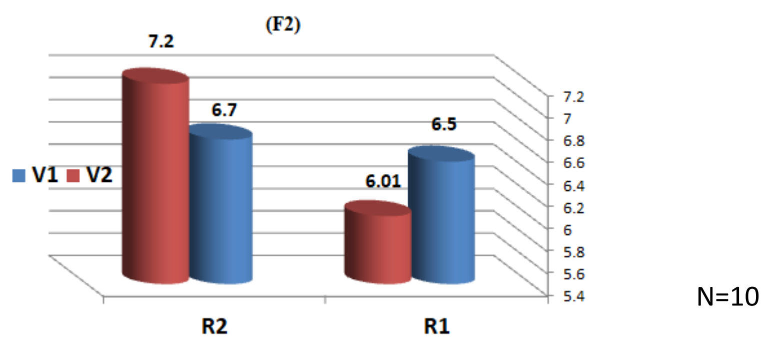


Figure (13): Differences in the use of "R1 & R2" ultrasonic sewing in the appearance test of "polyamide" fabric with heavy weight of "250" g / m2

Difference between conventional and Ultrasonic seam:

It'is clear from the previous table that there are statistical differences in the tensile strength between (conventional & ultrasonic) seam for ultrasonic seam on a polyamide fabric with light and heavy weight, and this is evident in the following figure (14).

Table (11): Differences between conventional and ultrasonic seam in the tensile strength test of "polyamide" fabric with light & heavy weight

Variable	Conventional seam		Ultrasonic Seam		"T" Test	For (N=20)
	Mean	± SD	Mean	± SD		
Tensile strength "light weight"	40.58	5.21	75.47	6.21	12.9*	**Ultrasonic seam**
Tensile strength "heavy weight"	39.51	0.51	41.87	3.05	2.29*	**Ultrasonic seam**

Tabular (T) value at a significant level (0.05) = 1.73

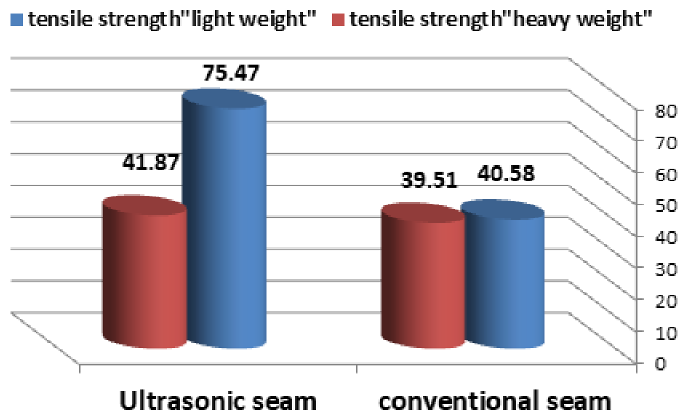


Figure (14) Differences between conventional and ultrasonic seam in the tensile strength test of "polyamide" fabric with light & heavy weight

It'is clear from the previous table that there are statistical differences in the sewing elongation between (conventional & ultrasonic) seam for ultrasonic seam on a polyamide fabric with light and heavy weight, and this is evident in the following figure (15).

Table (12): Differences between conventional and ultrasonic seam in the sewing elongation test of "polyamide" fabric with light & heavy weight

Variable	Conventional seam		Ultrasonic seam		"T" Test	For (N=20)
	Mean	± SD	Mean	± SD		
Sewing elongation"light weight"	67.58	8.25	130.45	6.87	17.6*	**Ultrasonic seam**
Sewing elongation "heavy weight"	69.12	3.46	82.37	4.21	7.29*	**Ultrasonic seam**

Tabular (T) value at a significant level (0.05) = 1.73

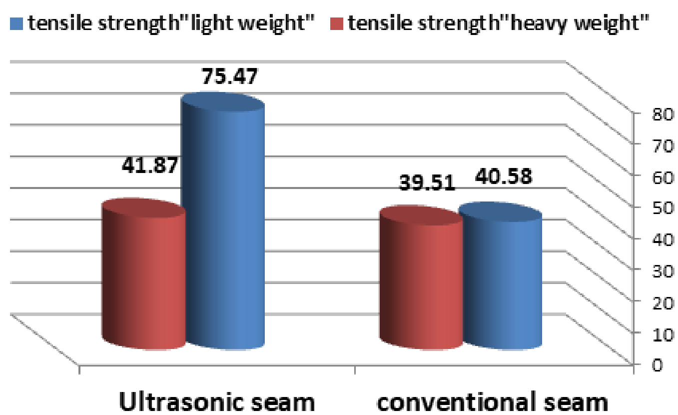


Figure (15): Differences between conventional and ultrasonic seam in the sewing elongation test of "polyamide" fabric with light & heavy weight

Table (13) Differences between conventional and ultrasonic seam in the sewing appearance test of "polyamide" fabric with light & heavy weight

Variable	Conventional seam		Ultrasonic seam		"T" Test	For (N=20)
	Mean	± SD	Mean	± SD		
Sewing appearance "light weight"	5.2	1.34	7.9	1.24	4.44*	**Ultrasonic seam**
Sewing appearance "heavy weight"	5.6	0.32	6.60	1.17	2.47*	**Ultrasonic seam**

Tabular (T) value at a significant level (0.05) = 1.73

It'is clear from the previous table that there are statistical differences in the sewing appearance between (conventional & ultrasonic) seam for ultrasonic seam on a polyamide fabric with light and heavy weight, and this is evident in the following figure.

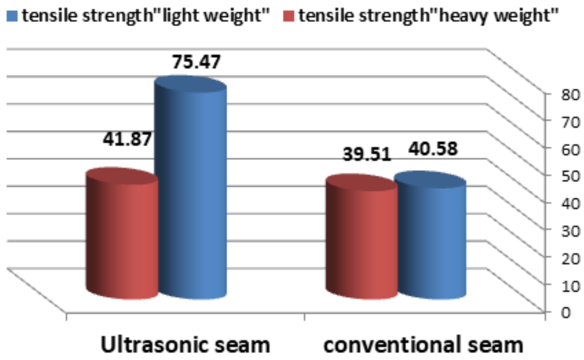


Figure (16): Differences between conventional and ultrasonic seam in the sewing appearance test of "polyamide" fabric with light & heavy weight

Conclusion

In light of the research sample, results, objectives and hypotheses Searches based on procedures, procedures and topic the research, the researcher reached the conciliatory settlement:

Comparison of sewing tensile strength

- The tensile strength results of sewing showed that ultrasonic sewing is higher in average strength than traditional sewing, as the average strength of ultrasonic sewing is 75.47%, while traditional sewing has an average strength of 40.58% lower than ultrasonic sewing; this is for the polyamide material, weighing 130 g/m ^{2}.
- The tensile strength results of sewing showed that ultrasonic sewing is higher in average strength than traditional sewing, the average strength of ultrasonic sewing is 41.87%, while traditional sewing has an average strength of 39.51% lower than ultrasonic sewing, for the polyamide material, weighing 250 g/m

Sweing elongation comparison

- The results of sewing elongation show that ultrasonic sewing is higher in average elongation than traditional sewing, the average elongation of ultrasonic sewing is 130.45%, while traditional sewing, the average elongation of sewing was 67.58% lower than that of ultrasonic sewing, for the polyamide material, weighing 130 g/m ^{2}.
- The results of sewing elongation showed that ultrasonic sewing is higher in average strength than traditional sewing, the average strength of ultrasonic sewing is 82.37%, while the average strength of conventional sewing is 69.12% lower than that of 250g polyamide ultrasonic sewing, for the polyamide material, weighing 130 g/m ^{2}.

Sewing appearance comparison

- The appearance results of sewing showed that ultrasonic sewing is higher in appearance than conventional sewing; the average appearance of ultrasonic sewing is 7.9%, while the average appearance sewing was 5.2% lower than that of ultrasonic sewing for the polyamide material, weighing 130 g/m ^{2}.
- The appearance results of sewing showed that ultrasonic sewing was higher in appearance than conventional sewing; the average of ultrasonic sewing for appearance was 6.60%, while conventional sewing was 5.6% appearance, and therefore it was lower than ultrasonic sewing for the polyamide material, weighing 130 g/m ^{2}.

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.

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