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Non-Stitch Joining Methods in Textile

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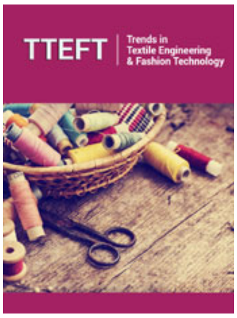

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Abstract

Stitch is the most common method to join textiles, however it has some disadvantages at certain applications such as waterproof garment production. To rule these disadvantages out, different joining methods have been investigated. Welding is a common non-stitch joining method. In this review, welding types are mentioned briefly, and benefits and handicaps of these techniques are discussed.

Keywords: Textiles; Fabric; Non-stitch joining; Thermoplastic fabric

Introduction

Stitch is a process of joining textile surfaces together by using threads to provide strength, flexibility, and aesthetic properties. However, in this process because of the needle, there are needle holes. In some specific applications like water-proof garments, these needle holes may cause water leakage. Therefore, other joining methods for textiles are investigated and developed [1].

In the last few decades, the textile industry has witnessed many new technologies of fabric joining methods. Many innovative alternatives that bring significant changes to garment production have arisen [2]. These methods are mainly developed for joining non-textile layers and textiles together. When untraditional materials are used with textiles such as in e-textiles applications, it is impossible to use stitches to combine these layers.

There are several classifications of non-stitch joining of textiles according to the heat source, techniques, etc. In this paper, non-stitch joining methods are divided into three groups:

A. Thermal bonding,

B. Ultrasonic welding and

C. Laser welding.

In Figure 1 [2], macroscopic views of these welding methods are given. Adhesives can also be used joining textile layers, yet adhesives are usually studied in coating and laminating applications. Previously mentioned welding techniques can be used with hot melt or film form adhesives.

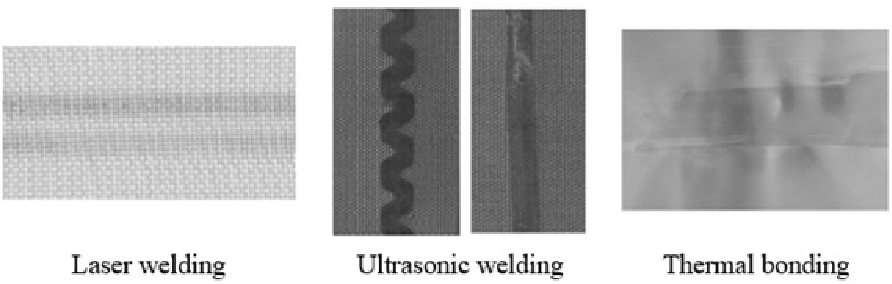

Figure 1: Macroscopic view of welding techniques [2].

Thermal welding is based on the principle of heating the thermoplastic fabric/adhesive layer with a heat source. The fabric layers are combined by applying pressure. Although there are different system designs and applications, as examples are given in Figure 2, thermal bonding systems consist of four basic units: a heat source, cooling section, pressure unit and process parameters control unit. Thermal bonding has advantages such as fast and easy application, low processing cost, low energy costs, flexible processing applications, and seamless joining. However, thermal welding is based on thermal conductivity, so it is not suitable for thick fabric or fabric which has low thermal conductivity [3].

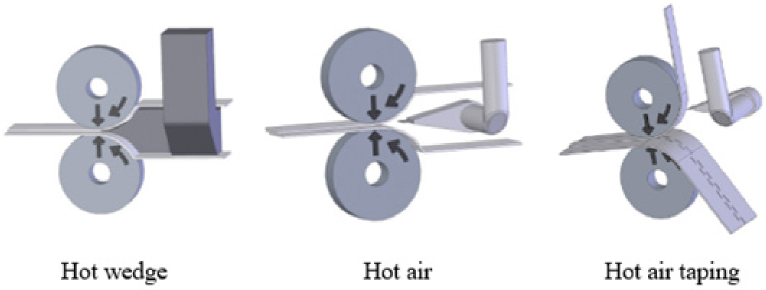

Figure 2: Thermal welding techniques [9].

Many authors presented thermal welding as an alternative to stitch. In a study, different seam types (stitch, bonding, and ultrasonic welding) were evaluated in terms of load, elongation and bending stiffness parameters. A wind and waterproof, breathable non-porous hydrophilic polyester fabric were used in the experiments. It has been observed that ultrasonic welding has a greater loading capacity. In terms of seam strength, ultrasonic sewing has the lowest strength. Although they allow for waterproof connections (there will be no needle holes, so there will be no leakage), seam strength can be up to 50% lower than with normal sewing [4]. In a study in which the seam strengths of truck tarpaulin, awning and tent fabrics were tested, 3 different connections with a thickness of 20mm were created (thermal welding (with hot air), ultrasonic welding, and sewing). Results showed that the highest strength was obtained with thermal welding connection with hot air. The lowest strength belongs to the sutured samples [5]. Chung [6] investigated the connection of hot melt adhesives with textiles for use in wearable electronics applications. Joints were created using 6 different fabrics and 4 different adhesives. The samples were exposed to temperature and humidity and their joint strength was tested. Strength decreased after high temperature and humidity in all adhesive and textile combinations. That's because the adhesive strength decreases with the moisture absorption of the polyamide adhesive. As a result, high temperature and humidity reduce the bond strength between layers, and rupture may occur in the adhesive or the adhesive-fabric layer depending on the textile fabric [6]. Jakubcioniene [7] studied the strength of adhesive joints in textiles. 4 different fabrics were used; thermal welding was done with two different temperatures and durations. When the temperature is low, the adhesive film cannot be sufficiently absorbed by the fabric; when the temperature is high, the adhesive film penetrates too much into the fabric. In addition, as the duration increases, the adhesion strength decreases. The reason for this situation is that as the transfer time increases, the film penetrates through the knitted fabric and cannot contact the upper fabric. Studies showed that adhesion strength depends on the structure of the fabrics, the contact surfaces and the applied surface treatments [7].

In a study investigating the use of thermal welding in joining optical fibers with textiles, it is shown that amplitude, pressure and thermal welding time are three key parameters for the process. It is observed that the thermal welding strength increases with the increase of pressure during the process (upto 15%). Likewise, the increase in the processing time also increases the strength up to a point. By increasing the adhesive thickness, an increase of up to 80% was recorded in the thermal welding strength. This research indicates that thermal welding with optimum process parameters will provide similar strength to traditional sewing [4].

Figure 3: Ultrasonic welding working principle and commercial welding machines [9,11].

Ultrasonic welding is a process in which mechanical vibrations are used to soften or melt the thermoplastic material in the joint line. Fabrics are joined using ultrasonic vibrations and pressure, usually at a frequency of 20-40kHz [8]. Ultrasonic welding is commonly used in the production of disposable protective clothing, medical textiles, filters, underwear, and outerwear (Figure 2) [9]. Fabrics containing 100% synthetic or up to 40% natural fiber can be joined by this method without needing a thermoplastic adhesive layer. It is a fast and low-cost method for garment manufacturers [10]. In Figure 3 [11], the general working principle of the system and examples of commonly used machines are given.

Ultrasonic welding performance has been investigated in several studies. Polyurethane-coated polyester fabrics joined with ultrasonic welding and regular stitch and their performance were compared. Samples were also washed in a domestic washing machine at 30 °C. The authors found that the higher speed of the welding process and washing reduces the joint strength [12]. In another study, ultrasonic welding and stitch performance of 4-layered fabric structure was investigated. This 4-layered fabric structure consisted of 85/15% PA/PES knitted fabric, PU foam, SympaTex® membrane, and PA knitted fabric. Results showed that the ultrasonic welding deformed the membrane and water resistance performance got worse [13]. With ultrasonic welding, fast production is possible and the process does not produce needle/thread waste and uses less energy [14]. In another study, the ultrasonic welding and traditional stitch performance of disposable medical gowns and cold climate shoes. Even though the welding had lower seam strength, it provided waterproof, windproof and breathable functions which could not be gained with stitch. The welding parameters had a great effect on seam strength. However, the parameter for high seam strength caused deformation on the membrane and reduced the waterproof performance [13]. In terms of comfort, ultrasonic welding had lower elasticity than stitching [15]. Still, subjects who wore ultrasonic welded t-shirts reported no negative comfort performance [16]. Also, a wider wheel provided more seam strength [10]. Studies show that the optimum process parameters change according to the fabric raw material [17].

Laser welding uses electromagnetic radiation to soften thermoplastic fabrics or adhesive layers between the fabrics. Laser welding can be classified according to the wavelength of the laser. Laser welding is suitable for thermoplastic fibers. An adhesive layer is required for bonding natural fibers or thermoset fibers. Laser welding joints do not generally cause undesirable deterioration on the fabric surface, since only the joint line is heated locally. However, elastane content fibers can be problematic in laser welding process [18]. The laser welding working principle and laser welding machine are given in Figure 4. The laser welding process has a high setup cost and limited usage areas, but the system is suitable for automation, has high speed and it is possible to produce joints as durable as sewing [19].

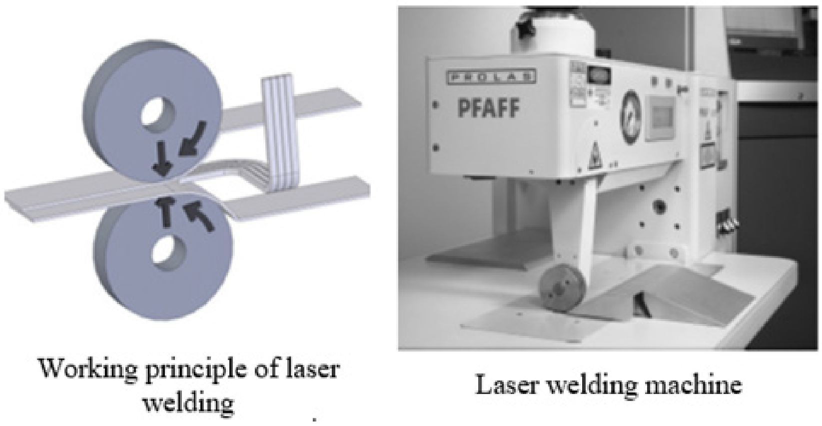

Figure 4: Laser welding working principle and commercial welding machines [9,18].

In airbag production, traditional sewing has problems such as the possibility of leakage, limited automation, and sewing defects. However, the seam strength requirement is too high to be met by ultrasonic sewing. Since laser welding can provide much higher seam strength than ultrasonic welding, it is presented as a better alternative. It has been observed that laser welds obtained by using PA 6.6 fabric provide the desired seam strength [20].

Conclusion

Although stitching has been the most fundamental way to join textiles for many years, welding applications are becoming widespread with expanding application areas nowadays. Welding techniques, which were first developed for special applications, later started to be used more widely. The seam strength is highly dependent on the process parameters. Although the strength of ultrasonic welding applications is lower than the strength of the stitching, higher-strength joints can be obtained with laser welding technique. Since the welding process is based on melting of fabric layers by heat, it can be used in fabrics with a high thermoplastic content without the need for an additional adhesive layer. An additional adhesive layer should be used to join the fabrics containing thermosets and natural fiber. In terms of providing high-speed production, welding processes are widely preferred especially in disposable products.

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