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INFLUENCE OF FINISHING PRODUCTS ON SEWING NEEDLE PENETRATION FORCE

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ABSTRACT

The aim of the present work is to investigate the influence of finishing products on sewing needle penetration force. For this purpose, only concentration of chemical product was varied, three different concentrations of each chemical additive were used. Fabric's characteristics (weight, weave, density, composition and thickness), needle properties (size, shape and metal) and the speed of needle penetration were conserved for all treatment. Various treatments were applied such as mercerizing, water proofing, wrinkling treatment, stiffening and softening. Many encouraging results were established. Thus, needle penetration decreased when using products improving threads movement for instance the softening products. Finishing fabric with 35g.L-1 of softening resin decreases needle penetration force by 27% compared to untreated fabric. However, it rose when making films on the fabric surface for example the waterproofing treatment.

KEYWORDS

Needle penetration force; finishing product; Denim fabric.

1. INTRODUCTION

Textile fabrics are used in numerous fields in human life, to address the need of wearability. During the conversion of linear structure (yarns) to bidirectional structure (woven and/or knitted) textiles fabrics acquire different properties due to residual tensions. In order to make the fabric (direct from the loom) acceptable to the consumer, several finishing treatments are applied. Textile finishes are made to improve existing properties and/or to introduce new characteristics (Howard L. Needles, 1986). Numerous methods are available to finish textile fabrics: physical, chemical and physic-chemical processes. Such treatments affect external and/or internal structure of treated fabric. Chemical treatments were applied by adding chemical substances which can react with macromolecular chain and form covalent bonds. This type of finishing is known as permanent finishing. So the fabric's behaviour depends on the new fabric's properties (Shakyawar, Behera, 2009) (Yahia et al., 2009). As a result, fabric's sewability is also affected. Finishing treatments are considered as the most important problem of sewability which is the ability of the fabric to be sewed (Parthasarathiet al., 2014).

Seaming process is very important and complicated. It requires great efforts in order to achieve good quality to satisfy consumers' needs. It depends on several parameters (fabric, sewing thread, needle, machine...), which can be recently justified by the large number of research studies. Indeed, theses studies

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aim to investigate seaming operation and its environment (Evangelos et al., 1999); (Hersh, Grady, 1969); (Sundaresan et al., 1998); (Kawabata, Masako, 1998); (Dorkin, Chamberlain, 1963); (Gojko et al.,2003); (Kordoghli et al.,2009).

Needle penetration through textile fabric can be either after thread slippage or after thread damage (Stylios, Xu, 1996). So, controlling needle penetration force has a great importance in the seam's operation to ensure good quality for seamed articles. It depends on seam's speed, fabric's properties (weave, weight, thickness, compostion) needle's metal (Groz, 2002); (Leeming, Munden, 1978); (Matthews, Little, 1988).
Gurarda and Meric (Gurarda, Meric, 2005) studied the variation of sewing needle penetration force during the sewing of cotton/elastane woven fabrics after washing at different temperatures and after silicone finishes. They exhibited that later treatment decreases the needle penetration force, but temperature doesn't reveal any influence.

In terms of fabric finishing, Leeming and Munden (Leeming, Munden, 1978) showed that the penetration force is critically affected by the use of lubricant or softener. This parameter increases in case of fabrics exhibiting sewing damage when using standard sewing tests. Also, Gurarda and Meric (Gurarda, Meric, 2005) concluded that different finishing stages can diversify values of needle penetration force (Carvalho et al., 2009).

The present work aimed at investigating the variation of needle penetration force when changing finishing additives' concentrations. Each treatment was applied with three different concentrations. Then the needle penetration force in the warp direction (seam follows the weft yarns), and in weft direction (seam follows the warp yarns).
For the best of our knowledge, studying the influence of finishing stage on needle penetration force was presented in numerous publications, but the effect of products concentration was not investigated. This is the reason why we have undertaken this study.

2. EXPERIMENTAL

2.1. Materials

To achieve the main objectives of the present investigation, DENIM fabric released in SITEX (Industrial Company of Textile) was used. The fabric is composed of 95% Cotton and 5% Elastane (C95E5, Its characteristics are presented in the following table.)

Table 1: The properties of fabric C95E5

Fabric code	Weave	Density(thread cm^{-1})		Thickness.(mm)	Weight(g m^{-2})
		Warp	Weft		
C95E5	Twill 4	26	17	0.720	294

Needle penetration force was measured by the device given in Figure1. It was detected by a piezoelectric sensor, which allows us to determine the needle penetration force at fixed speed (1000 mm/min). Needle produced by Groz-Beckert, Nm 90/14 and covered by titan (in order to avoid the needle heating) was used.

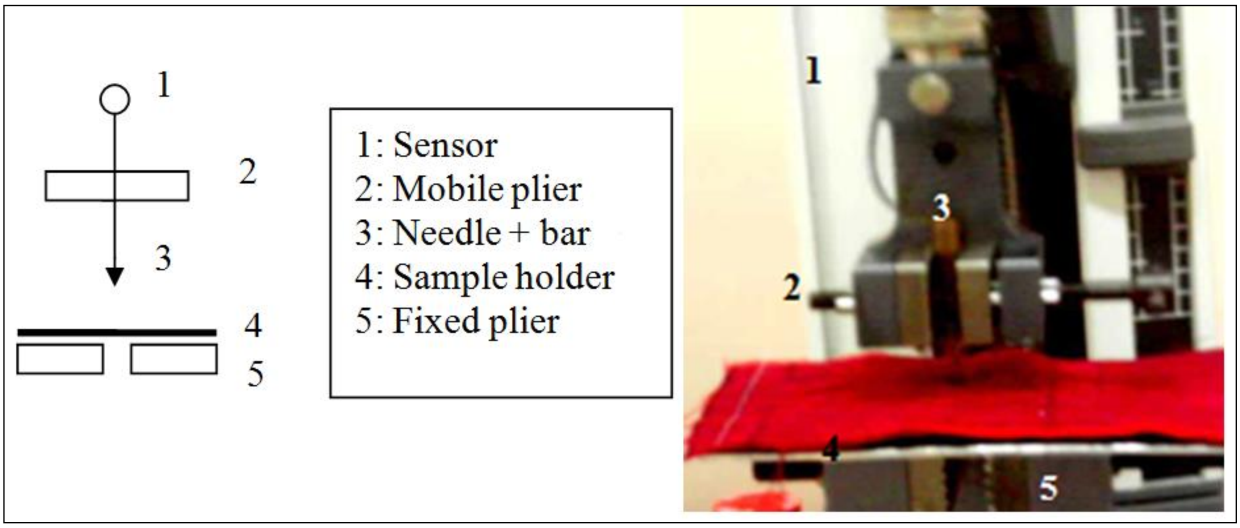

Figure 1: Device to measure needle penetration force

2.2. Methods

Grey fabric was mercerized and then impregnated in a bath containing resins for stiffening, wrinkling treatment and softening. Next, it was softened by a polishing substance. Waterproofing treatment was applied on finished fabric. These various treatments were carried out with three different concentrations of products. Mercerizing and softening by polishing substance were applied in the Industrial Company of Textile "SITEX". Stiffening,wrinkling treatment, waterproofing and softening using resin were done in the finishing factory in the same company. To ensure the reaction of resin's polymerization, all last resin treatments were done at 170°C for 1-2min. Then samples were cooled at room temperature. Finally, the needle force penetration was determined. Each indicated value presents the average of 5 tests and the difference among the force values is less than 5%.

Table 2: Different concentrations of used products

Treatments	Products	Concentration($g.L^{-1}$)		
		C1	C2	C3
Mercerizing	Sodium hydroxide	140	160	180
Stiffening	*Rhenappret RBA (Thor SARL France)	40	60	80
Wrinkling treatment	*Quecodur LT(Thor SARL France)	5	10	20
Softening by resin	*Finistrol (Thor SARL France)	20	25	35
Softening by polishing substance	*Appreture 166(Cognis)	10	15	20
Waterproofing	*Tubbugard	20	35	50

*: commercial name of chemical additives

3. RESULTS AND DISCUSSION

3.1. Influence of mercerizing

The fabric made from cotton wrinkles easily and is difficult to dye. It is, therefore, treated with sodium hydroxide to make it strong, lustrous and absorbent (Jordanov et al., 2010). This process is called mercerization. It consists in impregnating the fabric in aqueous solution of NaOH and then it is tightened. Figure 2 represents the evolution of force as function of the concentration of NaOH. We observe that the needle penetration force increases after mercerizing with a concentration of NaOH solution equal to 140g.L-1 compared to raw fabric. This increase is about 20% in the weft direction and about 30% in the warp one. Adding 160g.L-1 of sodium hydroxide raises needle penetration force. This evolution explains the difficulty of slippage between fabric's components. Such effect was justified by the influence of mercerizing which leads to swelling cotton threads (Nair et al., 2013). Also, due to mercerizing, cotton's crystal structure can be converted from cellulose I to II (Sameii, et al., 2008). During the process of mercerization, fibers are converted in swollen state. The orientation of microfibrils is changed. The original parallel-chains crystal structure of cellulose I changes to anti-parallel chains of cellulose II (Dinand, et al., 2002). But at high concentration (180g.L-1) of NaOH solution, the resistance to needle penetration decreases. This evolution can be explained by the destruction of cellulose structure caused by NaOH solution (Kamide, et al., 1990).

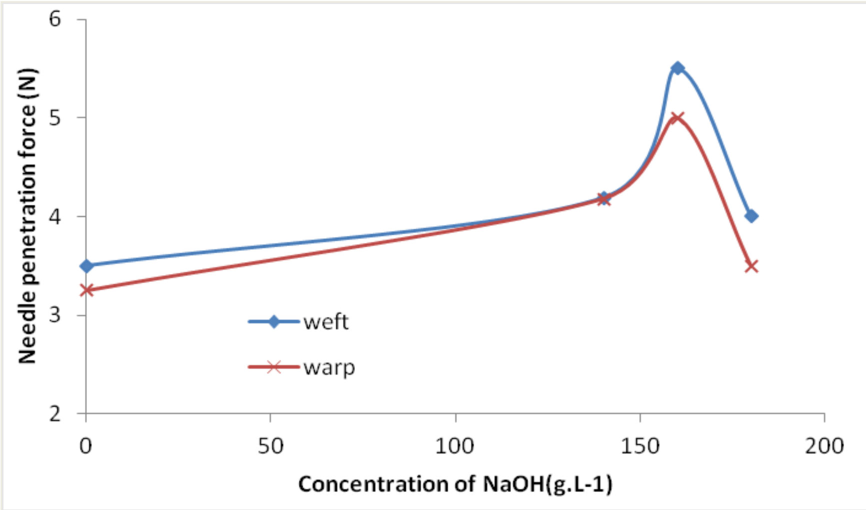

Figure 2: Influence of mercerizing on needle penetration force

3.2. Influence of wrinkling treatment

The wrinkling treatments improve the fabric's recovery after deformation. So such finishes affect internal structure of the treated fabric (Howard L. Needles, 1986). Figure 3 shows the evolution of needle penetration force with the quantity of resin responsible for the wrinkling treatment (Quecodur LT). As it can be seen, the resistance to needle penetration increases with the concentration increase. This variation achieves 65% if the concentration rises from 0g.L-1 to 20g.L-1. This result can be explained by cellulosic crystallinity, caused by this product (Michallet, 1991). The reaction of cellulosic structure and wrinkling resin engenders new cross linking. So, amorphous part in cellulosic fiber is reduced unlike the crystalline part which is increased. As a result the flexibility of weft and warp yarns declines, so their slippage becomes very difficult (Can et al., 2009). Thus, the needle penetration through fabric is possible only after fabric's damage. This effect justifies the important force value needed to seaming operation.

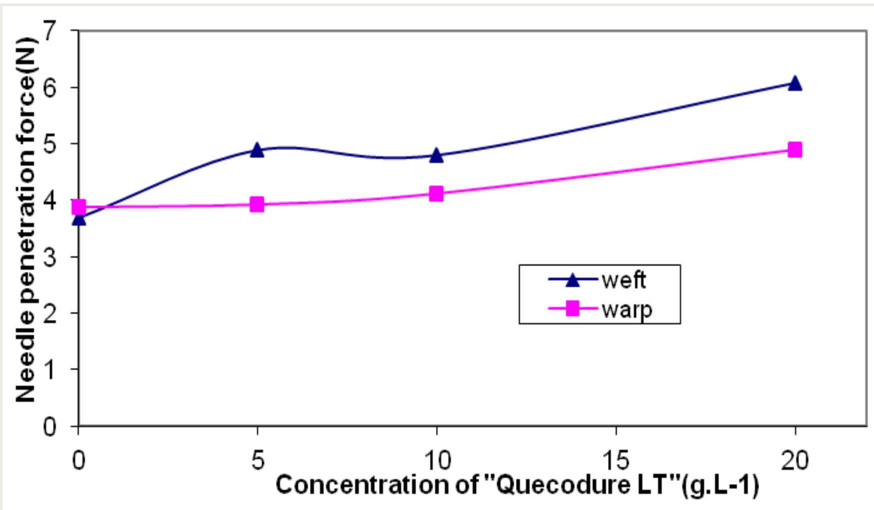

Figure 3: Influence of wrinkling treatment on needle penetration force

3.3. Influence of stiffening

Stiffening is generally applied to fabric of fine quality and light weight or loosely woven fibers. It makes the fabric heavier, stiff, and crisp. It also adds shine and smoothness to the fabric. The needle penetration force depends on stiffening treatment. During this treatment, finishing products (containing sizes and metal salts) stiffen the fabric through formation of bonds between fibers, particularly at fiber crossover (Howard L. Needles, 1986). In fact, the needle's penetration becomes very difficult after this treatment, especially, when resins are used with high concentration. This result is confirmed by data given in Figure 4. This evolution is due to the augmentation of fabric's stiffness which modifies fabric's properties. It makes the fabric's progress easy during sewing operation.

As a result, it is very important to optimize the appropriate quantity of the appropriate product (Rhenappret) in order to ensure the sewing process, with easier progress and lower needle penetration force.

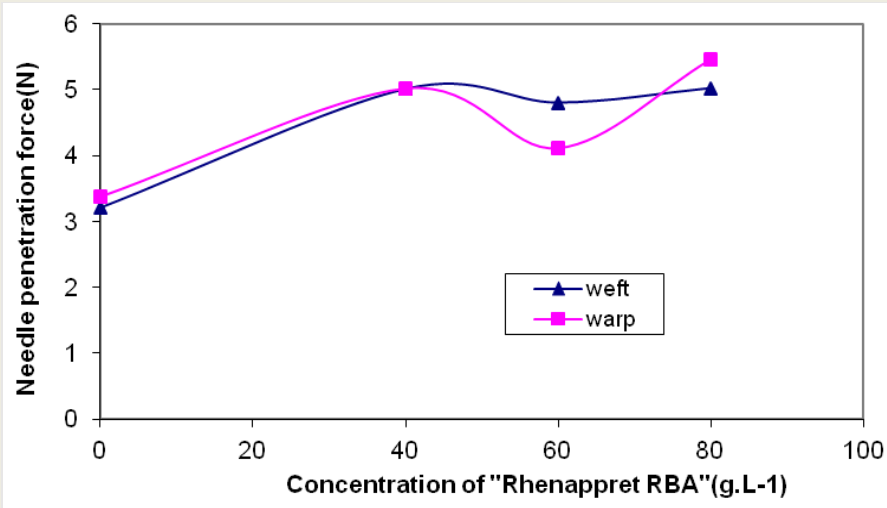

Figure 4: Influence of stiffening on needle penetration force

3.4. Influence of softening by resin

Softeners are added to textile structure to improve aesthetics, correct harshness and stiffness caused by other finishes and improve fiber resistance to abrasion and tearing forces (Howard L. Needles, 1986). During the softening treatment, the fabric was held flat, under tension both warp and weft ways. Figure5 shows that polishing resin helps needle to penetrate through the fabric. So that it lubricates the structure. So, it eases yarns' slippage. Softening treatment improves pore area and air permeability of treated fabric (Nair et al., 2013). That is why the needle penetration force declines by 27% comparing fabric treated with 0g.L-1 to the same one treated with 35g.L-1 of resin. This result is also proved by (Gurarda, Meric, 2005) and (Leeming, Munden, 1978).

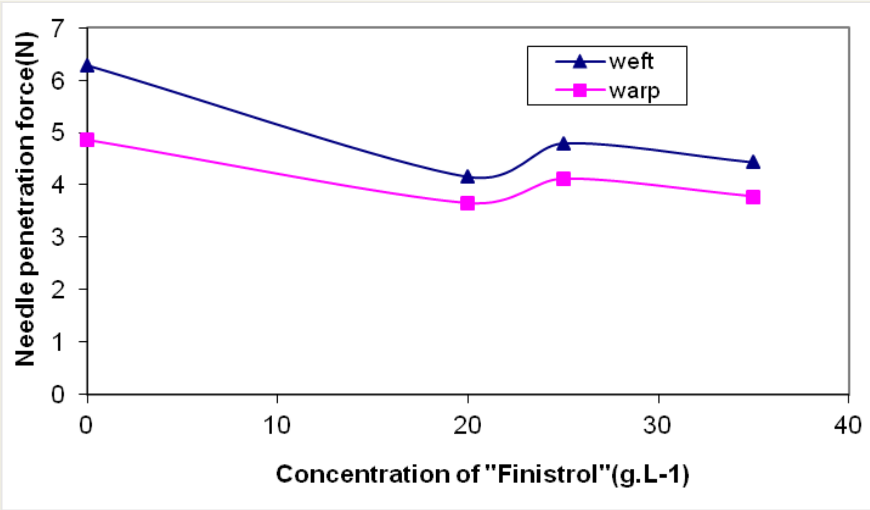

Figure 5: Influence of softening by resin on needle penetration force

3.5. Influence of softening by polishing substance

As it can be seen in Figure 6, the needle penetration force varies with the quantity of polishing substance. The treatment with 10g.L-1 of polishing substance increases the fabric's resistance to needle penetration because of the insufficiency of this product. Indeed, the wetting agent engenders the swelling of cotton yarns. So their slippage becomes more and more difficult. At a concentration equal to 15g.L-1, the needle penetration force has the lowest value. That is why it is used in the industrial protocol. When the quantity of polishing substance increases to20g.L-1, the resistance of treated fabric to needle penetration rises. This is caused by the ability of yarns to slip which causes their overlapping.

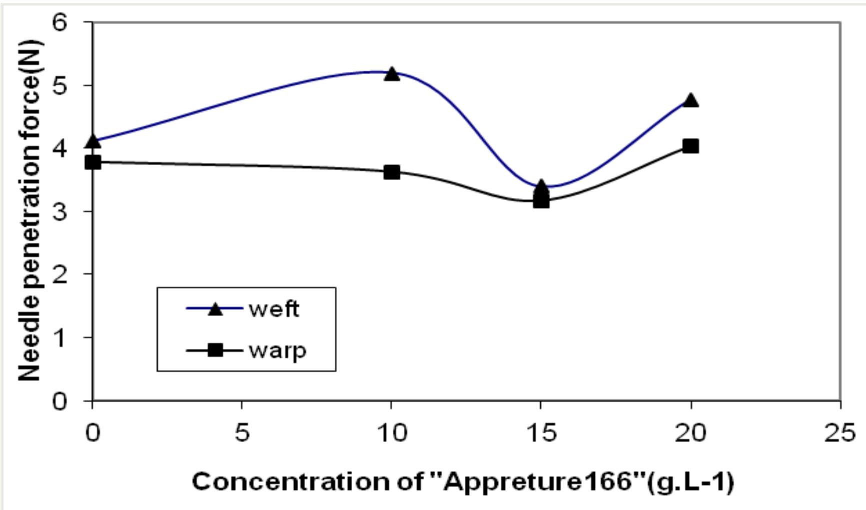

Figure 6: Influence of softening by polishing substance on needle penetration force

3.6. Influence of waterproofing

This treatment was applied on finished fabric which underwent all precedent treatment (mercerizing, wrinkling, stiffening, softening by resin and Softening by polishing substance) with conditions used in SITEX company. The last treatment, softening by polishing substance, was carried out with 15g.L-1 of "appreture166".

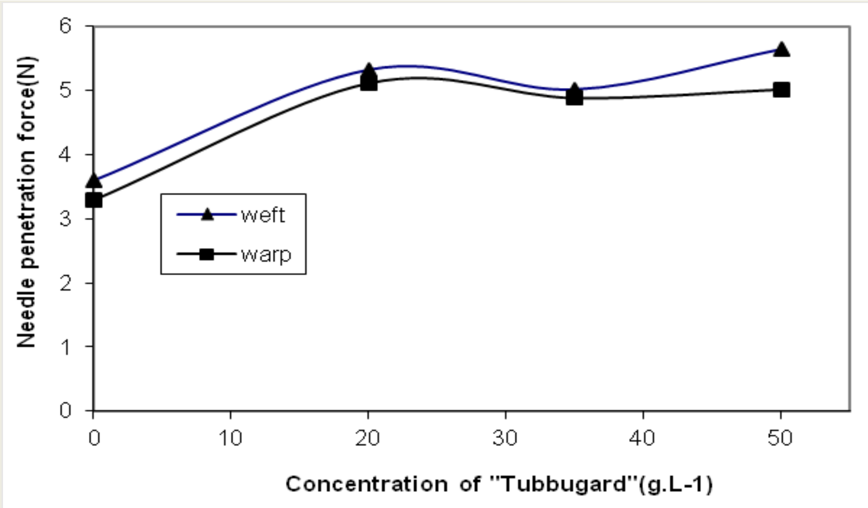

Figure 7: Influence of waterproofing on needle penetration force

Unlike water repellent finishes which permit the fabric to continue to breathe after treatment, water proof treatments completely seal the spaces between individual yarns (Howard L. Needles, 1986). This treatment consists in making a film of resin on the fabric's surface (Fiscus, 1997); (Schindler, Hauser, 2004) which enables the needle penetration. The thickness of this film improves the fabric's resistance to needle penetration. For instance, force needed for needle penetration through fabric treated with 50g.L-1 of "Tubbugard"is two times higher than that needed to pass through the untreated one. This result is confirmed by data presented in Figure 7. The increase of needle penetration force simultaneously with the augmentation of resin's quantity can be explained by the difficulty of moving threads into treated fabric. This resin (tubbugard) is considered as an adhesive agent which sticks weft and warp threads together. So their slippage becomes very difficult, in other words, needle penetration operation can be achieved only after fabric's destruction.

4. CONCLUSION

After different tests of various fabrics, it is clear that according to the properties wanted (softness, stiffness, wrinkling...) the finishing products affect the variation of the needle penetration force differently. So that stiffening, waterproofing and wrinkling treatment increase the fabric's resistance to needle penetration because of resins used when making film on the surface. But, concerning the treatment of softening, the needle penetration force is lower; this is due to lubrication produced by products responsible for this treatment either resin or polishing substance. On the other hand, all finishing product must be applied with optimum quantities.

The influences of finishing products on needle penetration force are slightly different in weft and warp ways. This result can be justified by the composition of yarns in two directions warp (100% cotton) and weft (95%cotton; 5%elastane).

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