Sewability interdependence on rigid structures

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Abstract. Sewability is the ability of the fabric to be sewn without faults and represents the ease of fabric processing at a satisfactory level. It can be used to predict problems which may occur in the garment sewing stage and it can be accurately measured using the L&M sewability tester as a function of that needle penetration force though the fabric. Sewability is attributed to fabric properties, pretreatment, finishing, sewing conditions and mishandling. Fabric softeners affect the ease of sewing processing of garments, which is mostly reflected by the needle penetration force. The current work was driven by previous study focused on the analysis of factors affecting the sewability of cellulosic woven fabrics of a wide range of designs and constructions, where the influence of several fabric properties on the needle penetration force had been investigated, revealing the existence of a relationship between the inherent properties of mass per square metre, breaking strength and bending length. However, the in-depth statistical analysis had shown that rigid structures follow a different trend in comparison to the light ones. In the current work, thin and light structured fabrics were excluded from the investigation and focus was given exclusively to the rigid structures of higher mass per square metre fabrics which are known to be problematic in sewing stage. Although the investigation was confined to the main three inherent properties which had proven to influence needle penetration, it included fabric treatments of washing and softening on the samples. Results show an increase in the interdependency of the studied properties while treatments show a minimal effect probably to low level of application.

Keyword(s). Needle penetration force, sewability, rigid woven structures.

1. Introduction

The ultimate and most critical stage in the chain process of textile construction is the garment making up process. Much of the commercial success of the final product depends on this last stage. Faulty products deriving from this stage do not have the chance to be corrected as it is not followed by any subsequent. Additionally, being the last stage, it bears the total cost from all previous stages. This underlines the importance of the area to investigate. Sewability has always been a major aspect of textile processing but quite often has not been given the correct attention by the textile manufacturers.

The ability of a fabric to be converted into a garment without faults through stitching process defines its sewability. It is attributed to fabric properties, pretreatment, finishing, sewing conditions and mishandling [1]. The finishing treatments influence fabric properties as well as the stitching quality of resulting garments. Studies have demonstrated that customer product selection is strongly related to the handle and softeners can significantly help meet the customer demands [2, 3, 4].

Sewability of fabric composes of merely two basic aspects, namely tailorability and sewing damage. Several studies have focused in the aspect of the sewing damage as seam puckering of the processed fabric (ASTM D1683 and ISO 7770), while fewer concentrated in the tailorability aspect. Tailorability reflects the ease of process during stitching of fabric at a satisfactory level and it can be used as a prediction tool to avoid processing problems which may result in poor performance of the garment sewing stage [5]. Several studies aimed to quantify the previously mentioned aspects of sewability as an expression of needle penetrating force through fabrics using sewing or overlock machines equipped with sensors or cameras. Although they help in building knowledge and
understanding, they were mainly used for research purposes [6]. Woven fabrics were investigated with the use of an Instron tester with some modifications [5,7,8]. The L & M Sewability tester, devised by Leeming & Munden, served the same scope and was widely used mainly for the investigation of knitted fabrics [9]. Finally, other researchers devised modelling methods for predicting the sewability of cotton fabrics by establishing of a ratio between the strength of the original and the strength of the seamed fabric, as a more reproducible and sensitive test [10].

2. Methods and Materials

2.1 Scope

The scope of the current work was to investigate dependence of the inherent properties such as strength, bending and mass per unit area with the needle penetration force through rigid fabrics of mid-high weight per square metre, in their natural, washed and softened states.

2.2 Analysed Properties

Studies have explained that needle penetration causes the yarn to move away from it but friction against it is inevitable [11]. As friction is much dependant of the vertical force and the coefficient of friction, fabric properties related to these factors such as fabric bending, yarn strength and fabric mass per unit area were investigated for the following reasons.

1. **Fabric mass per unit area** which represents the mass density of the material to come in contact with the needle. Fabric with higher mass would normally impose more impedance to the moving needle. Additionally higher mass could make the structure more rigid affecting fabric deformation and flexibility during needle penetration. Yildiz et al [12] claimed that the penetrating needle force increases exponentially with the increasing mass.

2. **Fabric bending length** representing the ability of the fabric to deform perpendicular to its plane before or during needle penetration. Deformation takes place at the moment of the needle contact with the warp and weft yarn found on its path. Fabric bending length is directly related to the seam puckering formation [13]. Additionally, flexural rigidity which is derived from bending length, and is the factor which Stylios [11] has based his mathematical model for prognosis of sewability damage.

3. **Fabric strength** representing the force which the fabric yarns are able to withstand when needle force penetration displacement occurs in in two planes [14]:
   a. **Perpendicular (z-displacement) to the plane of the fabric** when a number of yarns come in contact with the penetrating needle. The yarns are tensioned until they slide aside of the point of the needle or stay on top of it with the pressure building until fail.
   b. **Within the plane (x-y displacement) of the fabric** when the yarns are pushed away by the penetrating needle as its diameter increases between the point and the bud, which characterises the needle title.

2.3 Samples

Fabric samples from rigid and heavier cellulosic fabrics of a more than 220g/m² of weight per square metre were selected as previous work had shown to follow different trend to lighter structures. The fabrics covered a range of weave designs, since fabric construction play important role in the needle penetration [15]. Weave design diversity reassured taking this factor well in to account. The sample fabrics used are presented with the same sequence throughout the study and can be seen in table 1:
Table 1. Sample Fabrics.

| No | Name               | Weave         | GSM  |
|----|--------------------|---------------|------|
| 1  | Twill              | 3/1           | 220  |
| 2  | Panama (Rib)       | 2/1-1/1       | 500  |
| 3  | Double Face        | 1/1 and 2/1   | 850  |
| 4  | Denim              | 2/1           | 270  |
| 5  | Dobby              | Dobby design  | 370  |

2.4 Specimens and Sample Treatment

The fabrics in the table were used to create samples for testing. Three sets of samples were created, namely, control, washed, and softened samples.

- Control samples were derived from fabrics in their normal finished state and were named as control.
- Samples derived from fabrics that have undergone a washing cycle at 90°C under Wascator with ECE Detergent (5A program) (BS EN ISO 2633) were named as washed. Washing treatment acts as a de-lubricating process by removing any fatty substances on its surfaces and hence intent to increase the coefficient of friction.
- Finally, samples resulting from fabrics that were processed with a cationic softener, known for their strong affinity to cellulosic substrate, were named as softened. The presence of softener on the fabric’s surface decreases the coefficient of friction and improves abrasion performance[16]. The softener application was performed at 10g/l applied by mechanical deposition with a Benz pad mangle at wet pick-up 75% and dried evenly in a Mathis Steam Drier fabric-stenter at 85°C under the absence of any tension for a period of 2-5 minutes, depending on their dry weight.

2.5 Testing Machinery and Procedure

The previous mentioned properties have been measured in warp and weft direction and their average was taken in to account, while in the case of bending an additional set of samples was prepared and examined at a 45° to warp (or weft). Merely the readings are expressed as:

   a) Bending Length for Warp, Weft and 45° (mm). Measurements conformed the BS 3356:1990 procedure with 5 samples for each direction
   b) Strength for Warp and Weft (kg). Measurements conformed the ISO 13934-1 procedure with 5 samples for each direction
   c) Mass per unit area (gr/m²). Measurements conformed the ISO 3801:1977 procedure with 5 samples
   d) Needle Penetration Force (known as Sewability Force). Measurements were conducted using L&M sewability test apparatus. The instrument enables consecutive readings of force build during the penetration of a fabric by the selected needle (90s ball point) to be measured on a sample fabric at a rate of 100 penetrations/min [17]. The average force of 100 perforations is measured over a specimen length of about 350mm wide.
3. Results and Discussion

The SPSS software ver.13.0 was used for the statistical analysis of the correlation between the above mentioned variables. The dependency of the needle penetration force as a function of sewability value of the fabric was compared against the independent variables of the bending length, strength and mass per unit area. The degree of the dependence was expressed by Pearson R correlation value. The scatter diagrams were used to check the spread of the data which is also reflected by the coefficient of determination $R^2$ when a linear fit line passes through them, indicating a linear relationship. The analysis was performed under the confidence level of 95% using a 2-tailed model, while the data population was 75 reading for each case. The analysed data derived from the average values of the readings taken in the warp and weft direction for all samples for the needle penetration force and for all the above properties. In case of the bending a third set of data was analysed at 45° to the warp in order to detect best fit.

The resulting Pearson R values from the correlation statistical analysis are presented in the table 2 and their scatter diagrams of the figures 1, 2 and 3. In case of bending the resulting values of Pearson R from the data set of the average of the warp and weft data exhibit closer relationship than those taken at 45° to the warp. The $R^2$ values of 0.767, 0.784 and 0.732 reveal a high degree of goodness of fit and a good linear relationship, as presented by the corresponding scatter diagrams.

Table 2. Results from correlations analysis between needle penetration force and fabric property

| Dependent Value          | N  | Correlation | Sig.*** |
|--------------------------|----|-------------|---------|
| Needle Penetration Force |    |             |         |
| 1                        | 75 | .876        | .000    |
| 2                        | 75 | .838        | .000    |
| 3                        | 75 | .885        | .000    |
| 4                        | 75 | .856        | .000    |

***Correlation is significant at the 0.01 level (2-tailed).

Figure 1. Scatter diagram of needle penetration force (g) against bending length (cm)

Figure 2. Scatter diagram of needle penetration force (g) against fabric strength (kg)
Figure 3. Scatter diagram of needle penetration force (g) against mass per unit area (g/m²)

The significance values of below 0.01 in table 2, validate the Pearson R values which demonstrate the existence of a strong relationship between the penetration force and all three properties, fabric strength 0.885, bending length 0.876 for average of weft and warp and 0.838 for 45° to warp, and mass of the fabric per unit area 0.856. Bending and mass are measurements which compose the flexural rigidity of the fabric, a property which exerted a similar behaviour to the model of Stylios [11] with similar accuracy, about 85%, confirming the above results. Additionally, the correlation values found are significantly higher than that observed in previous work [18], were light and heavy fabric structures were analysed together, underlining that the fact the more rigid the structure is the stronger becomes the interdependence of the sewability, in form of penetration force, and fabric strength, mass per unit area and bending length.

High needle penetration values may alert problems in fabric processing when they are over a certain threshold. L&M sewability empirically quantifies this limit in single or double jersey knitted structures [17]. Currently work is in progress to model this threshold on woven structures.

In order to investigate and identify the effect of the fabric treatments, washing and softening, on the needle penetration force the previous data were analysed by one way ANOVA. In the means of that the average value of needle penetration force for weft and warp of every fabric was compared in its control, washed and softened state and checked for its statistically significant difference in order confirm alterations in the behaviour of the fabric.

The confidence level used was α=0.05 with population of 15 cases (15 averages of all warp and weft tests), while the LSD post hoc test was selected to identify group statistical significant differences. Values for significance of one way ANOVA were tabulated in the first row, and between group differences (treatments) LSD sig. are presented in the following rows, of the table 3.

| Fabric   | ANOVA Sig. | L.S.D. Sig. |
|----------|------------|-------------|
|          | Control-Washed | Washed-Softened | Softened-Control |
| Twill    | 0.005       | 0.001       | 0.075           |
| Panama   | 0.781       | 0.633       | 0.845           |
| Double Face | 0.953     | 0.975       | 0.782           |
| Denim    | 0.217       | 0.316       | 0.088           |
| Dobby    | 0.009       | 0.003       | 0.068           |
Table 4: Needle Penetration Force Values for treated fabric

| Fabric      | Penetration Force |
|-------------|-------------------|
|             | Control | Washed | Soften |
| Twill       | 229.40  | 185.80 | 267.80 |
| Panama      | 460.80  | 453.20 | 458.60 |
| Double Face | 541.40  | 543.00 | 543.20 |
| Denim       | 250.00  | 276.40 | 310.40 |
| Dobby       | 248.80  | 233.80 | 265.80 |

The ANOVA Sig values and LSD Sig values are over 0.05 in almost all the cases. Therefore the null hypothesis cannot be rejected and any difference in the Table 4 is statistically insignificant. This can be attributed to the low level of softener application in comparison to the course fabric structure. As a consequence, alterations, due washing or softening, of the needle penetration force through rigid fabrics could not be claimed. In the case of Twill fabric, which has the least rigid structure bearing the least mass per unit area of the fabrics and most flexible construction, the values were on border line of acceptance with the washed sample to differ from the rest as the LSD pair values reveal. Previous work in thin and light structures had confirmed a significant drop in needle penetration force [18] similarly to Alime’s findings [9] were silicone softeners were used as lubricants on knitted structures.

4. Conclusions

Bending length, mass per unit area (grams/m²) and strength are properties of rigid fabrics which are closely relate to the force needed for a needle to penetrate those fabrics which reflects their sewability. This relationship seems to get stronger as the fabric structure becomes heavier and more rigid in a proportional manner. However, washing and softening fabric treatments of rigid structures seems to have a negligible effect on the needle force needed to penetrate through them, on low level application.

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References

[1] Grancaric, A. M., Lima, M., Vasconcelos, R., Tarbuk, A., Handle of Cotton Knitted Fabrics-Influence of Pretreatments, 5th World Textile Conference AUTEX, Portoroz, Slovenia, 43-47, (2005).
[2] El-Dessouki, H. A., The Thermal Comfort Properties of Certain Egyptian Stretched Knitted Fabrics, International Design Journal, 5 (1), 69, (2015).
[3] Sand, C., Brückmann, R., Zyschka, R., Fashionable Trends in Textile Finishing, Melliand International, 7 (1), 71, (2001).
[4] Bernd Wahle.and Falkowski Jurgen, Softeners in Textile Processing. Part 1: An Overview, Coloration Technology 32 (1), 118, (2010).
[5] Stylios, G., The Principles of Intelligent Textile and Garment Manufacturing Systems, Assembly Automation, 16 (3), 40, (1996).
[6] Chmielowiec R., Sewing Machine, Fabric and Thread Dynamics, PhD Thesis, University of Leeds, 6-26, (1993).
[7] Ezzatollah Haghighat, Seyed Mohammad Etrati, Saeed Shaikhzadeh Najar, Evaluation of Woven Denim Fabric Sewability based on Needle Penetration Force, Journal of Engineered Fibers and Fabrics, 9, (2), 47, (2014)

[8] Stepan V. Lomov, A Predictive Model for the Penetration Force of a Woven Fabric by a Needle, International Journal of Clothing Science and Technology, 10 (2), 91, (1998)

[9] Alime Ashli Iliiez, Eylen Sema Dalbasi, Gonca Özcelik Kayseri, Improving of Sewability Properties of Various Knitted Fabrics with the Softeners, World Conference on Technology, Innovation and Entrepreneurship, Procedia - Social and Behavioral Sciences 195, 2786–2795, (2015).

[10] Frederick, E.B., Development of a Sewability Test for Cotton Fabrics, Textile Research Journal, 22 (10), 687, (1952).

[11] Stylios, G., Prognosis of Sewability Problems in Garment Manufacture Using Computer Based Techniques, Proceedings of the IEEE International Conference on Systems Engineering, Pittsburgh, PA, USA, 371-373, (1990)

[12] Yildiz E. Z., Pamuk O., Ondogan Z., A Study about the Effects of Interlinings to Sewability of the Woven Fabrics, Tekstil ve Konfeksiyon, 21(1), 87, (2011).

[13] Stylios, G., Lloyd D. W., The Mechanism of Seam Pucker in Structurally Jammed Woven Fabrics, International Journal of Clothing Science and Technology, 1 (1), 5, (1989).

[14] Mallet E. and Du R., Finite Element Analysis of Sewing Process, International Journal of Clothing Science and Technology, 11 (1), 19, (1999).

[15] Khan R. A, Hersh S.P. and Grady P.L., Simulation of Needle-Fabric Interactions in Sewing Operations, Textile Research Journal, 40 (6), 489, (1970).

[16] Karypidis M., Wilding M. A. & Carr C. M. and Lewis D. M, The Effect of Crosslinking Agents and Reactive Dyes on the Fibrillation of Lyocell, AATCC Review, 1(8), 40-44, (2001).

[17] L&M Sewability Tester Manual, John Godrich, (2010).

[18] Karypidis M., Savvidis G, Analysis of Factors Influencing Needle Penetration Force through Woven Fabrics, Journal of the Textile Association of India, 80, Preprint Jul-Aug, (2018).