Effect of needle type and backing fabric structure on sewing needle penetration force in artificial leather

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Abstract: According to the role of sewing process in technical textile industry, investigation the effect of sewing parameters on sewing performance of those materials is of great importance. One of the main sewing parameters, directly related to artificial leather sewability and quality of final product, is the needle penetration force (NPF). In this study, artificial leather samples were produced by laminating a PVC film with woven, knitted and needle-punched nonwoven fabrics, all from polyester fibers and with similar areal weights. The samples were then subjected to needle penetration test using straight needles with three different points (cloth point and cutting points with different cutting angles) and different metric sizes. The results showed that the effect of backing fabric structure on NPF is significant. The highest NPF values were observed in woven fabric reinforced samples, followed by those reinforced with knitted and then nonwoven fabrics. It was observed that effect of needle point type on NPF is not significant. Moreover, it was seen that finer needles enhances sewability in terms of reducing the amount of force exerted on the artificial leather.

***Keywords*—Artificial leather, Backing fabric, Needle type, Penetration force, Sewing.**

I. Introduction

NOWADAYS, artificial leather is extensively used in many applications such as clothing, automotive, upholstery, luggage, footwear, etc. It has become increasingly popular within these markets because of its appearance, flexibility, and also its lower cost compared to natural leather. Moreover, it has a positive effect on the environment, since the more it is used as a substitute for natural leather, the fewer animals are killed each year, and less pollution is generated from the processing of animals' skin.

Artificial leather is usually produced by coating or laminating a backing reinforcement fabric with such polymers as polyvinyl chloride (PVC) or polyurethane (PU) [1]. The backing reinforcement fabric can be a common textile structure such as a woven, knitted or nonwoven one [2]. Artificial leather materials are sewn on special machines in order to make the final product. The quality of the sewn leather product not only does depend on fabric and film quality, sewing threads and sewing machine parameters, but also depends on synthetic leather sewability. Sewability is defined as the ability of the material to be sewn efficiently and to provide a suitable performance for its end use .Needle penetration force (NPF) is an important factor influencing the quality of seams and fabric sewability. Many parameters such as substrate fabric properties, needle size, and shape of needle point influence the NPF.

The effect of NPF has been studied by several researchers to investigate the sewing damages in fabrics during sewing process. It is found that a high penetration force is one of the key reasons for sewing damages in the fabrics. Sewing damage has directly negative effects on quality of garments. Therefore, the quantitative value of NPF could be used to determine the damage of sewn fabrics during sewing process.

Stylios et al. [3] discussed the distributions of the tangential and radial stresses acting on the yarn of a fabric during sewing as the sewing needle is inserted into the fabric by means of the mechanical principles of elasticity. They also investigated the influence on the needle penetration force caused by the shape of the cross section and the profile curve at the needle point. It was suggested that five parameters. i.e., the mechanical properties of the textile material, the variation ratio of the needle radius, the contacting arc length, the frictional coefficient and the sewing machine speed are the main factors that determine the penetration force of the sewing needle.

Gotlih [4] developed a mathematical model for the calculation of the sewing needle penetration force. The comparison of the measured and calculated values shows that the values are very different. Thus means that the mathematical model must be further developed.

Lomov [5] predicted a model for the penetration force of a woven fabric by a needle. The comparison with the published and specially measured penetration force data proves the predictive ability of the model to be qualitatively accurate and quantitatively reasonable.

Carvalho et al. [6] developed a system for measuring needle penetration forces in an industrial high-speed sewing machine. They concluded that the most influencing factor on the penetration values was the sewing speed.

Haghighat et al. [7] predicted the NPF in denim fabrics using the artificial neural network (ANN) and multiple linear regression (MLR) models based on the effects of various sewing parameters. The results indicated that the NPF in denim fabrics can be well predicted in terms of sewing parameters by using ANN and MLR models, in which the ANN model exhibits greater performance than MLR.

Haghighat et al. [8] theoretically predicted needle penetration force in denim fabrics. Comparing the predicted and experimental values showed that the preciseness of model to predict the NPF in twill 3/1 weave pattern is partly acceptable.

The abovementioned studies are mainly focused on predicting and measuring NPF in textile fabrics. However, sewing performance of artificial leather products or similar coated fabrics is less elucidated in the literature. Therefore, the aim of this study is to investigate the effect of backing fabric structure, type of needle point and needle number (size) on needle penetration force (NPF) in artificial leather reinforced with woven, knitted and nonwoven fabrics.

II. Materials And Methods

A. Materials

Artificial leather samples were produced by laminating a PVC film with woven, knitted and needle-punched nonwoven fabrics, all from polyester fibers and with similar areal weights (in the range of 129-144 g/m^2). Contact adhesive (Premium) “Pattex” made by Henkel Co. was used for bonding the PVC film to the backing fabrics. Characteristics of the samples are given in Table I.

TABLE I
CHARACTERISTICS OF THE SAMPLES

Sample Code	Description
L	PVC film with thickness of 0.93mm and areal weight of 47 g/m2
WL	The film L reinforced with woven fabric
KL	The film L reinforced with weft knitted fabric
NL	The film L reinforced with nonwoven fabric

B. Testing Procedure

Needle penetration test was conducted on Testometric Micro 350 universal testing machine using straight needles with three different points; regular cloth point (R), cutting points with cutting angles of 45° (LL) and 90° (P) with respect to the direction of transport (Fig. 1) , and different metric sizes. The needles were coded using the mentioned parameters. For example in the needle P100 the point is P and the number is 100 metric. All needles were made by Groz-Beckert Co., with chrome surface coating. Characteristics of the needles are given in Table II.

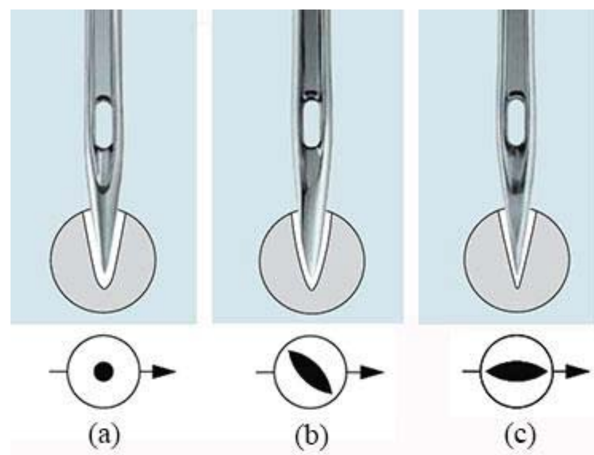

Fig. 1. Three different needle point types used in this study; regular cloth point, R (a), cutting points with cutting angles of 45°, LL (b) and cutting points with cutting angles of 90°, P (c) [9].

TABLE II
CHARACTERISTICS OF THE NEEDLES

Needle Code	Needle Point Type	Needle Size (Nm)
R80	regular cloth point (R)	80
R100	regular cloth point (R)	100
LL80	cutting points with cutting angles of 45° (LL)	80
LL100	cutting points with cutting angles of 45° (LL)	100
P75	cutting points with cutting angles of 90° (P)	75
P100	cutting points with cutting angles of 90° (P)	100

30 tests were done on each sample with each needle at crosshead speed of 999 mm/min. NPF values were then measured and average values were reported. Fig. 2 shows a specimen under needle penetration test.

Fig. 2. A specimen under needle penetration test.

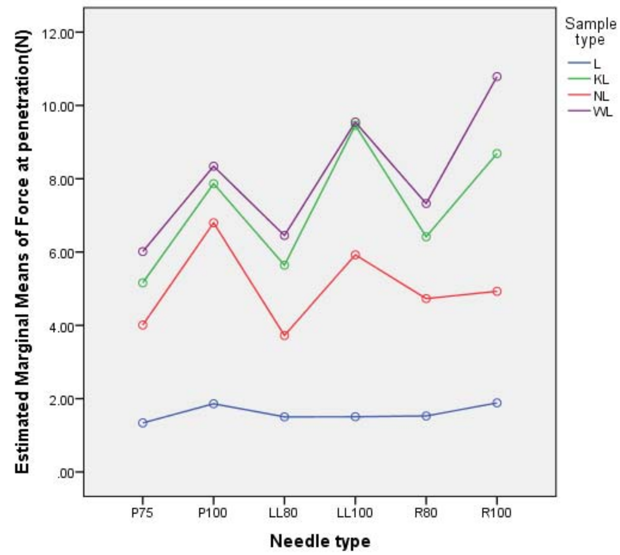

Fig. 3. Estimated marginal means of NPF for the artificial leather samples with various needles.

III. Results and Discussion

ANOVA analysis was done on the results using SPSS software in order to check the significance of the effect of the backing fabric structures and type of sewing needles on NPF. Average values, the standard deviations (SD) and coefficients of variation (CV%) are given in Table III.

TABLE III
Results of Needle Penetration Test

Sample Code		P75	P100	LL80	LL100	R80	R100
	NPF (N)	1.33	1.86	1.50	1.50	1.52	1.88
L	SD	0.09	0.12	0.12	0.12	0.15	0.21
	CV%	6.76	6.45	8.00	8.00	9.86	11.17
	NPF (N)	4.00	6.01	3.72	5.92	4.73	4.92
NL	SD	1.24	1.98	1.54	2.61	1.58	1.74
	CV%	31.00	32.94	41.39	44.08	33.40	35.36
	NPF (N)	5.16	7.86	5.64	9.45	6.41	8.68
KL	SD	1.24	1.69	1.35	1.73	1.49	1.80
	CV%	24.03	21.50	23.93	18.30	23.24	20.73
	NPF (N)	6.01	8.34	6.45	9.54	7.32	10.78
WL	SD	1.08	1.07	0.80	1.52	1.73	1.67
	CV%	17.97	12.82	12.40	16.08	23.63	15.49

Estimated marginal means of NPF for the artificial leather samples with various needles are shown in Fig. 3.

Statistical analysis showed that the effect of backing fabric structure on NPF is significant. It is seen in Fig. 3 that in general, NPF has the highest values in samples reinforced with woven fabrics, followed by those reinforced with knitted and then nonwoven fabrics. Pure PVC film has the lowest NPF among the samples. Woven fabrics has the highest strength and lowest deformability among the fabrics. Therefore, it shows a more effective reinforcement which makes the PVC film to resist more against puncture. Moreover, its dense and dimensionally stable structure exert high amount of load on the needle during penetration. The yarns do not have much freedom for moving, so the needle is subjected to higher frictional forces during penetration. However, their higher resistance against penetration of the needle may increase the probability of needle point damages in sewing. Knitted fabric reinforced samples show lower NPF due to their less dimensionally stable structures. In fact the structure has more open spaces (comparing with the woven structure with the same areal weight) and it is more deformable too. Thus the yarns can move more in order to provide some space for the needle to penetrate through the structure. The nonwoven reinforced artificial leather has the lowest amount of NPF among the reinforced samples. Since the nonwoven fabric is made from individual fibers bonded together using needle punching process, it has an open and porous structure which makes the sewing needle to penetrate through with much smaller frictional forces. Moreover the fibers have high moving freedom for escaping from the path of the needle. It should be noted that when the amount of NPF is low in a sample, it is less probable to be damaged during sewing by the needle. On the other hand, needle breakage rate is expected to be less in sewing, which means that the sewing speed can be increased.

Fig. 4 compares the average NPF values for the needles in all the samples.

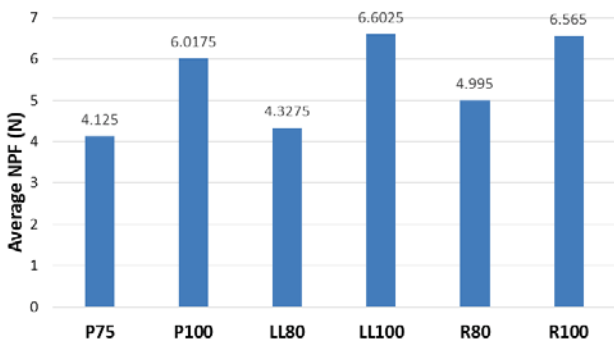

Fig. 4. The average NPF values for the needles in all the samples.

As it can be seen by comparing R100, LL100 and P100 needles and according to the statistical analysis, the effect of needle point type on NPF is not significant. It is an interesting finding since it may be normally expected that cutting point needles can cut the membrane more easily due to the blade type point and thus results in lower NPF. However, this effect may be more pronounced in natural leather and heavy coated textiles which may be a subject for further studies. In the current study the differences observed for various needle types in the reinforced samples seems to depend on how many fibers the needles run into during penetration, which is a random phenomenon based on the penetration position.

It can be clearly seen in Fig. 4 that in needles with the same points but different numbers (R80 and R100), (LL80 and LL100) and (P75 and P100), the lower the needle size, the lower is the NPF. In fact, using finer needles enhances sewability in terms of reducing the amount of force exerted on the artificial leather.

IV. Conclusion

In this research, effect of needle type and backing fabric structure on sewing needle penetration force in artificial leather was experimentally analyzed. Based on the results:

- Samples reinforced with woven fabrics showed the highest values of NPF due to their high strength and low deformability, more effective reinforcement and their dense and dimensionally stable structure.
- Knitted fabric reinforced samples showed lower NPF than the woven ones due to their less dimensionally stable and more deformable structures.
- The nonwoven reinforced artificial leather has the lowest amount of NPF among the reinforced samples, because of their open, loose and porous structure which makes the sewing needle to penetrate through with much smaller frictional forces, and also for high moving freedom of fibers for escaping from the path of the needle.
- The effect of needle point type on NPF is not significant
- Needle with less metric sizes shows lower NPF values.

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