STUDY ON FRICTION PROPERTIES OF SPUNBOND NONWOVEN FABRICS

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ABSTRACT

Friction has been an interesting subject because it is a quality-related property. Although Kawabata Evaluation System (KES) is the standard test method, researchers have been trying to establish a quick and an easy method to determine it.

This thesis conducts the frictional properties of spunbond nonwoven fabrics that differ in fabric density, embossed pattern, and material itself. A simple whisker-type tactile sensor friction-testing machine that measures the friction coefficient regardless of the dragging direction within a short period was used. The stick-slip phenomenon of friction coefficient and its mean deviation trace varied with the surface morphology of each kind of fabrics was observed. The ANOVA result confirmed that the bonding pattern, the fabric density and constituent filaments have a significant impact on the frictional property of spunbond nonwoven fabrics. A comparative study of KES and a whisker machine showed the resultant tendencies of each kind of spunbond nonwoven fabrics were the same. The correlation between these two methods was high for weave-pattern and low for minus-pattern and point-pattern spunbond nonwovens.

Therefore, a whisker-sensor machine is an alternative method to measure the friction properties of spunbond nonwoven fabrics objectively. However, doing more experiments is a must-need in order to establish the standard testing condition.

1. Introduction

As soon as the bombing in the usage of spunbond nonwoven fabrics, especially in the industrial textiles, analysis of mechanical, physical, and hand-related properties of spunbond nonwoven plays an important role in obtaining the desired quality product. Since friction is one of the qualities-related properties, there have been a number of investigations into the frictional behavior of spunbond nonwoven fabrics at various testing conditions. Although Kawabata system is a well-known method to investigate the frictional characteristics of textiles, many researchers have been trying to establish the new techniques. The reason is that friction is not an inherent property and it changes with the testing environment and the material itself.

Because of aforementioned reason, the frictional property of spunbond nonwoven fabrics has been investigated in this study. The 100% polyester (PET), nylon, and polypropylene (PP) spunbond nonwoven fabrics bonded with three bonding methods, namely, minus pattern, point pattern and weave pattern, and differences in fabric density were tested. A whisker-type tactile sensor friction testing machine was used to determine the coefficient of friction. The advantage of utilizing this machine is that it can detect the frictional coefficient of the fabric surface in all directions within a short period. Additionally, it can determine the variation in frictional resistance of spunbond nonwoven fabric surface relative to the dragging direction and specific surface geometry of each bonding method.

Firstly, the frictional resistance of spunbond nonwoven fabrics and its influencing factors were investigated. SPSS analysis software was used to analyze statistically. In the second, the comparative study between the KES_SF and a whisker-type tactile sensor machine was carried out. According to the experimental result, it can be concluded that a whisker-type tactile sensor machine is an alternative objective evaluation method of the frictional property of spunbond nonwoven fabrics.

2. Basic Principle of Measuring Friction in Textile

This chapter concerns with the basic principle of friction measurement of textiles, the stick-slip phenomenon in measuring friction, and influencing factors in the friction measurement. Friction in textiles fails to obey the Amonton' s law because of its viscoelastic nature and the nonlinear relation occurs with most polymeric materials. The most widely accepted of this relation can express as

$$F = aN^n$$

where a and n = empirical constants

F = friction force with the unit of N

N = normal force with the unit of N

However, friction test of textile material where the normal force is usually maintained constant, the primary parameter assessed is still the coefficient of friction, μ.

In general, there are two basic principles, the horizontal plane principle and the inclined plane principle to measure fabric friction. In the horizontal plane principle, a block of mass *m* is pulled over the sample rest on a flat surface. The line fastened to the block is connected to the load cell that can measure both the static friction force and kinetic friction force. In the inclined plane principle, the block of mass *m* rests on the inclined plane where the test sample is rest. When testing, the inclined plane angle, α is increased gradually until the block just begins to slide. At this point, the friction force and normal force can be measured. The Kawabata surface tester is the standard test method to measure the frictional properties of fabric objectively.

In measuring friction, the nature of plot of force against time is typically stick-slip in nature, which reflects a characteristic of most materials. Since the frictional resistance of textile materials is governed by many variables, the prediction of friction and SSP is still very difficult. In general, the stick-slip pattern is more prominent as the material is softer and more viscose-elastic. In yarn and fabric state, the structure, surface morphology or roughness and bulk properties may influence the fluctuations of the stick-slip trace.

The factors effect on the frictional property are the nature of detector, the morphology of the surface, the applied normal force and sliding speed, the direction of dragging, the area of contact, the testing environment, and the number of traverses.

3. A Whisker Type Tactile Sensor Friction Testing Machine

This chapter deals with the working principle of a simple whisker type friction testing machine. A sample of 12 × 12 cm^2 is placed on the sample stage that rotates on the z-axis with the velocity of 1 mm/s. When the desired load (30 g) is placed on the load cell, the sensor wire is brought into contact with the specimen surface and thrusts into the sample. The friction force is generated between the sensor wire and the sample surface while the sample stage is kept in motion. Both the normal force and friction force are recorded simultaneously with the help of a data acquisition system and wave logger software. Hence, the value of the coefficient of friction is calculated by taking the ratio of these two forces. Then, the mean coefficient of friction and mean deviation that represents the scatter of the coefficient of friction around its mean were calculated by averaging every 5° of dragging angle. The experiment was carried out in a standard testing atmosphere (20 ± 2 °C and 65 ± 2 % RH).

4. Friction Properties of Spunbond Nonwoven Fabrics

The friction property of 100 % polyester, polypropylene and nylon spunbond nonwoven fabrics embossed with minus pattern, point pattern and weave pattern and the differences in fabric density were investigated. The fabric weight ranges from 15 g/ m^2 to 70 g/ $m^{2.}$ It is observed that the nature of the stick-slip phenomenon (SSP) was regular when the sensor wire position is perpendicular to the machine direction of the minus-pattern bonding nonwovens.

For that reason, a higher value of mean deviation was visually observed at a dragging angle of around 180° compared with other angles. In point-pattern bonding nonwovens, even though the SSP of the friction coefficient was regular in some dragging directions, there is no clear characteristic in mean deviation trace. In weave-pattern bonding nonwoven, the regularity of SSP appeared at every 90° of dragging angle, and hence a high value of mean deviation was observed at around every 90° of dragging angle. These phenomena indicate that the coefficient of friction of spunbond nonwovens varies in relative to the dragging direction and surface geometry. However, this characteristic is not clear in thin-weight fabrics because the protrusion of unbonded areas on the fabric surface is extremely small.

Table 4.1. ANOVA Result

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.398[a]	30	0.047	411.94	0.00
Intercept	13.487	1	13.487	119228.85	0.00
Fabric weight	0.152	5	0.030	269.13	0.00
Pattern	0.194	2	0.097	857.59	0.00
Filament	0.353	2	0.176	1559.01	0.00
Fabric weight * pattern	0.055	7	0.008	69.28	0.00
Fabric weight * filament	0.159	7	0.023	201.27	0.00
Pattern * filament	0.0	1	0.0	1.08	0.29
Fabric weight * pattern *filament	0.006	4	0.001	12.49	0.00
a. R Squared = 0.978 (Adjusted R Squared = 0.976)					

SPSS statistic software was used for statistical analysis. The three-way ANOVA illustrated in Table 4.1 was used to determine the relationship between the dependent variables and independent variables. The result shows that the fabric mass per unit area, component filaments, bonding pattern, and all interactions between factors except pattern and filament significantly effect on the friction coefficient.

In general, the coefficient of friction of minus-pattern and point-pattern bonding spunbonds increased when the mass per unit area increased. The reason is that the impact of surface architecture varies with the bonding methods in addition to the fabric density. On the other hand, the value of the coefficient of friction decreased with a higher fabric density in weave-pattern bonding nonwoven fabrics. This tendency was true for nylon weave-pattern spunbond nonwovens. Nevertheless, there was no significant difference within polyester weave-pattern spunbond nonwovens. In the case of same fabric density and component filaments, the coefficient of friction value of minus-pattern and point-pattern bonding spunbond nonwoven was larger than that of weave-pattern bonding spunbond nonwoven. Nylon spunbond nonwoven had a large coefficient of friction value compared to polyester spunbond nonwoven and polypropylene spunbond nonwoven had a high coefficient of friction value compared to nylon spunbond nonwoven in the case of same fabric density and bonding pattern. Therefore, it is concluded that a whisker type tactile sensor friction testing machine is sensitive enough in detecting the change of fabric density, bonding pattern and component filaments.

5. The Comparative Study of Kawabata (KES-FB) and Simple Whisker Friction Testing Machine

This chapter concerns with the comparative study of the standard test method (KES_ Kawabata System) and a whisker-type tactile sensor friction testing machine. Generally, it is observed that the MIU value for all samples is smaller than the mean coefficient of friction value.

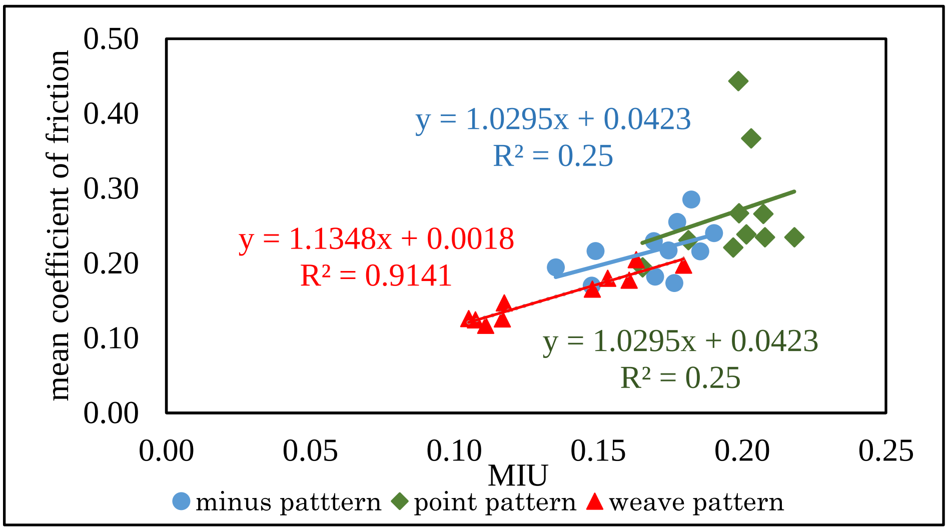

Figure 5.1. Relationship between MIU and mean coefficient of friction

Figure 5.1 shows the relationship between the mean coefficient of friction value and MIU. There is a high correlation (0.9) for weave-pattern spunbond nonwovens whereas a low correlation is observed for minus-pattern and point-pattern spunbond nonwovens with the value of 0.5 and 0.3 respectively. The reason is that friction is not an inherent property and it changes accordingly with the testing conditions such as detector type, compressive load and sliding speed, and dragging direction. The absolute difference between KES and whisker sensor is the nature of the detector and the area of contact. In KES, the detector is made from 10 pieces of 0.5 mm diameter piano wire whereas 0.5 mm diameter single piano wire is used as a detector in a whisker-sensor. As a result, KES sensor makes surface contact while a whisker-sensor is line contact. Further, the sample stage is in rotatory movement in a whisker-sensor machine while a sample moves forward and backward in both MD and CD in KES-FB. Moreover, 50 g of weight is used to give compressive load in KES whereas 30 g of weight is applied in a whisker-sensor machine.

6. Conclusion

Because of an explosion in usage of unconventional textiles, the performance of final good influenced partly by friction has been an interesting issue. Nowadays, because of bombing in the usage of nonwoven fabric, the performance of it in specific use that influenced by friction has become an interesting subject. Therefore, the frictional characteristics of the spunbond nonwovens were investigated in this study. A whisker-type tactile sensor friction-testing machine was mainly used. The advantage of this machine is that it can detect the varying in friction force within a short period. It was found that the stick-slip trace of friction coefficient and its mean deviation trace of spunbond nonwoven fabrics varied with the specific surface geometry of each bonding method. Hence, changes in coefficient of friction value in relative with the dragging direction and surface geometry can be achieved.

The bonding method, fabric density, and component filaments are the influencing factors on the frictional property of spunbond nonwoven fabrics. Although a comparative study of the standard machine (KES) and a whisker-sensor machine pointed out a significant difference between these two methods, a high correlation value was found in the weave-pattern bonding spunbond and a low correlation was observed in the point-pattern and minus-pattern bonding nonwovens. The reason is that friction is an inherent property and there still has been a limitation of using a machine for investigation friction of textiles. Nevertheless, it is summarized that a whisker-type tactile sensor friction testing machine is an alternative objective method of measuring frictional characteristics of spunbond nonwoven fabrics.

平成２９年　８月　３日

学位論文審査報告書（甲）

１．学位論文題目（外国語の場合は和訳を付けること。）

Study on Friction Properties of Spunbond Nonwoven Fabrics

（スパンボンド不織布の摩擦特性に関する研究）

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３．審査結果の要旨（600～650 字）

当該学位論文に関し，平成 29 年 8 月 3 日に第 1 回学位論文審査委員会を開催し，提出された学位論文及び関係資料について詳細に検討した．さらに，同日に行われた口頭発表後に，第 2 回学位論文審査委員会を開き，協議の結果，以下のように判定した．

布製品の中でも不織布は産業用途や衛生用資材として大きく生産が伸びており，日本製紙おむつ等の衛生用品はアジア各国で「使い心地がよい」と高評価を得ている．布製品の「心地よさ」に影響を与える大きな要因として，その幾何学特性および摩擦特性が挙げられる．本研究では，不織布の中でもとくに衛生用品として人の肌に接触する部分に多く使われる，スパンボンド製品に着目し，表面の融着パターン，面密度，構成繊維等の製造条件が異なる種々の不織布試料に対し，当研究室において独自に開発した回転なぞりによる摩擦試験装置を用いて，その摩擦特性を測定し，分散分析(analysis of variance :ANOVA)によりそれぞれの製造条件が摩擦特性に及ぼす影響を明らかにした．さらに布の「風合い評価」の世界的なスタンダードである Kawabata Evaluation System(KES)による摩擦特性試験結果と本試験結果を比較することにより，本試験方法の KES データとの互換性を検討するとともに，その有用性・優位性を実証している．

以上のように，本論文は不織布の幾何学特性および表面特性の評価に関して有用な知見を与えており，学術的な価値が高く，博士（学術）に値するものと判定した．

４．審査結果　(1) 判　　定（いずれかに○印）　（合　格）・　不合格

(2) 授与学位　　博　士（　学術　）