Manufacturing Technique of Stab-Resistant Laminated Composite Nonwoven Fabrics

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Key words:

Abstract

In this study, the nonwoven composites were made of high strength nylon 6 staples and low-melting-point polyester staples using needle-punching and thermal-bonding. By tensile strength test and constant-rate stab resistance test, the optimum parameters of the composites were obtained for developing and designing the stab-resistant nonwoven composites. The optimum experimental conditions for the nonwoven composites were as follows: the temperature for thermal-bonding was 150 ℃; and the wheel speed of thermal compression was 0.5 m/min.

Introduction

The theory of fabrics resisting bullets to penetrate differs from that against sharp objects. Thus, current common bulletproof woven are not stab-resistant. Despite European countries, Taiwan and China restrict to firearms closely, incisive weapons are easy to obtain. The public and policemen are at risk being hurt by incisive weapons than firearms, and thus stab-resistant clothing has been gaining attention gradually [1]. In the meantime, fiber materials have good flexibility and are easy for people to wear and move, but its stab-resistance was not as good as that of metal materials or ceramics. There are four stages for needles to penetrate the soft type protective clothing of multi-layer fibers. First, the tip of the needle touches the surface of fiber and curve the fiber. Second, tip of the needle glides into the void between fibers. Third, the needle pierces and expels the fibers. Finally, the tip of the needle penetrates the fabrics. When multi-layer fabrics resist the stab at the third stage, the maximum stab-resistance strength was obtained accordingly. Industrial-grade functional textiles are the one of the major productive goals for textile industry in the application fields [4-13]. The incisive weapons bringing about injuries can be divided into spikes sharp-edged blades and knives. Spikes used as a weapon hurt by the pointed tip instead of the sharp edge, such as the puncture by an ice chisel. Meanwhile, the threat of sharp-edged blades or knives was for thrusting the continual incisive edges [2, 3]. This research mainly developed and discussed the manufacturing of stab-resistant materials for spike puncture.

Experimental

High strength Nylon 6 staples with a fineness of 6.0 denier and a length of 64 mm, are manufactured with low-melting-point polyester staples with a fineness of 4.0 denier and a length of 51 mm in a process consisting of various stages, such as opening, cotton blending, carding and lining to form the net. Afterwards, the nets were needle-punched and thermal-bond, forming the high-strength Nylon 6 nonwoven composites. During the processing, manufacturing parameters were adjusted accordingly based on the tensile strength test and stab-resistance test, fulfilling the requirements of the high-strength nylon 6 nonwoven composites.

Results and Discussion

1. The influence on the thermal-bonding on the tensile strength of high-strength nylon 6 composites.

1.1 The influence of the temperature of thermal-bonding

According to Fig. 1, with a low thermal-bonding temperature, only partial low-melting-point polyester staples were melted, resulting in a smaller thermal-bonding area. Thus thermal-bonding failed in reinforcing the high-strength Nylon 6 composites, giving the nonwoven fabrics a lower tensile strength. Following an increase in thermal-bonding temperature, the tensile strength of the high strength nylon 6 composite increased as well. However, when the temperature reached to a certain level, the tensile strength went down. Because when the thermal-bonding temperature was too high, the degradation of thermal oxidation worsened, decreasing the tensile strength. Nevertheless, when it exceeded 160 ℃, the tensile strength went up again. When it was close to the glass transform temperature (Tg) of nylon 6 (around 170 ℃ to 180 ℃), the composites started thermal-shrinking. Additionally, when the density of nonwoven composites increased, the fiber contacting areas increased, as was the friction among fibers, raising the tensile strength of the nonwoven composites subsequently.

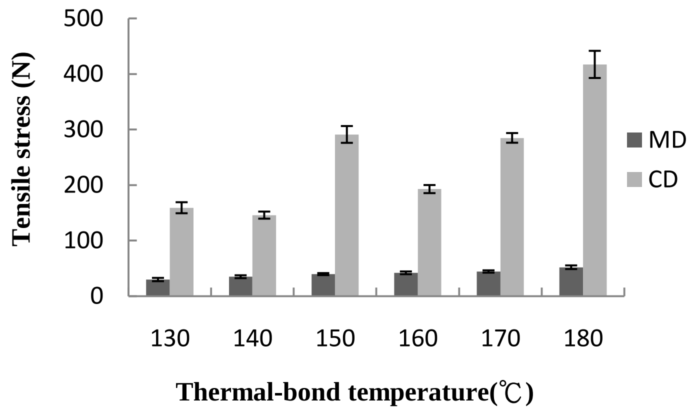

Fig. 1 The influence of the temperature of thermal-bonding on the tensile stress of high-strength Nylon 6 composites.

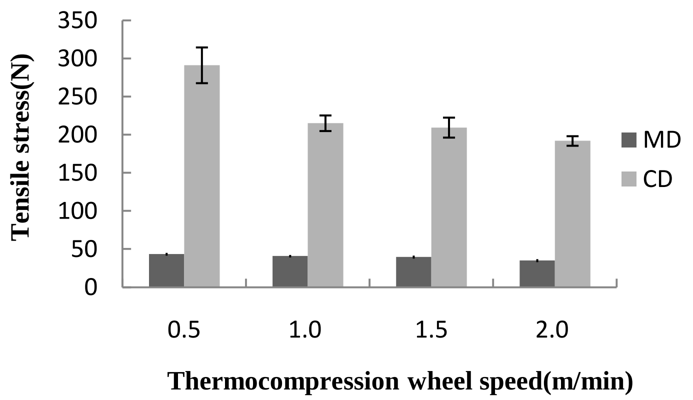

Figure 2 The influence of the thermo compression wheel speed on the tensile stress of the high-strength Nylon 6 nonwoven composites.

1.2 The influence of the wheel speed of thermo-compression

Figure 2 reveals that at low wheel speeds of thermo-compression, the wheels contact the nonwoven composites for a longer time, allowing a plenty of time to melt the low-melting-point polyester fibers, thus the thermal-bonding heightens the tensile strength effectively. In contrast, with the acceleration wheel speed, the tensile strength decreased due to a shorter time for the wheels contacting composites, so the heat was not efficaciously transmitted to the interior of the composites. Consequently, only a few amount of the low–melting-point polyester staples from the surface of composites melted, making the thermal-bonding ineffective and a decrease in tensile strength.

2. The influence of the thermal-bonding on the stab resistance of high-strength Nylon 6 composites.

2.1 The influence of the thermal-bonding temperature

The stab resistance of high-strength Nylon 6 nonwoven composites increases with the increment of the thermal-bonding temperature, exemplified in Figure 3. The density of the nonwoven composites increased with the temperature of thermal-bonding, so does the stab-resistance of the nonwoven composites. In sum, it was the higher thermal-bonding temperature that heightened the composites' density by clustering the fibers, contributing to the stab-resistance of the nonwoven composites subsequently.

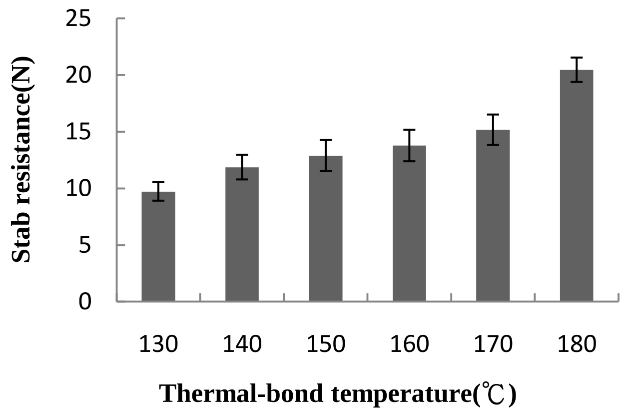

Figure 3 The influence of the temperature of thermal-bond on the stab resistance of high-strength Nylon 6 nonwoven composites.

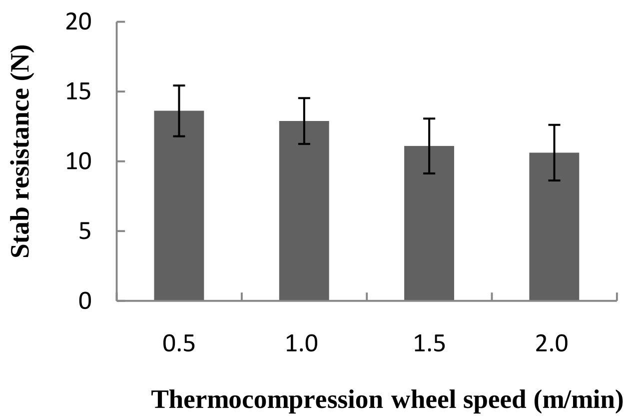

Figure. 4 The influence of the wheel speed of thermo-compression on the stab resistance of high-strength Nylon 6 composites.

2.2 The influence of the wheel speed of thermo-compression

Figure 4 illustrates that with the increment of the wheel speed of thermo-compression, the composites' stab resistance decreased. We inferred that when the wheel speed accelerated, the time for thermo-compression wheel to contact the composite was shortened comparatively, which only melted partial low-melting-point polyester staples. As the melt flow was not given enough time to cover a large area of the composites, the stab-resistance of the composites decreased when the wheel speed of thermo-compression increased.

Conclusion

In this study, we fabricate the stab-resistant laminated composite nonwoven fabrics successfully. The optimum parameters for high-strength Nylon 6 nonwoven composites were as follows: thermal-bonding temperature was 150 ℃, and the wheel speed of thermo-compression was 0.5 m/min. With the optimum parameters, the high-strength Nylon 6 nonwoven composites had the tensile strength of 187 N and stab resistance of 12.88 N.

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