International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:10, No:3, 2016

Effect of Sewing Speed on the Physical Properties of Firefighter Sewing Threads

Adnan Mazari, Engin Akcagun, Antonin Havelka, Funda Buyuk Mazari, Pavel Kejzlar

***Abstract*—**This article experimentally investigates various physical properties of special fire retardant sewing threads under different sewing speeds. The aramid threads are common for sewing the fire-fighter clothing due to high strength and high melting temperature. 3 types of aramid threads with different linear densities are used for sewing at different speed of 2000 to 4000 r/min. The needle temperature is measured at different speeds of sewing and tensile properties of threads are measured before and after the sewing process respectively. The results shows that the friction and abrasion during the sewing process causes a significant loss to the tensile properties of the threads and needle temperature rises to nearly 300°C at 4000 r/min of machine speed. The Scanning electron microscope images are taken before and after the sewing process and shows no melting spots but significant damage to the yarn. It is also found that machine speed of 2000r/min is ideal for sewing firefighter clothing for higher tensile properties and production.

***Keywords*—**Kevlar, needle temperature, Nomex, sewing.

I. Introduction

ARAMID and other high –strength fiber are extensively used in protective clothing; Kevlar and Nomex registered trademark of DuPont and are widely used for the flame resistant clothing due to high melting points and excellent durability [1], [2]. DuPont reported only the tensile properties of filament yarn [3], [4]; it is necessary to determine the properties of these Aramid threads after sewing process, where the thread goes under high needle temperature and abrasion and friction during the high-speed sewing process.

During sewing at high speed, the needle thread is subjected to repeated tensile stresses, bending, pressure torsion, wearing and heat. These forces act on the sewing thread repeatedly and the thread has to pass through needle eye, fabric and the bobbin case mechanism 50-80 times before becoming part of the seam [5]. The rubbing at the top of needle eye can cause local abrasion and cutting of the thread [6]. In early research work, [7] reported 60% reduction in thread strength after sewing. Later a number of researcher observed that there can be 30-40% strength reduction in the cotton thread after sewing [8]. In a recent research on the tensile properties of mercerized cotton thread, nearly 30% strength reduction is reported [9]. Furthermore, closer estimation of the seam strength was also possible after considering the loss in sewing thread strength [10], [11]. A number of researchers also study the dynamic loading of the sewing thread during high speed sewing process [12]. The mechanical performance of threads is governed by the properties of constituent fibers and their arrangement. In the course of tensile loading the tension induced by applied strain is transferred to the fibers through the interfacial shear stress, which leads to substantial changes in the yarn structure and fiber mechanical properties [13]. The friction, bending, and compression during the sewing process cause damage/pull-out of surface fibers resulting in a loss in mechanical properties. Heating of the needle cause synthetic fibers to soften or melt, leaving a weakened thread after sewing. Depending on the sewing conditions, maximum needle temperatures range from 100°C~300°C [14]. This high temperature weakens the thread, since thread tensile strength is a function of temperature, resulting in decreased production [15]. Most of these loadings are cyclic by nature and therefore cause the fiber fatigue [16].

Adnan Ahmed Mazari is with the Technical University of Liberec, Czech Republic (e-mail: adnanmazari86@gmail.com).

II. Material and Methods

The fire retardant sewing threads are obtained from company COATS and basic properties like tenacity and breaking extension are measured on the Instron Tensile Tester as per ASTM standard D2256, with a gauge length of 250 mm. The sewing thread tensile strength is measured before the sewing process and then seam is stitched at different speeds for a continuous 10 seconds; the thread is then pulled from the seam precisely by cutting the bobbin thread and each measurement is performed 10 times.

The coefficient of friction is an important factor to understand the effect of abrasion during the sewing process. Thread to metal coefficient of friction is measured for all threads with instrument CTT-LH401 (Company Lawson-Hemphill) according to standard ASTM D-3108 for 100m/min and contact angle of 180°.

The needle temperature is measured at different sewing speeds by inserted thermocouple method [17].

The thread properties are shown in Table I.

TABLE I
Thread Properties

Serial number	Material	Thread count [tex]	Ply	Twist angle
1A	Spun-Kevlar	40	2	Z/S
1B	Spun-Kevlar	70	3	Z/S
2A	Long staple spun-Meta Aramid	40	3	Z/S
2B	Long staple spun-Meta Aramid	70	3	Z/S
3A	Meta Aramid	40	3	Z/S
3B	Meta Aramid	70	3	Z/S

III. Results and Discussion

Firstly the metal to thread coefficient of friction for all threads with instrument CTT-LH401 (Company Lawson-

Hemphill) according to standard ASTM D-3108 for 100m/min and contact angle of 180°. Table II shows the result of coefficient of friction for the used threads.

TABLE II
COEFFICIENT OF FRICTION FOR THE THREADS

Serial number	Coefficient of friction [μ]
1A	0.25
1B	0.28
2A	0.38
2B	0.38
3A	0.4
3B	0.4

The result shows that the Kevlar has the lowest coefficient of friction followed by Meta-Aramid. The long staple Meta-Aramid causes a marginal change in the coefficient of friction compared to staple Meta-Aramid. The lower coefficient of friction is always better for the sewing threads as low abrasion and friction causes less heat and wear of the thread surface.

The threads are used for sewing the 4 layer of 320g/m^{2}denim fabric with different sewing speeds. The stitched thread is pulled from the seam precisely by cutting the bobbin thread and the tensile strength of the thread is measured on tensile tester by ASTM standard 2256.

Fig. 1 shows the breaking strength of sewing threads (before and after sewing at different speeds)

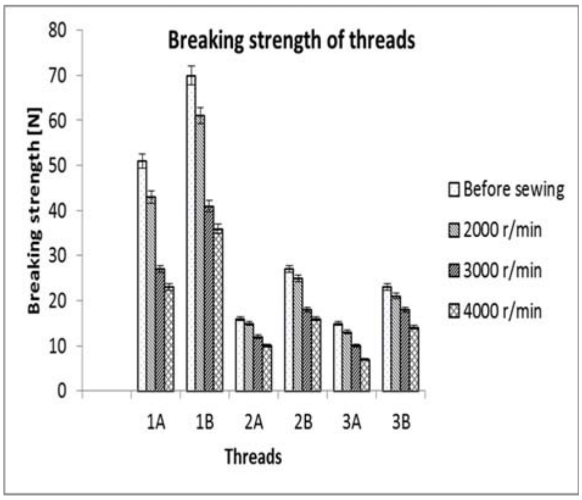

Fig. 1 Breaking strength of sewing threads

Fig. 1 shows that the tensile strength is decreasing dramatically at higher sewing speeds. The damage could be because of the abrasion or the needle heat. The needle temperature was also measured after 10seconds of continuous sewing at different sewing speed by inserted thermocouple method as shown in Table III.

Table III shows that the needle temperature rises with the higher thread count and sewing speed, the highest temperature is observed for the Meta-Aramid thread which is also due to higher coefficient of friction. Anyhow, the temperature at 3000r/min are nearly or above 300°C; which is much above the glass transition temperature of the threads' material but lower than the melting point.

Fig. 2 shows that the needle temperature rises linearly with the sewing speeds and tensile strength of threads decreases linearly.

TABLE III
SEWING NEEDLE TEMPERATURE

Threads	Sewing speed [r/min] 2000 r/min	3000 r/min	4000 r/min
	Needle temperature [°C] (standard deviation)		
1A	170(±4)	228(±4.5)	280(±5.2)
1B	192(±6.5)	251.5(±6.5)	305(±4)
2A	185(±6)	238(±2.5)	295(±6.5)
2B	196(±3.5)	258.5(±7)	315(±5)
3A	188(±3.2)	241(±3.3)	298(±7)
3B	199(±6)	263(±2.7)	321(±3)

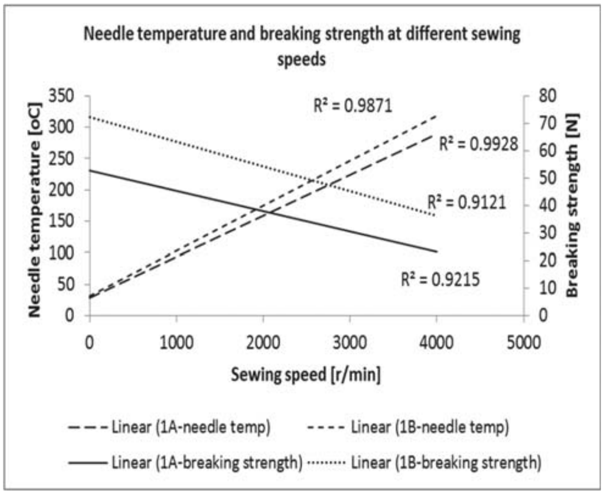

Fig. 2 Needle temperature and breaking strength of threads

To see the effect of abrasion and friction during the sewing process the threads sewed at different speeds are examined under the electron microscope for comparison. The samples are obtained before and after sewing and coated with Platinum under plasma sputtering and examined at 100&50 times magnification.

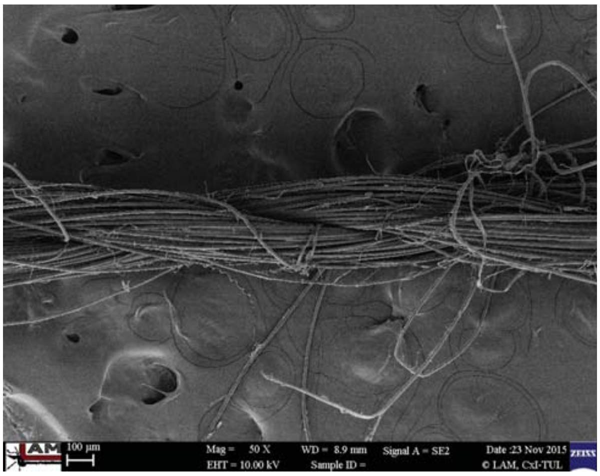

Fig. 3 SEM image of sample 1A before sewing

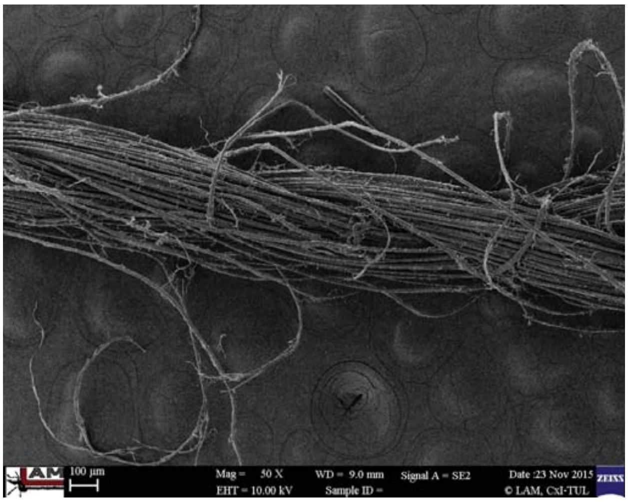

Fig. 4 SEM image of sample 1A after sewing (4000r/min)

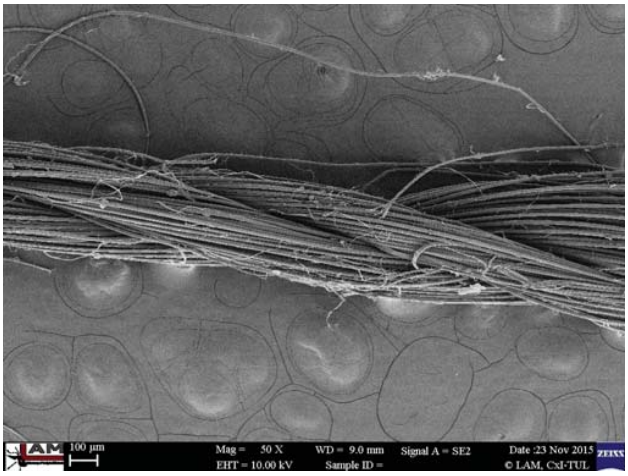

Fig. 5 SEM image of sample 1B before sewing

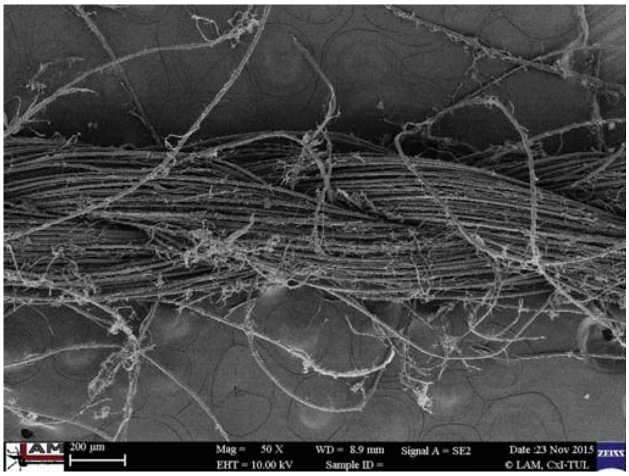

Fig. 6 SEM image of sample 1B after sewing (4000r/min)

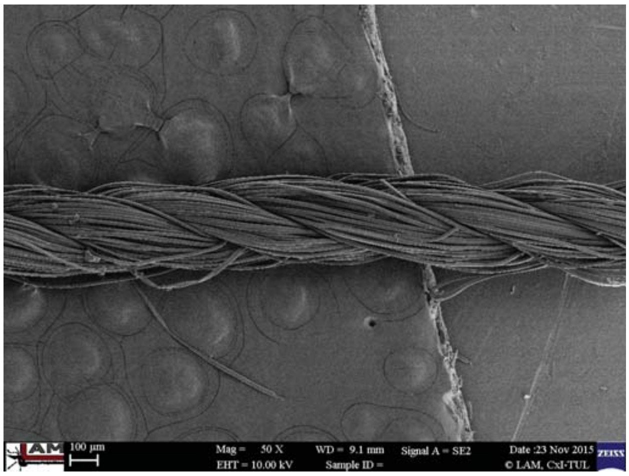

Fig. 7 SEM image of sample 2A before sewing

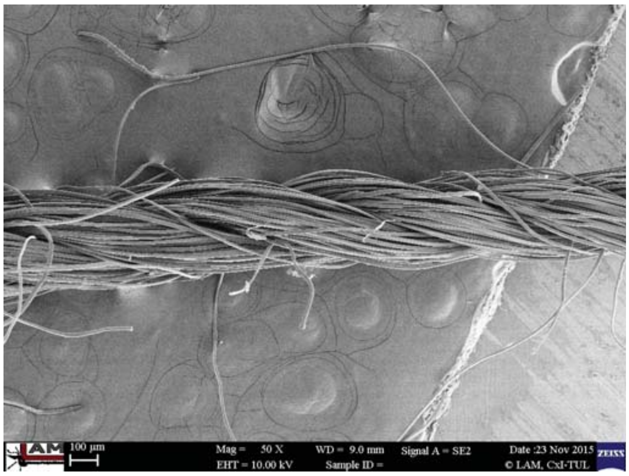

Fig. 8 SEM image of sample 2A after sewing (4000r/min)

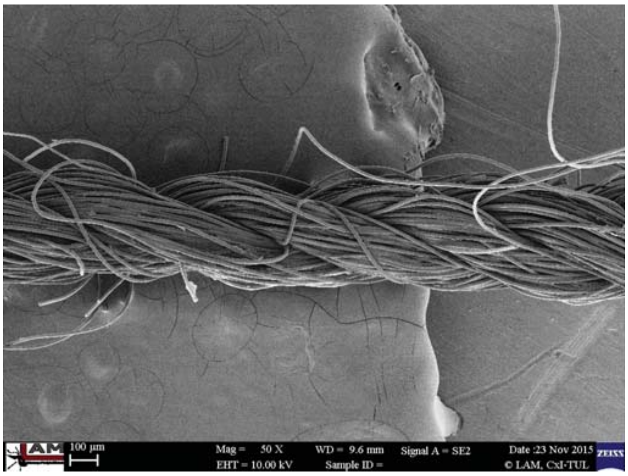

Fig. 9 SEM image of sample 3B before sewing

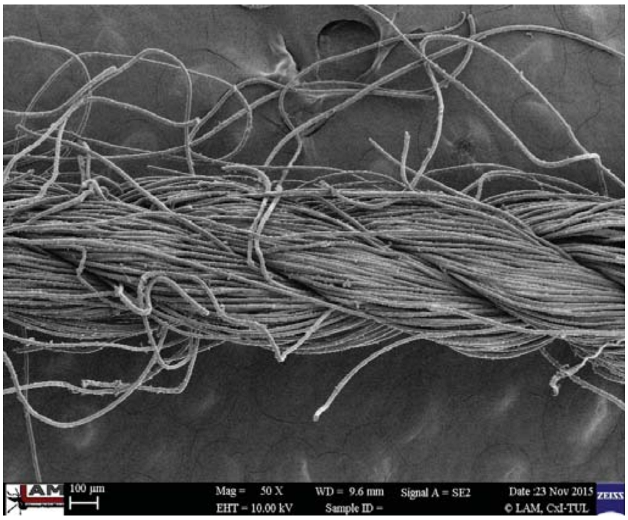

Fig. 10 SEM image of sample 3B after sewing (4000r/min)

The selected samples presented here shows the effect of sewing speed on the Meta-Aramid, the surface damage is visible but comparatively less as compared to the Kevlar thread. Even though the coefficient of friction of Kevlar thread is less as compared to the Meta-Aramid but visible friction damage is much more, which can be because of forward and backward motion of the thread in the needle eye and may have caused the Kevlar fibers to open and get more damage. The images of sample 2A are shown before and after the sewing process under SEM in Figs. 7 and 8.

Figs. 9 and 10 show the effect of sewing process on the Meta-Aramid thread (3B).

IV. Conclusion

The following is concluded from this research:

The tensile strength of the sewing threads significantly decreases with the speed of the machine. The abrasion and friction during high speed sewing causes yarn and fiber breakage. There is no melting spots observed on the sewing thread after sewing process but the needle temperature reaches 300^0C; which is much higher than the glass transition temperature of Kevlar and Meta-aramid fibers. The Electron microscope images shows the effect of sewing speed on the sewing thread; the damage is more for the Kevlar and least for the long-staple meta aramid fibers. The sewing speed should not be higher than 2000r/min when working with aramid threads as there is significant tensile strength loss at higher speeds.

Acknowledgment

The author is thankful to the company *Coats, Turkey* for providing the sewing threads.

References

[1] Seidt J. D., Matrka T. A., Gilat A., et al. Tensile behavior of Kevlar 49 woven fabrics over a wide range of strain rates. Conf Proc Soc Exp Mech Ser 2011; 99: 187–193.
[2] Aidani R. E., Dolez P. I. and Vu-Khanh T. Effect of thermal aging on the mechanical and barrier properties of an e-PTFE/NomexVR moisture membrane used in firefighters' protective suits. J Appl Polym Sci 2011; 121:pp 3101–3110
[3] DuPont. Technical guide for NOMEX brand fiber, July 2001 (accessed: March 2014).
[4] Nomex fabric characteristics, http://www.coverallsale.com /nomex-fabric-characteristics.htm (accessed March, 2014).
[5] Winkler, G. Modern sewing threads. In: 4th International Seminar on Developments in Production and Application. Shirley Institute, Manchester, 1971,pp 1–21.
[6] Mazari, A., Havelka, A., Kus, Z. The effects of Lubricant amount on sewing needle temperature and tensile properties of Polyester-polyester core-spun thread. Industria Textila, 2015, 66(2), pp 97-102.
[7] Mazari, A., Havelka, A., Wiener, J. and Zbigniew, R. A study on DLC-coated industrial lockstitch sewing needle. Industria Textila, 2015, 66(1),pp 43-47.
[8] Sundaresan, G., Hari, P. K., and Salhotra, K. R. Strength reduction in sewing Threads during High Speed Sewing in an Indus- trial Lockstitch machine: Part I: Mechanism of Thread Strength Reduction. International Journal of Clothing Science and Technology, 1997, 9(5),pp 334–335.
[9] Gersak, J., Rheological properties of threads: their influence on dynamic loads in the sewing process. International Journal of Clothing Science and Technology, 1995, 7(2/3), 71–80.
[10] Midha, V. K., et al. Effect of high speed sewing on the tensile properties of sewing threads at different stages of sewing. International Journal of Clothing Science & Technology, 2009, 21(4),pp 217 – 238.
[11] Mazari, A., Bal, K., Havelka, A., Temperature distribution on sewing needle at high speed industrial sewing lockstitch machine,Vlakna a Textil, 2015 (1), pp. 37-39.
[12] Ferriera, F. B. N. Harlock, S. C., and Grosberg, P. A Study of Thread Tensions on Lockstitch Sewing Machine, Part-I. International Journal of Clothing Science & Technology, 1994, 6(1), pp 14–19.
[13] Ajiki, I., and Postle, R. Viscoelastic properties of threads before and After Sewing International Journal of clothing Science & Technology, 2003, 15(1), pp 16– 27.
[14] Mazari, A. and Havelka, A. Sewing needle temperature of an Industrial lockstitch machine. Industria Textila, 2014, 65(6),pp 335-339.
[15] Mazari, A., Bal, K. and Havelka A. Prediction of needle heating in an industrial sewing machine. Textile Research Journal, DOI:10.1177/0040517515586160, 2015.
[16] Stylios, G. K. The mechanics of stitching. A volume in Woodhead publication series in textiles, Heriot-Watt University, UK 2013, pp 47-61.
[17] Mazari A., Havelka A. and Hes L. Experimental techniques for measuring sewing needle temperature, Tekstil ve Konfesiyon, 2014,1, pp 111-118.