(REFEREED RESEARCH)

INVESTIGATION OF DEXTERITY, MECHANICAL PROPERTIES, AND BURNING BEHAVIOR OF PROTECTIVE GLOVES PRODUCED WITH HIGH PERFORMANCE YARNS

YÜKSEK PERFORMANSLI İPLİKLERLE ÜRETİLMİŞ KORUYUCU ELDİVENLERİN MAHARET, MEKANIK ÖZELLİKLERİ VE YANMA DAVRANIŞLARININ İNCELENMESİ

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ABSTRACT

Using protective gloves is the most efficient way to reduce accidents at workplace because hands are often exposed to injuries. To reduce weight and thickness and to improve the dexterity and protection from injuries, gloves are now being made from high performance yarns. In this study para-aramid, meta-aramid, and 95/5% meta-aramid/para-aramid yarns were used to manufacture protective gloves on a 13 Gauge glove knitting machine. Dexterity test was carried out as proposed in EN 420 standard and mechanical risks such as cut, puncture, tear and abrasion were determined according to EN 388. The burning behavior of the gloves was measured in accordance with EN ISO 15025. The results revealed that para-aramid gloves are offering the highest protective performance. The dexterity of all the gloves performed the highest level. It was observed that blending of 5% para-aramid fibers with meta-aramid fibers reduce shrinkage of the fabric and prevents the fabric break-opening during flame exposure as well as improving the cut, tear and puncture resistance of the gloves.

Keywords: Protective gloves, aramid fibers, EN 388, glove dexterity, mechanical properties, burning behavior

Çalışma yerlerinde sürekli iş kazalarına maruz kalan ellerimizi korumanın en etkili yolu koruyucu eldiven kullanmaktır. Günümüzde eldivenler, hafif ve ince olmalarıyla el maharetini geliştiren ve yaralanmalardan koruyan yüksek performanslı ipliklerle üretilmektedir. Bu çalışmada para-aramid, meta-aramid ve %95/5 meta-aramid/para-aramid karışımıyla üretilmiş iplikler kullanılarak 13G eldiven makinasında eldivenler üretilmiştir. Kesme, delinme, yırtılma ve aşınma dayanımı gibi mekanik riskler EN 388 standardına uygun olarak ölçülmüştür. Ayrıca eldivenlerin mahareti ve yanma davranışları sırasıyla EN420 ve EN ISO 15025 standartlarına göre incelenmiştir. Test sonuçlarına göre para-aramid eldivenler en yüksek koruyucu performansı göstermiştir. Para-aramid liflerinin %5 olarak meta-aramid lifleriyle harmanlanması aleve maruz bırakıldığında kumaştaki büzülmeyi azaltarak kumaş kırılması ve açılmalarını önlemiştir. Bunun yanı sıra kesme, delinme ve yırtılma dayanımı değerlerinde iyileşme gözlenmiştir. Üretilen tüm eldivenler maharet testinde en yüksek seviyeyi yakalamıştır.

Anahtar Kelimeler: Koruyucu eldivenler, aramid lifleri, EN 388, eldivenlerde maharet, mekanik özellikler, yanma davranışı

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INTRODUCTION

According to International Labour Organization (ILO) statistics, approximately 2 million and 2 thousand people have been passing away every year, due to the occupational accidents and diseases [1]. Regarding the incidence of occupational accidents, Turkey took the first place in Europe and third place in the world [2]. Based on the work injury reports of Social Security Institution (Turkey), between 2011 and 2013, hand and finger injuries represented a large group of the accidents (40% of total 70 thousand accidents per year) [3]. To prevent our hands, which are the most important tools we use, the best solution is to wear protective gloves [4].

Protective gloves are a part of protective technical textiles (Protech) and they are especially used by military, security forces, firemen, rescue teams, miners and workers in the road construction, nuclear plants, chemical, electrical/ electronic and heavy industry sectors to ensure an optimal level of protection against encountered risks.

Protective gloves adapted to a specific type of risk do help protect the hands. Wearing them can help prevent slight to moderate injuries [5-7]. However, at the same time, protective gloves can significantly reduce work performance by affecting dexterity [8-9], tactile sensitivity [10-13], grasp force [14] and hand movement [15], especially when the glove material is thick. These are the main reasons workers give for not wearing gloves. Among workers who do wear gloves, some have a habit of altering their gloves, by cutting off the fingertips, for instance, to increase their dexterity. The feeling that gloves interfere with work is a major factor in a worker's decision about whether to wear them or not. Dexterity is therefore just as important for worker safety as actual protective properties, because they have a significant bearing on a worker's willingness to wear gloves [16].

There are many different types of protective gloves available on the market as personal protective equipment (PPE). Knitted gloves are the most useful types of gloves for activities implying objects manipulation or light assembly activities. They have the following advantages over other types of gloves: better fit on the wearer's hand given by increased formability of knitted fabrics, one stage knitting process, and the possibility of using high performance yarns [17-19].

Fibers used as raw material in protective gloves definitely differ from the conventional fibers and have superior properties. These technical fibers, which are also known as "high performance fibers", are generally derived from synthetic fibers (Meta-aramid: Nomex/Dupont, Teijin Conex/Teijin, X-Fiper/SRO Aramid Co. Ltd. and Para-aramid: Kevlar/DuPont, Twaron/Teijin, ultra-high-molecular-weight polyethylene fiber Spectra/Honeywell or Dyneema/DSM [20].

There are several studies [17, 21-28] on the characteristics of protective gloves. Ciobanu et al. performed a study regarding the technical solutions of producing knitted gloves on various knitting machines seeking innovative solutions for glove fingers, connection between fingers, glove border, thumb position, with the purpose of developing protective knitted gloves in one low cost manufacturing stage [17]. Irzmanska and Stefko proposed a method for determining the end of service life of all-rubber and polymer-coated gloves protecting against mineral oils and selected mechanical factors [21]. Dolez et al. investigated resistance to mechanical risks (cutting, puncture and tearing) of protective gloves used in metal working companies and garages which were exposed to relevant oils and greases [22]. Özdemir, compared mechanical properties of some protective gloves coated with latex and nitrile and found that nitrile coated gloves had higher abrasion and puncture values whereas latex coated gloves had higher tear resistance [23]. Harrabi et al. examined 23 gloves with different thickness values and reported that rubber coated gloves which are more rigid and thicker had higher cut and puncture resistance [24]. Klapötke et al. developed an experimental setup to test the performance of protective gloves under conditions similar to exploding glass ware in direct vicinity to the protected hand and found that that steel interwoven Kevlar® gloves or thick leather welding gloves or a combination of both provide fair protection against fragments from exploded glassware in case that mechanical manipulators are not at hand [25]. Flambard et al. used para-aramid fibres with first choice and second choice qualities and reported that the weight loss of recycled para-aramid fibres was 40% after 1000 cycles and the best behavior was obtained by first choice Kevlar ® which exhibited a weight loss of 30% after 2500 cycles [26]. Alpyıldız et al. developed a new double-face knitted structure which is composed of tuck stitches and has the same back and front faces manufactured from para-aramid fibres with and without inlay yarns and concluded that the newly derived structure with inlay yarns has the best cut and stab performances when a comparison is made between samples of different structures with the same mass per unit area and thickness values [27]. Ertekin and Kırtay investigated the cut, abrasion, puncture and tear resistance of plain woven fabrics produced with aramid core-spun yarns and found that decreasing core/sheath ratio of the hybrid yarns led to the increase in weight and thickness, resulting in improved cut, abrasion and puncture resistance properties [28].

In this study, it is aimed to investigate the effect of raw materials on the mechanical performance properties of the gloves according to EN 388. The intended use of the gloves was planned as protection against mechanical risks for several industrial applications. Besides mechanical performance characteristics, dexterity and burning behavior of the gloves, which play also very important roles in some of the industrial applications were also discussed.

MATERIALS AND METHODS

Fiber characteristics

Para-aramid, meta-aramid, and blend of 95/5% meta-aramid/para-aramid yarns were used to manufacture protective gloves. Tensile strength and elongation properties of the fibers were measured according to TS EN ISO 5079 standard are given in Table 1.

Table 1. Fiber properties

Fiber type	Mean fiber length/Fineness (mm/dtex)	Fiber tensile strength (cN/tex)	Fiber elongation (%)
Para –aramid (Twaron®)	38/1.7	134.5	4.2
Meta-aramid (X-Fiper®)	50/2.2	39	37

Production of yarns

Yarns used to manufacture the gloves were first spun on a laboratory ring frame (Pinter Merlin) with a linear density of 30Ne (20tex) and α_e=3,5 twist factor. Two yarns of 30Ne (20 tex) were fed to the glove knitting machine and this caused the plain knitted glove fabric to bias (Figure1a). In order to balance the yarns, an Ağteks DirecTwist® machine was used to fold the single yarns on the "S" direction with 300 TPM (turns per meter).

Production of gloves

The gloves were than plain knitted on a 13 Gauge full automatic Jomda glove knitting machine with same settings by using 30/2 Ne (20x2 tex) above mentioned yarns and with an average weight of 125 gr/m^2 (124, 125, 123 g/m^2 of para-aramid, meta-aramid and 95/5%meta-aramid/para-aramid yarns, respectively) (Figure 1b).

(a) (b)

Figure 1. (a) Gloves produced with single yarns (z twist) and two folded yarns (s twist) (b) Glove knitting machine

Methods

Dexterity

The test method used to measure dexterity is that found in EN 420 (Protective gloves: General requirements and test methods), whereby a subject wearing gloves must pick up five metal pins of increasingly smaller diameters: 11.0, 9.5, 8.0, 6.5 and 5.0 mm. The dexterity offered by the test glove is rated according to the smallest-diameter pin that the subject can pick up three times consecutively within 30 seconds. The finer the pin that can be picked up, the better the dexterity provided by the glove [29]. The performance levels of the dexterity is given in Table 2.

Table 2. Performance levels of dexterity according to EN 420

Performance level	The diameter of the metal pins (mm)
1	11.0
2	9.5
3	8.0
4	6.5
5	5.0

Mechanical properties

EN 388 specifies the requirements, test methods, marking and user information for protective gloves against mechanical risks. These risks are abrasion, puncture, tear and cut. Abrasion, puncture and tear resistance are classified into four (4) performance levels. Blade cut resistance is classified into five (5) performance levels. A glove to be certified as a glove against mechanical risks shall meet minimum one (1) level of these four (4) properties. In all cases, [0] indicates the lowest level of performance (Table 3).

Abrasion Resistance

Four test specimens of each type cut from the palms of gloves are abraded under known pressure on a Martindale Abrasion tester using an abrasive paper (OAKEY Glass Quality Cabinet Paper Grade F2, Grit 100). The resistance to abrasion is measured by the number of cycles required for breakthrough to occur. Breakthrough is understood to mean when a hole is worn through the test specimen.

Puncture resistance

Puncture resistance is measured as the force required to break through fabric samples with a standard puncture needle mounted on a Zwick/Roell Z010. The test is performed on four specimens and the classification is determined by the lowest force value recorded.

Tear resistance

The resistance to tear is defined as the force necessary to propagate a tear in a rectangular specimen slit half way along its length. Trouser-type samples were made from 100 × 50 mm strips with a 50-mm longitudinal incision on one side. The two legs of the trouser-shaped sample were secured in the grips of a mechanical test frame and pulled apart at a constant rate of 100 mm/min. Force-displacement data were continuously recorded, making the determination of the maximum value of the force possible. Four samples were measured for each sample and each condition. These four samples were cut in the palm section of four different specimens, two longitudinally and two transversally. Resistance to tearing was provided by the lowest value of the maximum forces corresponding to these four samples.

Cut resistance

Cut resistance is defined as the potential of the material to resist cutting with a sharp blade, which can be determined by means of various test and evaluation methods, depending on the tool which caused the cuts. Cutting the material requires the movement of a cutting element (a blade, knife) exerting appropriate force until the material integrity is disrupted [30]. Cut resistance was measured by Mesdan Cut Tester. Specimens are cut by a counter-rotating circular blade, which moves with an alternating motion under a specified load (500g/5N). For each glove series, two test specimens were taken and five tests shall be made on each test specimen according to the sequence with reference fabric described in the standard. A cut resistance index based on the data of these two materials is calculated [31].

Table 3. Performance levels according to EN 388

	Performance Level Rating					
Test/Evaluation	0	1	2	3	4	5
Abrasion resistance (cycles)	<100	>100	>500	>2000	>8000	-
Blade cut resistance (index)	<1.2	>1.2	>2.5	>5.0	>10.0	>20.0
Tear resistance (newton)	<10	>10	>25	>50	>75	-
Puncture resistance (newton)	<20	>20	>60	>100	>150	-

Burning Behavior

The burning behavior of the gloves were measured in accordance with EN ISO 15025 and evaluated as required in EN ISO 11612 for code letter A1. This method assesses the properties of textile fabrics in response to a short contact with a small igniting flame under controlled conditions. A flame with a height of 25 mm produced by a propane gas burner in height is exposed to the surface of the sample at a distance of 17 mm for 10 seconds. Afterflame and afterglow mean times are calculated and shall be ≤ 2 s. To meet the requirements for code letter A1, no flaming to the top or either side edge is allowed and no sample shall melt or give hole formation or molten debris [32].

Statistical Evaluation

Besides performance grading of the results according to EN 388, individual test results of puncture, tear and cut resistance were evaluated statistically using variance analysis. Any differences for each dependent variable are considered to be significant if the p-value was equal to or less than 0.05. In order to determine whether the effects of raw materials on measured parameters are significant or not, variance analysis is carried out by using Duncan multiple comparison procedure. The result of tests is a set of subsets of means where in each subset means have been found not to be significantly different from one another.

RESULTS AND DISCUSSIONS

The measured characteristics such as dexterity and mechanical property (abrasion, puncture, tear and cut resistance) are summarized in Table 4.

Dexterity

Dexterity is related to the skill, motion speed and control of the fingers and hands while handling objects. Hand dexterity is affected by several glove characteristics, especially the way a glove fits the hand, its flexibility and its grip adhesion. Para-aramid gloves were more rigid than meta-aramid and 95/5% meta-/para-aramid gloves. This is due to the low elongation properties of para-aramids [33]. But this characteristic did not affect the dexterity. All types of gloves manufactured in this study had performance level of "5" according to Table 2. This situation might be explained by the low thickness values of the plain knitted gloves. It is well established that glove thickness affects finger dexterity. All of the researchers who investigated the thickness of gloves on dexterity performance found that using thicker gloves compared to thinner ones, and/or using multiple layers decreased dexterity performance [34-37].

Abrasion resistance

While testing the abrasion resistance properties of the gloves, it was observed that all samples were worn out after 100 cycles indicating performance level "1". The abrasion of textiles is affected by numerous factors related to the textile material, the environment in which the tests are conducted and testing conditions. Factors concerned with textile material are fiber type, fiber properties, yarn twist, fabric structure and surface characteristics (hairiness, smooth, finishing, etc.). The most important factors regarding the procedure of performing tests are abrasion type, abradant type, pressure, speed, tension, the direction of abrasion, the duration of wear etc. [38, 39]. In this study, the same fibre type and fabric construction were used, so these parameters have not any effect on abrasion. This result is because of the abradant used in the testing, that is very strong for the fabrics at this weight level and without coating.

Puncture resistance

The puncture results (Table 4) revealed that para-aramid and 95/5% meta-/para-aramid gloves have performance level 1, whereas meta-aramid glove indicates the lowest level of performance.

As it can be observed in Figure 2 and was confirmed by variance analysis (Table 5), there is a significant influence of the raw material type on the puncture resistance. The resistance to puncture depends on the material, the cross-section of the yarns, their strength and the support points in the base fabric [40, 41]. Para-aramid fiber containing gloves have higher resistance than 100% meta-aramid glove. This can be explained by the tensile strength properties of para-aramid fibers [42]. Para-aramid fibers with high tensile strength and more rigid characteristics tend to be less stretched and the yarns will not move in course and wale directions easily, this lead to an increase in puncture resistance property [41].

Table 4. Measured parameters of the gloves

Parameter	Material	Measured values	Performance Level
Dexterity	Para-aramid	5.0 mm (diameter of the metal pin)	5
	Meta-aramid		5
	95/5% meta-/para-aramid		5
Abrasion Resistance (Cycles)	Para-aramid	100	1
	Meta-aramid	100	1
	95/5% meta-/para-aramid	100	1
Puncture Resistance (Newton)	Para-aramid	29.9	1
	Meta-aramid	18.8	0
	95/5% meta-/para-aramid	22.8	1
Tear Resistance (Newton)	Para-aramid	30.5	2
	Meta-aramid	21.6	1
	95/5% meta-/para-aramid	19.9	1
Cut Resistance (Index)	Para-aramid	**I_1: 2.91** I_2: 2.99	2
	Meta-aramid	I_1: 1.71 **I_2: 1.67**	1
	95/5% meta-/para-aramid	**I_1: 1.95** I_2: 1.99	1

Tear resistance

According to EN 388 standard, the tear resistance of para-aramid glove performed level "2" and meta-aramid containing gloves had performance level "1". Tearing strength is shown to be dependent mainly on the spacing and strength of the yarns being torn and the force required to make them slip over the crossing yarns [43]. Para-aramid glove has higher resistance to tear and has statistically different from meta-aramid containing gloves, due to the high tensile strength of the para-aramid fiber. A slight difference is observed between the meta-aramid and 95/5% meta-/para-aramid gloves' tear resistance values, which is a result of the 5% para-aramid fiber in the blend (Figure 2 and Table 5).

Cut resistance

The cut resistance of a fabric is determined by several factors, including the material used in the fabric's construction, the weight of the fabric per unit area, the type of weave, the number of threads and stitches per unit area and the presence of coatings [44, 45]. In this study, gloves manufactured with inherently cut resistant [46] para-aramid fibers have higher cut resistance (performance level 2) followed by 95/5% meta-/para-aramid and meta-aramid gloves (performance level 1) and was also confirmed by variance analysis (Table 5).

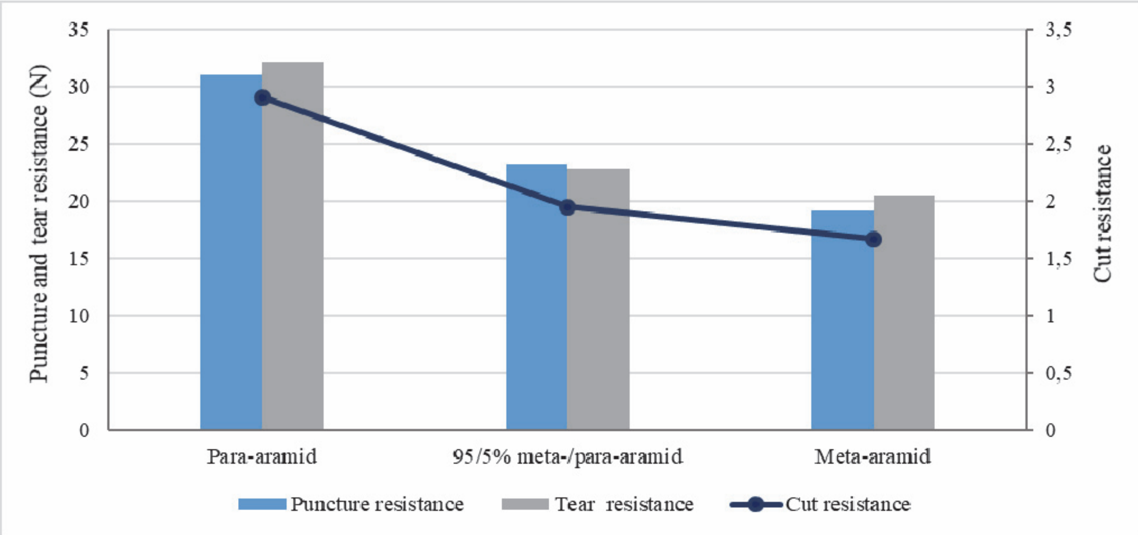

Figure 2. Puncture, tear and cut resistance test results

Table 5. Variance analysis of puncture, tear and cut resistance results

Puncture resistance (p=.000)				
		Subset for alpha = 0.05		
Fabric type	N	1	2	3
Meta-aramid	4	19.2		
95/5% meta-/para-aramid	4		23.2	
Para-aramid	4			31.05
Sig.		1.000	1.000	1.000
Tear resistance (p=.000)				
		Subset for alpha = 0.05		
Fabric type	N	1	2	3
Meta-aramid	4	20.55		
95/5% meta-/para-aramid	4		22.78	
Para-aramid	4			32.23
Sig.		1.000	1.000	1.000
Cut resistance (p=.000)				
		Subset for alpha = 0.05		
Fabric type	N	1	2	3
Meta-aramid	5	1.67		
95/5% meta-/para-aramid	5		1.95	
Para-aramid	5			2.91
Sig.		1.000	1.000	1.000

Burning Behavior

Para-aramid samples did not shrink and no holes or break-opening occurred on the fabric. However, that can be classified as restrictive for fire protection clothing. When exposed to flames, para-aramid fibers absorb hardly any heat energy [47] as seen in Figure 3 (a), so a large proportion of the energy can penetrate the fabric. While testing meta-aramid specimens, shrinkage and fabric break-opening occurred after 4 seconds (Figure 3(b)). In flame 100% meta-aramid garments exhibit some shrinkage, which in turn can lead to fabric ‘‘break opening’’ and loss of protective barrier. At higher exposure to flame, meta-aramid fibers carbonize and form a tough char at a temperature of ~800ºF (427ºC). The intumescent nature of the char provides additional protection [48]. The gloves produced with 95/5% meta-/para-aramid yarns had a lower shrinkage than meta-aramid gloves and fabric break opening did not occur which is due to the %5 para-aramid fibers within the blend (Figure 3(c)). Blends with para-aramids are often utilized to stabilize the protective garment against shrinkage and to reduce fabric ‘‘break-open’’ during flame exposure [48]. All samples extinguished immediately after the flame is removed.

CONCLUSIONS

In this study, it is aimed to investigate the effect of raw materials on the mechanical performance properties of the gloves according to EN 388. The intended use of the gloves was planned as protection against mechanical risks for several industrial applications. Besides mechanical performance characteristics, dexterity and burning behavior of the gloves, which play also very important roles in some of the industrial applications were also discussed. Major conclusions from this study are summarized as follows:

- All gloves had the maximum level “5” of dexterity test, although para-aramid glove felt more rigid to the skin. Meta-aramid and 95/5% meta-/para-aramid gloves were found to be softer and more flexible.
- All gloves had a performance level of “1” for abrasion resistance.
- Para-aramid containing gloves had higher puncture resistance properties (performance level 1) than meta-aramid glove.
- Para-aramid gloves showed performance level “2” for cut and tear resistance followed by 95/5% meta-/para-aramid and meta-aramid gloves.
- All gloves extinguished immediately after the flame is removed. They did not melt or drip.
- It was observed that blending of 5% para-aramid fibers with meta-aramid fibers reduce shrinkage of the fabric and prevents the fabric break-opening during flame exposure as well as improving the cut, tear and puncture resistance of the gloves.

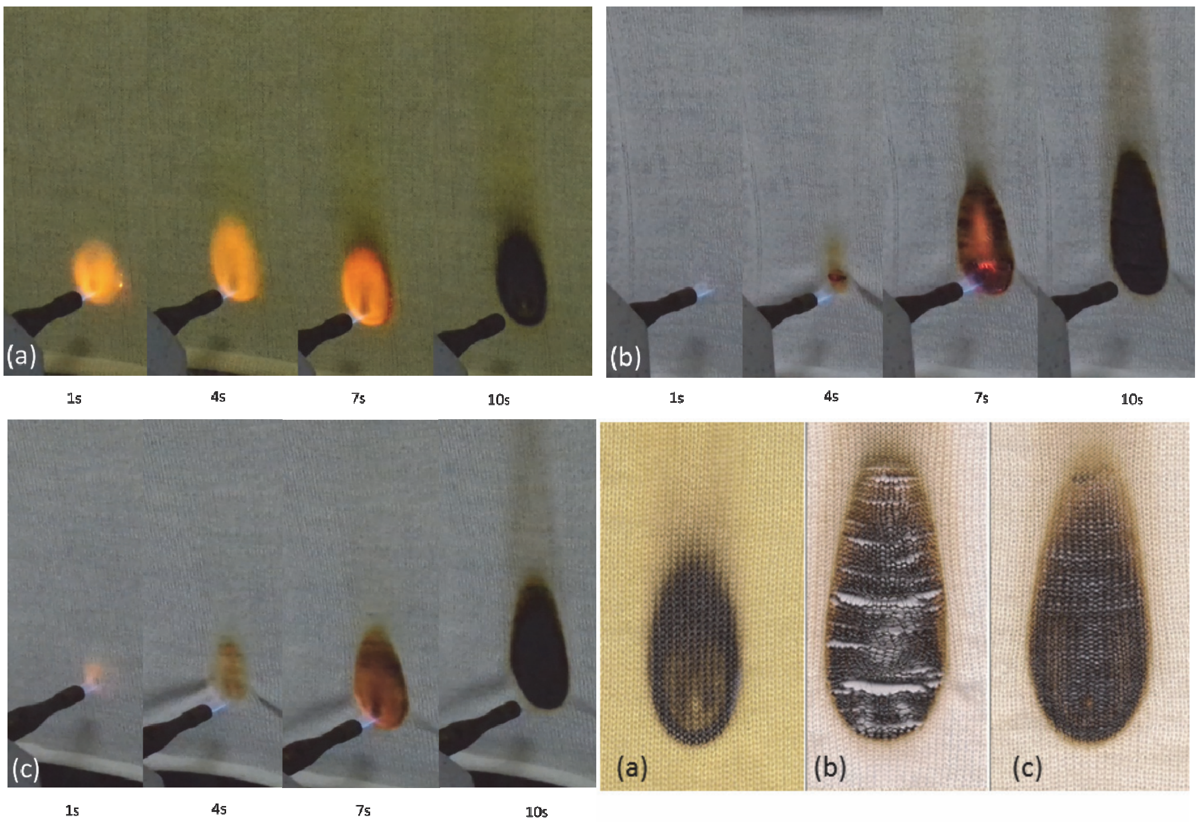

Figure 3. Image sequences of the flame spread for ten seconds (a) Para-aramid (b) Meta-aramid (c) 95/5% meta-/para-aramid glove

Gloves are the final physical barrier between hazard and skin. There are no gloves that provide simultaneous protection for all types of existing hazards. The variety of existing gloves depends on the type of protection they must provide; so, they must be chosen with great precision according to the risks the workplace, and individual tasks involve.

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REFERENCES

1. İş sağlığı ve güvenliği, Available from: https://goo.gl/Lviomi (Accessed at 05.06.2017).
2. İş kazalarında Avrupa birincisiyiz, Available from: https://goo.gl/a9Bi7f (Accessed at 12.06.2017).
3. T.C. Sosyal Güvenlik Kurumu iş kazaları, SGK istatistikleri, Available from: www.ssk.gov.tr (Accessed at 12.06.2017).
4. Davas Aksan, A., Durusoy, R., Bal, E., Kayalar, M., Ada, S. and Tanık, F. A., 2012, "Risk factors for occupational hand injuries: Relationship between agency and finger", Am. J. Ind. Med., 55: 465–473.
5. Hertz, R. P.; Emmett, E. A., 1986, "Risk factors for occupational hand injury", J Occup Med, Vol. 28, No 1, 1986, p. 36-41.
6. Sorock, G. S.; Lombardi, D. A.; Peng, D. K.; Hauser, R.; Eisen, E. A.; Herrick, R. F.; Mittleman, M. A., 2004a, "Glove use and the relative risk of acute hand injury: a case-crossover study", Journal of Occupational and Environmental Hygiene, Vol. 1, No 3, p. 182-190.
7. Sorock, G. S.; Lombardi, D. A.; Hauser, R.; Eisen, E. A.; Herrick, R. F.; Mittleman, M. A., 2004b, "A case-crossover study of transient risk factors for occupational acute hand injury", Occup Environ Med, Vol. 61, No 4, p.305-311.
8. Bradley, J. V., 1969, "Glove characteristics influencing control manipulability", Human Factors, Vol. 11, No 1, p. 21-36.
9. Bradley, J. V., 1969, "Effect of gloves on control operation time", Human Factors, Vol. 11, no1, 1969, p. 13-20.
10. Bishu, R. R.; Klute, G.; Kim, B., 1993, The Effects of Extra Vehicular Activity (EVA) Gloves on Dexterity and Tactility. Designing for Diversity. The Human Factors and Ergonomics Society, Vol. 2, p.826-830.
11. Brunick, A. L.; Burns, S.; Gross, K.; Tishk, M.; Feil, P., 1990, "Comparative study: the effects of latex and vinyl gloves on the tactile discrimination of first year dental hygiene students", Clinical Preventive Dentistry, Vol. 12, No 2, p. 21-25.
12. Chandler, N. P.; Bloxham, G. P., 1990, "Effect of gloves on tactile discrimination using an endodontic model", Int Endod.J, Vol. 23, No 2, p. 97-99.
13. Woods, J. A.; Leslie, L. F.; Drake, D. B.; Edlich, R. F., 1996, "Effect of puncture resistant surgical gloves, finger guards, and glove liners on cutaneous sensibility and surgical psychomotor skills", J Biomed Mater Res, Vol. 33, No 1, p. 47-51.
14. Kinoshita, H., 1999, "Effect of Gloves on Prehensile Forces during Lifting and Holding Tasks", Ergonomics, Vol. 42, No 10, p. 1372-1385.
15. Bellingar, T. A.; Slocum, A. C., 1993, "Effect of Protective Gloves on Hand Movement: An Exploratory Study", Applied Ergonomics, Vol. 24, No 4, p. 244-250.
16. Gauvin C., Lara J., 2013, "Worker Evaluation of Manual Dexterity, Tactile Sensitivity and Comfort When Wearing Needlestick-Resistant Gloves,Exploratory Study", IRSST Report.
17. Ciobanu R., Ionesi D., Budulan C., 2010, "Protective Gloves Against Mechanical Hazard", TEXSCI, September 6-8, Czech Republic.
18. Ertekin,G., Oğlakcıoğlu, N., Marmaralı, A., 2012, "High Tenacity Weft Knitted Fabrics for Protective Garments , 46th IFKT Congress, Romania.
19. Oğlakçıoğlu, N., Ertekin, G., Marmaralı, A., 2014, "Yüksek Performanslı İpliklerden Üretilen Örme Kumaşların Mekanik Etkilere Karşı Dayanımlarının İncelenmesi", Tekstil ve Mühendis, 21(95).
20. Hearle, J.W.S., 2001, High Performance Fibers, Textile Institute, CRC Woodhead Publishing.
21. Irzmanska, E., Stefko, A., 2015, Simulation Method for Assessing the End of Service Life of Gloves Used by Workers Exposed to Mineral Oils and Mechanical Factors, International Journal of Industrial Ergonomics, 47, 61-71.
22. Dolez, P., Soulati, K., Gauvin, C., Lara, J., Vu-Khanh, T., 2012, Information Document for Selecting Gloves for Protection Against Mechanical Hazards, Available from: https://www.irsst.qc.ca/gants/en/InfoDocu.pdf, Accessed at 06.04.2017.
23. Özdemir, F., 2011, Mekanik Risklere Karşı Koruyucu Eldivenlerin Performanslarının İyileştirilmesi Üzerine Çalışmalar, Yüksek Lisans Tezi, Ege Üniversitesi, İzmir.
24. Harrabi, L., Dolez, P.I., Vu-Khanh, T., Lara, J., Tremblay, G., Nadeau, S., Lariviere, C., 2008, Characterization of Protective Gloves Stiffness: Development of a Multidirectional Deformation Test Method, Safety Science, 46, 7, 1025-1036.
25. Klapötke, T.M., Krumm, B., Mayr, N., Steemann, F.X., Steinhauser, G. Safety Testing of Protective Gloves, Available from: http://publik.tuwien.ac.at/files/PubDat_169519.pdf, Accessed at 06.04.2017.
26. Flambard, X., Ferreira, M., Vermeulen, B., Bourbigot, S., & Poutch, F., 2003, Mechanical and Thermal Behaviors of First Choice, Second Choice and Recycled P-Aramid Fibres, Journal of Textile and Apparel, Technology and Management, 3, 2, 1-13.
27. Alpyıldız, T., Rochery, M., Kurbak, A., Flambard, X., 2011, Stab and Cut Resistance of Knitted Structures: A Comparative Study, Textile Research Journal, 81, 2, 205–214.
28. Ertekin, M., Kirtay, H.E., 2016, "Cut resistance of hybrid para-aramid fabrics for protective gloves", The Journal of The Textile Institute, 107(10), 1276-1283.
29. EN 420 Standard. 2010, "Protective gloves - General requirements and test methods"
30. Irzmańska, E., Stefko, A., 2012, "Comparative evaluation of test methods for cut resistance of protective gloves according to polish standards", Fibres & Textiles in Eastern Europe.
31. EN 388 Standard, 2003, "Protective Gloves Against Mechanical Risks".
32. EN ISO 15025 Standard, 2017, "Protective clothing - Protection against heat and flame - Method of test for limited flame spread".
33. Lewin, M., ed., 2007, "Handbook of Fiber Chemistry", Crc Press, p. 1014.

34. Pourmoghani, M., 2004, “Effects of gloves and visual acuity on dexterity”, Graduate Thesis, University of South Florida, USA, p.31.
35. Bensel, C.K., 1993, “The effect of various thicknesses of chemical protective gloves on manual dexterity”, Ergonomics, 36, 687-696.
36. McIntosh, J.D., 1987, “A manual dexterity methodology and evaluatıon of selected chemical protective gloves”, West Virginia University, Morganton.
37. Plummer, R. et al., 1994, “Manual dexterity evaluation of gloves used in handling hazardous materials”, West Virginia University, Department of Industrial Engineering.
38. Saville, B.P., 1999, Physical testing of textiles, Woodhead Publishing Limited, ISBN 1 85573 367 6, Cambridge, England.
39. Škoc, M. S., & Pezelj, E., 2012, Abrasion Resistance of High Performance Fabrics. In Abrasion Resistance of Materials. InTech, p.37.
40. El Messiry, M., 2014, “Investigation of puncture behaviour of flexible silk fabric composites for soft body armour”, Fibres & Textiles in Eastern Europe, 5, 71-76.
41. Fangueiro, R., Carvalho, R., Silveira, D., Ferreira, N., Ferreira, C., Monteiro, F. and Sampaio, S., 2015, “Development of high-performance single layer weft knitted structures for cut and puncture protection”, Journal of Textile Science and Engineering, 5, 225.
42. Gunnarsson, M., Nyman, J., 1998, “Short Fibre Reinforced Elastomers.”.
43. Kotb, N., El Geiheini, A., Salman, A., Abdel – Samad, A., 2009, “Engineering of tearing strength for pile fabrics”. Journal of Textile and Apparel, Technology and Management, 6(1), 1-8.
44. Vajko, R., 2008, “Making sense of cut resistance”, National Safety Ing.
45. Moreland, J. C., 2010, “Production and characterization of aramid copolymer fibers for use in cut protection”, Doctoral dissertation, Clemson University p.5.
46. Dunbar, James J., 1992,"Cut resistant yarn, fabric and gloves." U.S. Patent No. 5,119,512. 9.
47. Lawrence, C.A. ed., 2014, " High Performance Textiles and their Applications, Elsevier, p111.
48. Scott, R.A. ed., 2005, “Textiles for protection”. Elsevier, p. 536.