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Manufacturing of Industrial Fire Retardant Gloves using Blends of Cotton and Synthetic Fibers

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Abstract

The aim of this research work was to develop flame retardant gloves and describes the performance requirement as well as the design of specialized fabric to provide protection against thermal/flame hazards.Fabric flammability is affected by various factors such as Fibre composition, fabric construction, oxygen concentration and the environmental conditions (moisture content, heat, air flow), but the effects of finishing material fabrics cannot be overlooked. FR properties of 100 % knitted cellulose materials and their blends with Modacrylic fibres and Nomex were investigated in this paper. In order to design an optimal blending ratio different blend ratios were used. The flame behavior and thermal stability of knitted fabric were evaluated with different tests.

Keywords: Fire retardants gloves, Nomix fiber, Ballistic hazards.

Introduction

Modern technological developments have brought with them a vast increase in the kinds of hazards to which workers are exposed. The dangers are frequently so specialized that no single type of clothing will be adequate for work outside the normal routine. Some of the hazards to which workers are subjected are:

Hazards from

1. Extreme heat & fire, 2. Extreme cold, 3. Harmful chemicals and gases, 4. Bacterial/ viral environment, 5. Contamination, 6. Ballistic hazards, 7. Electrical hazards, 8. Radiation hazards

In the last decade, extensive work has been carried out in a number of laboratories to develop protective clothing for both industrial workers and the army. Protective clothing made from the woven,knitted and non-woven fabric has designed to suit specific requirements, and performance evaluation technologies to stimulate the work wear condition have been developed.

Safety and protective textiles refer to garments and other fabric-related items designed to protect the wearer from harsh environmental effects that may result in injury or death.

Fire science factors

Thermal protection relates to the ability of textiles to resist conductive, convective and radiant thermal energy or a combination of two or more. For example a flame constitutes a convective oxidative chemical reaction zone in which the energy is contained within the extremely hot gas molecules and particulates including smoke.

Table 1. Thermal properties of different Fibres

Fibre	Softening Temperature T_g°C	Melting Temperature T_m°C	Pyrolysis Temperature T_p°C	Ignition Temperature T_i°C	LOI %
Cotton	-	-	350	350	18.4

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Polyester	80-90	255	424-447	480	20-21
Nylon 6,6	50	265	403	530	20-21.5
Mod acrylic	<80	>240	273	690	29-30
Mata-aramids (Nomex)	275	375-430	425	>500	29-30
Para-aramids (Kevlar)	340	560(decompose)	>590	>500	29

Gloves and hand protection

For employees, workplace safety is synonymous with hand safety. Not only do gloves protect workers, they protect consumers in environments in which employees handle food. Facility managers in many workplaces also know that hand safety must comply with requirements.

Heat resistant gloves are made using high-quality raw material – the gloves are then chemically treated to give them a fine finish and to prolong their life span, and they can be easily customized to meet the needs of every client. Heat proof gloves offer enhanced protection against heat in critical temperature environments, which are usually common for those who work in the welding or manufacturing industry. Heat resistant gloves are essential in many different fields (especially in the steel manufacturing process), as they protect the hands against severe burns by keeping them cool and comfortable.

Types of gloves

Low heat proof gloves are durable and provide minimal protection against heat and abrasions – they are perfect insulators and they usually come with reinforced thumb, index finger and palm for the best protection. Generally speaking, this type of gloves can withstand temperatures of up to 400 degrees Fahrenheit.

High heat proof gloves offer an enhanced heat protection of 600 degrees Fahrenheit or above, they ensure efficient grip and they provide the best hand protection. On the other hand, fire-resistant gloves are especially designed to withstand open sparks or flames without melting – these gloves are made from top-notch materials and they usually have three or more material layers, for increased protection. They are very durable over the years and they are resistant to cuts and abrasions as well, thus being ideal for handling rough, sharp objects.

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Standards and methods

BS EN 659: 2003 + A1: 2008

A specialist standard for gloves used in firefighting that references test procedures from EN 420, EN 388 and EN 407 plus other specific tests for properties such as resistance to water and chemical penetration.

ASTM methods

- ASTM F 1060 - Standard Test Method for Thermal Protective Performance of Materials for Protective Clothing for Hot Surface Contact
- ASTM F 1930 - Standard Test Method for Evaluation of Flame Resistant Clothing for Protection Against Fire Simulations Using an Instrumented Manikin
- ASTM F 1939 - Standard Test Method for Radiant Heat Resistance of Flame Resistant Clothing Materials with Continuous Heating.
- ASTM F 2700 - Standard Test Method for Unsteady-State Heat Transfer Evaluation of Flame Resistant Materials for Clothing with Continuous Heating.

Materials and Methods

Cotton and its blends with Modacrylic and Nomex were used to produce a technical yarn by using rotor Spinning Technique on schlafhorst Autocoro SE-9. Fourteen different samples of yarns were prepared. Seven samples of 10s count and seven samples of 6s count.

Fibre parameters

***Cotton*:** Cotton is a natural fibre. The micronaire, length, strength, color and fibre maturity properties vary very much between fibres.Out of these, fibre micronaire, color, maturity and the origin of growth results in dye absorption variation.

Cotton of following parameters was used:

Micronaire	= 4.53 ug/in	maturity index = 0.92		SCI	= 122
Length	= 1.104 inch	Uniformity = 81.8 %		SFI	= 10.5 %
Strength	= 30.1cN/tex	Elongation = 7.8 %		Moisture	= 8.5 %
Reflectance (Rd)	= 73.1	Yellowness	(+b)	=	8.7

***Nomex*:** Recycled and virgin nomex both were used. Recycled nomex was obtained from different rags and strips while virgin nomex was imported from Dupont USA.

***Modacrylic*:** Modacrylic was obtained from *iTextiles*® (Pvt) Ltd. They provided us Kanecaron. Kanecaron is a registered trade name of inherently flame-retardant modacrylic fibers manufactured by Kaneka Corporation, JAPAN.

Fineness =1.5 denier Cut length= 38 mm Crimp level = 3.8 crimps / cm

Yarn sample details

Table 2. Yarn sampling details

Sample ID	Composition	Count
S 1	100 % C	Ne 6
S 2	100 % C	Ne 10
S 3	90 % C , 10 % M	Ne 6
S 4	90 % C , 10 % M	Ne 10
S 5	70 % C , 30 % M	Ne 6
S 6	50 % C , 50 % M	Ne 6
S 7	70 % C , 30 % N	Ne 10
S 8	50 % C , 50 % N	Ne 6
S 9	50 % C , 50 % N	Ne 10

*C= cotton M= Modacrylic N = Nomex

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Yarn manufacturing process

All yarns were made by rotor spinning technique.

For this purpose the fibres were first mixed by automatic mixing.

Automatic mixing

In this process fibres from the bales picked up by the machines and that is mixed automatically.

For this purpose different type of machine are used which includes "A11 Blendomate".

Temperature and humidity

Specific temperature and humidity is maintained in the blow room in order to get good quality yarn at the end Air conditioners are used to get this temperature and humidity.Then fibres were processed through following trutzschler's Blow room line.

Blow room

- Auto pucker , LVS, Maxi flow, MPM 6chamber, LVS, Hopper feeder, RN beater Dustex DX

Production and quality parameters related to selected count

Table 3. Production and quality parameters related to selected count in carding

Delivery speed	160 m / min
Grains / yard (100 % cotton)	85
Grains / yard (100 % synthetic)	55
Number of card used	1
Efficiency	90 %

Drawing

The carded slivers of 100 % cotton and other synthetic fibres are then subjected to drawing frame of Rieter RSB- 951.

Three passages were given in order to achieve a uniform mixing. By feeding the optimized number of slivers we achieved here our required blend ratios, i.e 70:30 CN , 90:10 CN , 50:50 CN and 70:30 CM , 90:10 CM , 50:50 CM. Output grains were 85 grains/ yard.

Production and quality parameters related to selected count

Table 4. Production and quality parameters related to selected count in drawing

Delivery speed	375 m / min
Grains / yard (100 % cotton + optimized blends)	85
Number of drawings used	1
Efficiency	70 %

Terry Knitting

We used Shima seiki glove knitting machine for the manufacturing of gloves.

On shimaseiki 7 gauge needle machine we manufactured the 8 samples of gloves.

- With 100% C 2End S1 as ground yarn , 2End S2 as pile yarn
- With 90:10 C:M 2End S3 as ground yarn , 2End S4 as pile yarn
- With 50:50 C:M 2End S7 as ground yarn , 2End S8 as pile yarn
- With 70:30 C:M 2End S5 as ground yarn , 2End S6 as pile yarn
- With 90:10 C:N 2End S9 as ground yarn , 2End S10 as pile yarn
- With 50:50 C:N 2End S13 as ground yarn , 2End S14 as pile yarn
- With 70:30 C:N 2End S11 as ground yarn , 2End S12 as pile yarn

Glove was manufactured on Shima Seiki Glove knitting Machine. Shima Seiki has since been at the forefront of knitting technology. With consistent advancement in original technology that anticipates market needs, Shima Seiki's computerized knitting machines have now become the global standard.

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Machine	Schlafhorst Autocoro
Model	SE- 9
No. of frames	1
Efficiency	90 %
RH %	65-70%
Temperature	24°C
Opening roller used	S -21
Opening roller speed	8700 rpm
Rotor used	T -46
Rotor speed	60000 rpm
Navel	KN – 8R
Take up tension	99.67 %
Feeding rate	1.14 m/min
Delivery speed	107 m/min

Figure 2. Shimaseiki 7 gauge needle machine

Sizes

When measured according to 6.1 of EN 420:2003", the sizes shall correspond with those requirements Established in the applicable clause of EN 420, but the minimum length shall be in accordance with table below

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Glove size	6	7	8	9	10	11
Fits	Hand size 6	Hand size 7	Hand size 8	Hand size 9	Hand size 10	Hand size 11
Minimum length of glove (mm)	260	270	280	290	305	315

NOTE: the user should take care that the gloves are compatible with the sleeves of the selected protective clothing and ensure that no skin is exposed when the arms are stretched.[6]

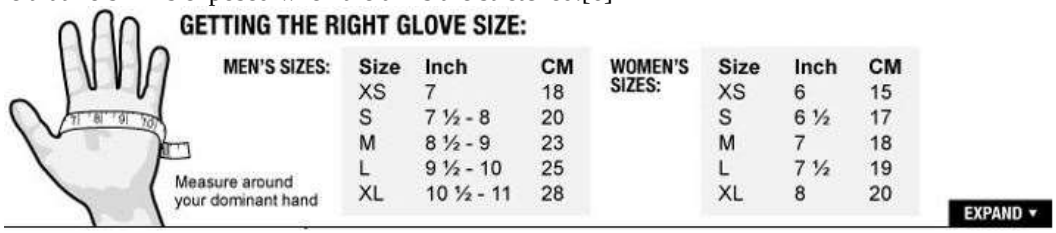

Table 7.Glove specification sheet and machine data

KNITTED GLOVE SIZE									
	Length (mm)		**Girth (mm)**		**Cuff width (mm)**		**Shell wt. /pair (gms)**		
	450		**146**		**0**		**202**		
Tolerance	± 5 mm		± 5 mm		± 5 mm		± 7 %		
For production use									
Yarn Details	**Ends**		**Count**		**Color**		**Fibre Content**		
	02		**10/S**		**NATURAL**		**Cotton & Cotton + synthetic**		
	02		**6/S**		**NATURAL**		**Cotton & Cotton + synthetic**		
Elastic Yarn	**Nil**								
Machine Type	**SPG – 7 L2L**								
MACHINE DATA									
F1	**F2**	**F3**	**F4**	**U.P**	**Thumb**	**L.P**	**Cuff**	**Elastic Setting**	**C.P.I setting**
00	**00**	**00**	**00**	**00**	**00**	**200**	**00**	**2.00.1**	**8**
Principle Feeder : 02 (06/S) ends Secondary Feeder : 02 (10/S) ends									

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Methods for testing yarn samples and gloves

After manufacturing the gloves we tested the gloves samples, and yarns used for the manufacturing of these gloves.

Fibre Analysis (Quantitative)

After the required yarns were manufactured, we conducted the Fibre Analysis (Quantitative) test According to AATCC 20-A test method and obtain the following results of each blend ratio.

Cotton – Modacrylic composition

Table 8 . Cotton – Modacrylic composition

Yarn Count	Cotton	Modacrylic	Representative code
6 s	89.37 %	10.63 %	CM91
10 s	89.29%	10.71%	CM91
6 s	70.52%	29.48%	CM73
10 s	71.07%	28.93%	CM73
6 s	50.37%	49.63%	CM55
10 s	51.40%	48.60%	CM55

Cotton – Nomex composition

Table 9 . Cotton – Nomex composition

Yarn Count	Cotton	Nomex	Representative code
6 s	88.64 %	11.36 %	CN91
10 s	88.29%	11.71%	CN91
6 s	72.86%	27.14%	CN73
10 s	74.03%	25.97%	CN73
6 s	54.70%	45.30%	CN55

Results and Discussion

Fibre analysis results

Fibre analysis test according to AATCC 20-A gives the following details about the composition of yarns made for protective gloves. This test was performed to check the real blend ratio of synthetic fibres and cotton in the yarn samples. The required blend ratio and the obtained blend ratio was almost the same. So, Fibre analysis result shown in figures 29 and figure 30 confirmed our required results.

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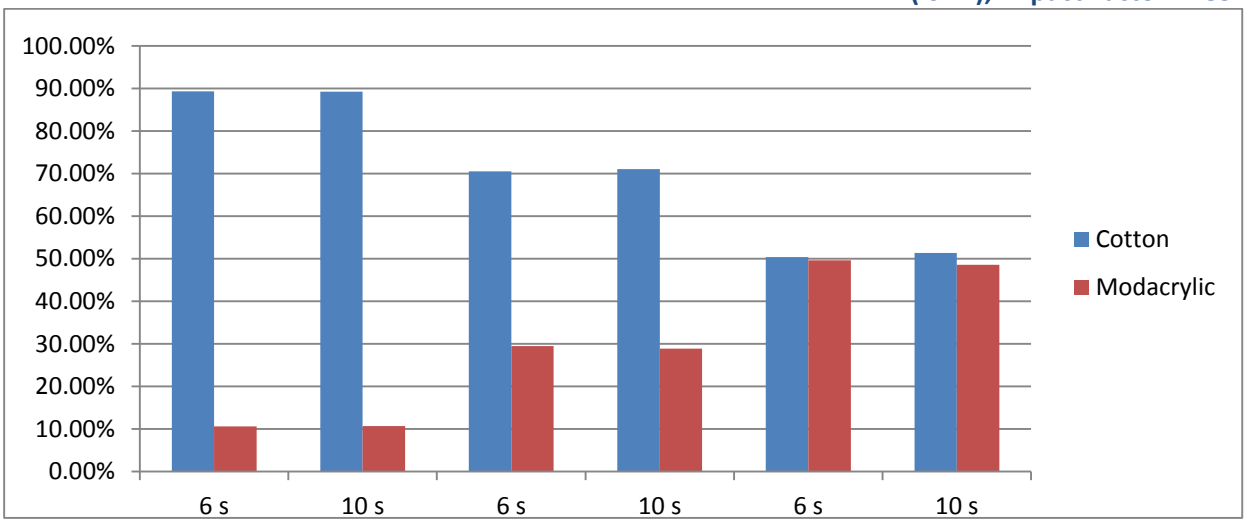

Figure 3 . Fibre analysis of Cotton Modacrylic blend yarns

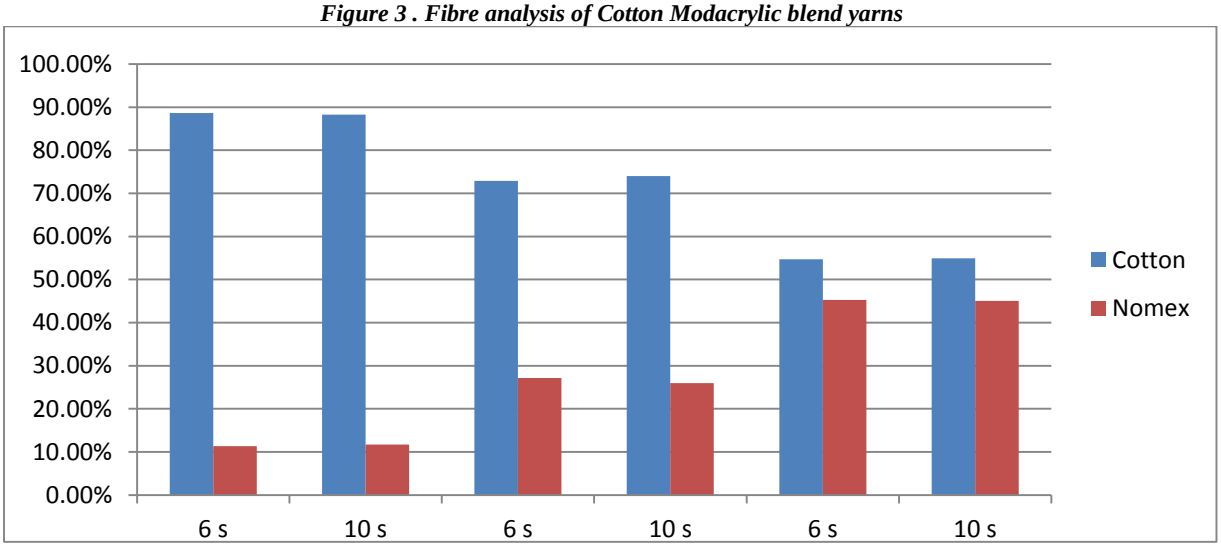

Figure 4. Fibre analysis of Cotton Nomex blend yarns

Flame resistance test (Vertical Test)

Vertical test for the manufactured fire resistant gloves is performed according to the ASTM standards D 6413 / D6413 M-12

Table 10. Vertical Flame test results

Test		CN 91		CN 73		CN 55		CM 91		CM 73		CM 55		C 100	
		One side	Other side	One side	Other side	One side	Other side	One side	Other side	One side	Other side	One side	Other side	One side	Other side
F.R test	After Flame time	110 sec	137 sec	106 sec	106 sec	100 sec	92 sec	56 sec	41 sec	Nil	Nil	Nil	1 sec	39 sec	72 sec
	After glow time	>1000 sec	>1000 sec	>1000 sec	>1000 sec	86 sec	72 sec	>1000 sec	>1000 sec	>700 sec	>700 sec	10 sec	135 sec	>500 sec	>500 sec
	Char length	Char completely		Char completely		Char completely		295 mm	209 mm	60 mm	66 mm	10 mm	15 mm	Char completely	

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Burning behaviour of gloves

Burning behaviour is tested according to EN ISO 6941 with the glove mounted and tested vertically. A flame is placed directly below and in line with the glove at an angle of 30° and a distance of 20mm[32]. The glove is tested for each ignition time i.e. 3 seconds and 15 seconds. The flame time and afterglow time for each performance level is as follows:

Table 11. Burning behaviour results

SAMPLE	Loop position	Start flame	After flame	Star glow	After glow	Performance level achieved
CM 91	Loop –in	38 s	Unlimited	40 s	Unlimited	1
	Loop – out	25 s	Unlimited	28 s	Unlimited	1
CM 73	Loop –in	40 s	No Flame	No glow	No Glow	4
	Loop – out	36.52 s	36.72 s	No glow	No Glow	1
CM 55	Loop –in	40 s	No Flame	No glow	No Glow	4
	Loop – out	36 s	37 s	37 s	39 s	1
CN 91	Loop –in	15 s	Unlimited	18 s	Unlimited	1
	Loop – out	6 s	12 s	8 s	Unlimited	2
CN 73	Loop –in	18 s	Unlimited	21 s	Unlimited	1
	Loop – out	9 s	Unlimited	15 s	Unlimited	1
CN 55	Loop –in	19 s	55 s	24 s	53 s	1
	Loop – out	10 s	Unlimited	13 s	Unlimited	1

Contact heat of Gloves

Contact Heat is tested according to EN 702. Samples are taken from the palm area and placed in contact with a cylinder of the appropriate temperature. To gain the relevant performance level, the temperature of the inside of the glove cannot rise by more than 10°C within the threshold time.

Table 12. Contact heat results

SAMPLE	At 100 °C Threshold time(s)	At 250 °C Threshold time(s)	Performance level achieved
CM 91	33	16	2
CM 73	38	18	2
CM 55	35	17	2
CN 91	34	16	2
CN 73	34	16	2
CN 55	35	18	2

Both sides of each sample of gloves were tested for flame resistance according to ASTM D 6413M-12 and table 20 elaborates the fact, that the most suitable gloves for high performance fire resistance purpose are CM 55 , CM 73 and CM 91 respectively.one side of glove in table refers to the subjection of glove to the flame with loop inside. Other side of glove in table refers to the subjection of glove to the flame with loop outside.CM 55 gloves with loop inside show the best favourable result for fire resistant gloves, with after flame time almost zero, least afterglow time of 10 second and the minimum char length of 10 mm only.Contact heat performance level of all the samples are almost the same, 2, with a very little change in threshold temperature.

Table 12 shows the burning behaviour and it also directs as to same results as in vertical flame test.CM 73 and CM 55 with loop inside have the highest start flame time of 40 seconds, both having no after flame time and negligible afterglow time .So both are subjected to performance level 4.

Important thing to note is the highest elongation of base yarn for the CM 55.CM 55 when subjected to flame with loop inside, yarn with the highest elongation is in direct contact with flame, so it gives better performance result.

Conclusion

From the above experimentation and results we can conclude that the glove sample of CM 73 and CM 55 are the closet to our requirements of heat resistance gloves. One of the important thing to note is that both gloves of cotton and Modacrylic blends gives high performance when they are turned to loop inside i.e. when the terry side of the gloves is used inside ,and in direct contact with hands.

CM 55 has the highest performance level among all the samples of gloves. Above discussion discloses that there is also a positive relationship between elongation and the strength of the yarn used and the performance level of the glove.

Optimized Blend of cotton with synthetic Fibres like Modacrylic and nomex can gives us a better performance gloves in the field of fire resistance with relatively very low cost of raw material and the production cost . High level of comfort and dexterity is achieved by using blends of cotton while on the other hand if we use pure inherent fire retardant fibres, such level of dexterity and comfort can never be acquired.

References

[1.] *R A Scott, Textiles for protection, RASCOTEX UK Woodhead Publishing Series in Textiles No. 44.*
[2.] *Textiles for safety http://textilelearner.blogspot.com/2012/03/textiles-for-safety-flame-resistant.html (Accessed on19th August, 2013)*
[3.] *Moncrieff, R. W., Man-Made Fibres 6th ed. London: Newnes-Butterworth, 1975.*
[4.] *Cook, Gordon J. Handbook of Textile Fibres, Part 2: Man-Made Fibres. 5th ed. Durham, U.K.: Merrow, 1984.*
[5.] *Nova shield Industrial Products Inc, A Technical Paper on Para Aramid filament http://www.novashieldindustrial.com/w04.aspx (Accessed on15th August,2013)*
[6.] *W.W. Grainger, Inc. 1994 - 2013 "Getting Right size of the gloves" http://www.grainger.com/Grainger/flame-retardant-gloves/gloves-and-hand-protection/safety/ecatalog/N-mlh (Accessed on19th August, 2013)*
[7.] *Charles Q. Yang and Hui Yang "The Flame Retardant Nomex/cotton and Nylon/Cotton Blend Fabricsfor Protective Clothing" The University of Georgia,U.S.A.*
[8.] *Rebouillat, S. High Performance Fibres, Woodhead Publishing, Cambridge, U.K., pp23-61 (2001).*