International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

Development of Fabrics using Various Fibres Blends to Develop Protective Clothing for Oil & Gas Industry Workers

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***Abstract* - Oil and Gas industries contain high concentrations of highly flammable substances. These are placed in high risk categories as there is a continuous threat to the life of workers due to presence of highly inflammable gases in the surrounding atmosphere. In India there are approx 41,947 (2011) retail outlets, 22 refineries and 178/637 rig wells where huge number of manpower is engaged. Fire accidents are very common at fuel stations which results devastating burns and some time death of workers. A little negligence may cause havoc. Most of the cases these injuries due to burn are preventable if the right type of work wear is worn by the attendants. As per Government of India, the majority of severe and fatal burn injuries are due to the individual's clothing igniting and continuing to burn, not by the exposure itself. Keeping the safety of workers in oil and gas industry in mind, a survey was conducted in Delhi and NCR to understand the effectiveness of worker's uniform to tackle fire hazard. The work-wear and fabric sample used by attendants were also collected evaluated for their suitability. The results indicated that these collected samples were not qualified the passing criteria of flammability. The current study aimed to develop different woven blended fabrics. FR viscose (V1), Nylon 6, 6 (N1) and Modacrylic (M1) 100 percent compositions and their blended fabrics such as FR viscose 50 % / Nylon 6, 6 20 %/ Modacrylic 30% (VNM523) and VNM325 were produced. Produced fabrics were evaluated for limiting oxygen index, radiant heat index, contact heat index, convective heat index, heat resistance, limited flame spread and mechanical properties after 5 and 50 washes according to ISO 11612 International standard method for protective clothing for industrial workers. From the study it was clear that fabric samples M1, VNM523, VNM325 along with commercially available MPA samples are meeting the all requirements of ISO 11612. This study will guide the manufacturers to select suitable fibre blends to make the product cost effective without compromise the minimum requirement as mentioned in the ISO 11612.**

Keywords— Inherent FR Fibres, Heat And Flame Properties, Comfort And Oil And Gas Industry

1. INTRODUCTION

The oil and gas sector consists of three segments—upstream, midstream and downstream. The upstream segment primarily comprises companies that are engaged in exploration and production activities, while the midstream segment comprises of players in storage and transportation, and the downstream segment comprises of players that are engaged in refining, processing and marketing of petroleum products. The Indian oil and gas industry is a back boon of Indian economy. It is one of the major sources of energy after coal. As Indian economy is growing, the consumption of oil and gas are increasing every year as it is directly linked to the development of the nation. India is already the fifth-largest energy consumer in the world, with oil and gas accounting for 45% of the country's energy needs. A large number of work forces engaged in this industry. Oil and Gas workers are subject to some of the most hazardous industrial conditions in India. Serious injuries and fatalities occur too often from an oil accident or gas accident. Given the amount of people employed by the gas and oil industry and the dangerous nature of oil and gas drilling and refining, it is almost inevitable that accidents will not occur. One of the most common accidents occur in this industry is related to fire as oil and gas are highly inflammable in nature. For the safety of workers, flame retardant (FR) coverall or overall is provided in the developed countries. However in India still the workers working in this field (especially those are on contract), are not provided with suitable coverall or protective work wear. Keeping this in mind the main aim of the study is to develop suitable cloth using various types of fiber combinations, which can fit in Indian environment condition, for the Indian oil and gas refinery industry workers.

2. MATERIALS AND METHODS

This study was divided in to two parts. In the first part a survey was conducted to understand the present scenario of work-wear worn by the workers in Oil and Gas refineries. In the second part suitable fabrics for work-wear cloth were

developed. To compare the developed work wear cloth, a fabric sample, which is being used in the developed countries for oil and gas industry workers, was also developed using blends of P-aramid (88%), M-aramid (10%) and Antistatic (2%) fibres and coded as MPA.
FR Viscose, Nylon 6, 6, Modacrylic, P-aramid and M-aramid fibres were sourced for the study. These fibres properties are given in Table 1. Their blends were prepared with 20^s count yarn (16 tpi) using ring spinning system. Percent of fibre blends and the sample codes can be seen in Table 2.

Table 1: Fibre Properties

Fiber / Properties	Modacrylic	Nylon 6,6	FR Viscose	Meta-Aramid	Para-Aramid
Length, mm (ASTM D 5867)	40.7	38.0	51.2	51.9	53.7
Denier (ASTM D-1577)	2.06	1.60	1.98	2.39	1.61
Tenacity, g/tex (ASTM D -3822)	25.83	48.51	24.21	28.26	112.41
Elongation at break, % (ASTM D - 3822	25.29	27.46	13.78	36.25	26.48
Moisture Regain, (%) (IS 199)	1.01	3.49	7.11	5-5.5	5

Table 2: Fibre blend percentage

S. No	Blend percentage	Code
1	100% FR Viscose	V_1
2	100% Nylon 66	N_1
3	100% Modacrylic	M_1
4	50% V_1+20% N_1 + 30 % M_1	VNM532
5	30% V_1 + 20% N_1 + 50% M_1	VNM325
6	88% M- aramid+ 10% P-aramid + 2 % Antistatic	MPA

The developed yarns were converted into plain rip stop woven fabrics (Ends/inch: 80 and Picks/inch: 60) using rapier loom. These fabric samples were washed in hot water for the duration of 30 min to remove sizing lubricants followed by heat setting (depending upon the fibre type except FR viscose) in the laboratory curing chamber. Finally, the fabric samples were evaluated using standard test methods for various physical properties. These samples were also evaluated for safety, comfort and wear properties as given below:

- Safety property: Limiting oxygen index (IS 13501), contact heat index (ISO 12127), radiant heat index (ISO 6942)
- Comfort property: Air permeability (ISO 9237), water vapour permeability (ASTM E-96/E 96 M-05 at 32 ± 2°C and RH: 50± 2%)
- Wear life property: Tear strength (IS 6489), taber abrasion (guideline of ASTM D 3884, abrasive wheels CS-10, applied 500 g)

The results of these fabrics were also compared with the specified values given in the specification ISO 11612: Protective clothing -- Clothing to protect against heat and flame. Electrical resistivity properties of developed fabric samples were compared with the specified values given in ISO 11611: Protective clothing for welder cloth.

3. RESULT AND DISCUSSION

3.1 Finding of Survey

Main objective of the survey was to study potential hazards like heat and flame which a worker comes across while working in oil and gas industries.

Refinery processes are closed processes; there is always a potential risk of fire accident due to leakage of inflammable oil and gases during various operations. It is reported that fire accidents occurred due to leak or release of crude oil and hazardous chemicals from heating tubes, over pressuring the unit and failure of control devices, inadequate desalting sometimes causes fouling of heater tubes and heat exchangers throughout the refinery which causes cracks in pipelines. Officers and workers also reported that they had to face chemical splash, cut & abrasion, heat exposure etc on various operations.
Contract workers who work under a contractor are hired for maintenance of pipelines, unloading of equipments, replacement of distillation columns and welding of equipments etc. It was observed that there was no suitable uniform for contract workers, that could protect them from heat and flame related hazards but shoes and safety helmet were compulsory, which they wore.
It was also found that the permanent workers, who were entitled to get safety work wear, are not provided work wear timely after the consumption of old work wear.

3.2 Analysis of developed work-wear fabric

3.2.1 Physical properties:

Developed fabrics were assessed for their physical parameters. The results are given in Table 3.

Table 3: Physical Properties of Developed Fabric Samples

Properties	Fabric					
	V_1	N_1	M_1	VNM523	VNM325	MPA
Mass, g/m^2	194	204	184	181	183	183
Thickness, mm	0.50	0.75	0.42	0.52	0.46	0.51
Drape Coefficient, %	30	63	38	34	37	77
Stiffness, cm - Warp	1.3	1.9	1.5	1.2	1.3	2.4
- Weft	1.3	2.2	1.4	1.3	1.4	2.0

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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It is clear from the Table 3 that mass of V_1, N_1, M_1, VNM523, VNM325 and MPA fabrics are between 181 and 204 g/m^2.Thickness of a fabric is one of its basic properties giving information on its warmth, heaviness or stiffness in use.Thickness of V_1, N_1, M_1, VNM523, VNM325 and MPA are 0.50, 0.75, 0.42, 0.52, 0.46 and 0.51 respectively. It is clear from the table that V_1, M_1, VNM523, VNM325 exhibited less drape coefficient i.e. 30, 38, 34, 37 respectively as compared to N1, MPA.

Cusick (1965) studied effect of bending and shear stiffness. Statistical analysis based on experimental measurement revealed that bending length showed a high correlation with drape coefficient. He also found that shear stiffness was highly correlated with drape coefficient.

Stiffness of the fabrics can be assessed by measuring bending length. The more the bending length, the more is the stiffness. Bending behavior is also an important factor affecting drapability. It can be used to assess cause and affect relationship.

According to the Cusick there is a significant co-relation between stiffness and drape coefficient. As stiffness increases, drape coefficient also increases.

V_1 showed less stiffness than M_1 while N_1 displayed the highest stiffness. On other hand viscose blended fabric such as VNM325 fabric consisted more percent of modacrylic, showed higher stiffness as compare to VNM523.MPA also displayed highest stiffness.

3.2.2 Comfort Properties

The influence of fibre composition on air permeability and water vapour permeability was investigated. Results are given in Figure 1.

When the body is in motion, approximately 30 % of the heat and moisture can be removed by air convection in the microclimate and air exchange via the clothing (Umbach, 1993). Air permeability can be defined as the degree to which a fabric allows air to pass through its construction. Results presented in Figure 1 show that V1, N1 and M1exhibit approximate air permeability 28, 10 and 15 cc/sec/cm^2 respectively. The air permeability of a fabric is affected by many factors such as fibre fineness, structural properties such as shape and value of pores of the fabric and the yarn and fabric thickness (According to Hu et. al.). FR viscose fibre fineness was less than Modacrylic fibre; this could be the reason for higher air permeability. FR Viscose blended fabric as VNM523 and VNM325 exhibited reduced air permeability in comparison to 100% FR viscose. It was clear from Figure 1 that VNM523 showed more air permeability than VNM325 due to the fact VNM325 had less percentage of FR Viscose fibre. On the contrary, MPA sample showed good air permeability.

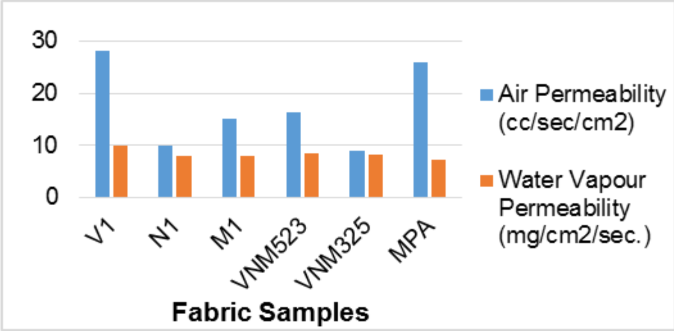

Fig 1: Comfort Properties of Developed Fabric Samples

Water vapour permeability determines breathability of the clothing material. The mechanism involved in water vapour transmission through fabric from the skin to the outer surface by diffusion and absorption-desorption method [Das et al.1] (Skenderi et al. 2009) (Wang et al, 2009). Results presented in Figure 1 shows that N1, M1, VNM523 and VNM325 had approximately same water vapour permeability except V1 fabric, which is having highest water vapour permeability among the all.

3.2.3 Wear Life Property

Tear strength and taber abrasion properties were evaluated to assess fabric's wear life. Results of these properties are given in Table 4.

Table 4: Wear Life of Developed Fabric Samples

S.No.	Fabric Samples	Tear strength, N (IS 6489)				Nos. of cycles required to first hole formation-Taber abrasion (ASTM D 3884
		After 5 wash		After 50 wash		
		wp	wt	wp	wt	
1.	V1	18	15	15	12	58
2.	N1	58	48	56	49	Above 1000
3.	M1	22	24	20	21	157
4.	VNM523	30	28	30	27	713
5.	VNM325	31	31	30	29	670
6.	MPA	40	38	39	38	359

Tear strength (after 5 and 50 washes) of N1 is also found to be higher than other fabrics, while V1 fabric sample is having lowest tear strength (Table 4). It is clear from the Table 5 that blended fabric samples VNM523 and VNM325 are having tear strength higher than V1 and M1. It was also clear from the Table 5 that there is no much change in the tear strength of all samples after 50 washes except V1 fabric. The probable reason of deceasing tear strength after 50 washes of V1 sample due to its lower wet strength. As per ISO 11612 minimum tear strength of fabric should be 15N. Hereby all fabric meet the minimum requirement given in ISO 11612.

Abrasion of the fabric can lead to a reduction weight, thickness, and eventually the failure of the fabric with a hole forming which exposes the wearer directly to an electric arc or fire threat. Having fabrics made of improved abrasion resistance yarns can result in longer lasting protective garments. From the figure 4 (Table 4) it is explicit that N1 fabric is having highest taber strength while V1 had lowest. M1 had taber strength more than V1 but less than other samples. On the other hand, fabric samples coded as VNM523 and VNM325, having taber strength more than V1 and M1 but lower than N1. MPA blended fabric showed higher taber strength than V1 and M1 but less than other samples.

3.2.4 Evaluation of safety related properties

Limited oxygen index, contact heat test and radiant heat test were performed after 5 washes as well as 50 washes. Results are shown in figures.

Limited Oxygen Index

Limiting Oxygen Index (LOI) is the preliminary test to ascertain that fabric is flame retardant or not. For flame –resistant fabric a value of 21% and above is required (Horrocks and Kandola, 2004). It is clear from the Fig. 2 that except N1 (LOI : 21) all fabric samples are having LOI more than 23 after 5 and 50 washes. LOI of M1 (Modacrylic) and MPA are found to be around 33 and 40 respectively.

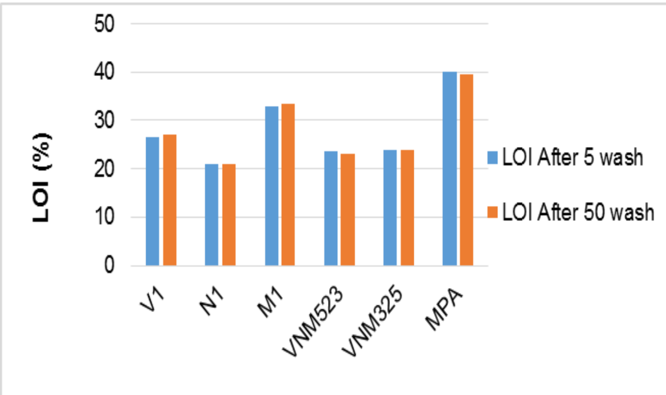

Fig 2: Limited Oxygen Index

Contact Heat Index

Contact Heat Index of these samples was determined using ISO 12127 test method. The threshold time was determined by monitoring the temperature of the calorimeter. Higher the threshold time of a fabric, better will be heat protective property. It is clear from the Fig. 3; MPA had the highest threshold time.

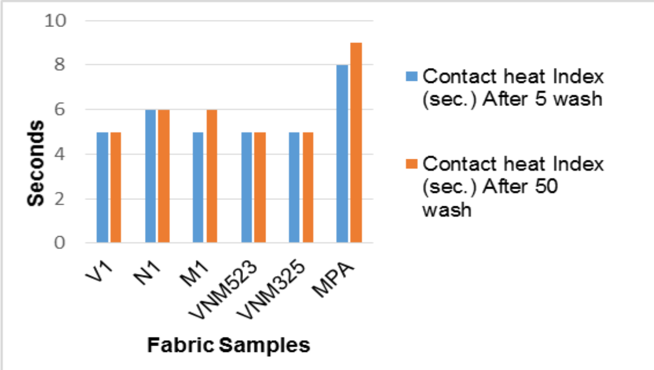

Fig 3: Contact Heat Index

Radiant Heat Index

Radiant Heat Index was determined in accordance with ISO 6942. Under this sample was exposed to radiant heated source emitting 20 kW/m^2 heat fluxes. As per Fig. 4, it is clear that sample MPA shows lowest radiant heat index after 5 and 50 washes.

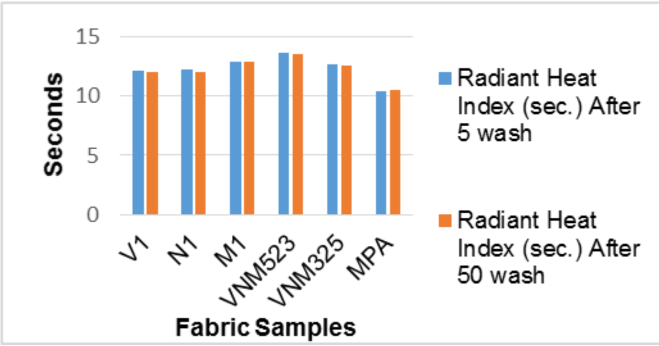

Fig 4: Radiant Heat Index

CONCLUSION

Survey of refineries indicated that workers were not provided suitable safety work wear. The workers working on contract were the most neglected.

MPA and N1 fabric samples were found to be stiffer than other fabric samples. Drape coefficient of these two fabric samples (MPA and N1) were also on higher side than others.

Air permeability and water vapour permeability of V1 fabric was found to be higher than others. The second highest air permeability was of MPA fabric sample. Water vapour permeability of all the samples except V1 is nearly the same.

Tear strength (after 5 and 50 washes) of the N1 and MPA fabric were found to be higher than other fabric samples. Taber abrasion test indicated that N1 fabric was having higher abrasion resistance behaviour as there was no hole formation after 1000 cycles of abrasion. V1 has lowest abrasion resistance property. The blended fabric samples VNM523 and VNM325 were having higher abrasion resistance than MPA.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 03, March-2016

Limiting oxygen index property indicated that MPA fabric is having higher LOI than others, Second higher LOI was found to be of M1 fabric and lowest was of N1 fabric. Contact heat index of the entire sample were ranging between 5 and 6. Radiant heat index after 5 and 50 washes of all the samples ranging between 10 and 13.5.

From the study it is clear that fabric samples M1, VNM523, VNM325 along with commercially available MPA samples are meeting the all requirements of ISO 11612. This study will guide the manufacturers to select suitable fibre blends to make the product cost effective without compromise the minimum requirement as mentioned in the ISO 11612.

ACKNOWLEDGEMENT

This work was financially supported by University Grant Commission in form of research felloship – JRF and SRF. We are grateful to Northen India Textile Research Association for their support.

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