CHAPTER - 7
INFLUENCE OF FABRIC CHARACTERISTICS ON FLAMMABILITY OF FABRICS

7.1 INTRODUCTION

From the analysis of results of various saree fabrics subjected to flammability tests, it was observed that cotton saree along with cotton supporting garments shows higher hazard potential a compared to other materials. Usually in practice also most of the fabrics used for supporting garments are made up of cotton. Hence in-depth analysis of thermal properties of various types of cotton fabrics became essential in this study. Therefore, cotton fabric with varying pick density of various types of weaves has been prepared as sample fabrics for the study. As dyeing of fabric also affect the mass and structure of fabric, different finishing processes were also used especially using different types of dye. Methodology and procedure used for determining the flammability hazard of such fabrics is explained in the following sections followed by the test results.

7.2 MATERIALS AND METHODS

A plain power loom with dobby attachment was used to manufacture the fabric samples. The sample fabrics were woven from 34^s warp and weft combed cotton yarns using various pick densities with Plain, Matt, Twill and Satin weaves. The various loom particulars and fabric specifications are given in Table 7.1. Warp sheet of 50 ends per inch was used on loom to weave 42" wide fabric with weft at five different pick densities. The actual pick densities and the sample code based on the nominal picks per inch are given in Table 7.2. Warp sheet was sized using Maize-starch, Gum and Mutton Tallow, with 12% Size add-on. The fabric was de-sized by the process of rot steeping with a total loss of 8.5% in fabric mass. These samples were further scoured, bleached and finally dyed with Direct, Reactive and Vat dyes. In order to remove natural fats, waxes and other fatty matters, which are added during sizing (softener). These are insoluble in water. Scouring converts these things to water-soluble. Scouring is carried out for improving the absorbency of fibre,

Table 7.1 Loom Particulars and Fabric Specifications

Sr. No.	Loom Particulars	Specification
1	Type of loom	Over-pick non-automatic loom
2	Loom width	60”
3	Loom speed	120 picks per minute
4	Shedding equipment	Left hand Climax dobby (8 healds)
5	*Denting-in:*	
	Reed count	50
	Denting order	2 ends/dent
	Healding order	1/3, 2/4 (skip draft)
6	*Sample Particulars:*	
	Warp	34^s combed
	Weft	34^s combed
	Fabric width	42”
	Ends/ inch on loom	50

Table 7.2 Actual Pick Density of Fabric with Different Weaves (Picks per inch)

Sr. No.	Type of weave	Plain	Matt	Twill	Satin
	Sample Code	(P)	(M)	(T)	(S)
1	30	30	30	30	30
2	40	43	43	43	43
3	50	53	53	53	53
4	60	62	62	62	62
5	70	-	72	72	72

which is essential, if dyeing and printing are to be successful. The process was performed using a solution of 5% sodium hydroxide at a temperature of about 100° C for 90 minutes, and then fabric was washed thoroughly. Bleaching is carried out by soaking fabric in a cold solution of sodium hypochlorite under alkaline conditions, pH 10 -11 at a concentration of 4gms/ liter. The fabric was then neutralized in a solution of diluted hydrochloride acid. After washing the fabric is dried. The dyeing of samples was done as mentioned in Table 7.3; fabric samples were dyed with same concentration of dye. The effects of these finishing processes on mass of the fabric samples have been given in Table 7.4.

7.3 RESULTS AND DISCUSSIONS

7.3.1 Effect of Pick Density

Increasing the picks per inch of fabric, increases the weight per unit area of the fabric, due to which, It is observed from the Table 7.5 that the FPT value increases as per the Pick density. Plain weaves P30 sample shows 4.61 s, P40 shows 4.24 s, P50 shows 5.25 s, P60 shows 5.29 s. Similarly, Twill weave T30 sample shows 4.25 s, T40 shows 5.44 s, T50 shows 6.25 s, T60 shows 7.73 s and T70 shows 7.90 s. Satin S30 sample shows 4.52 s, S40 shows 5.64 s, S50 shows 6.25 s, S60 shows 7.93 s and S70 shows 8.90 s. Matt weave, M30 sample shows 04.74 s, M40 shows 5.96 s, M50 shows 6.73 s, M60 shows 8.32 s and M70 shows 9.28 s. These values indicate that as the as the pick density increases the flame propagation time increases for all the plain, twill satin and matt weaves.

Table 7.3 Dyeing Particulars of Samples

Dye	Direct	Reactive	Vat
Concentration	3%	3%	3%
Process	Nacl 1%	Nacl 1%	NaOH3%
	$Na_2CO_3$2%	NaOH2%	TRO
		Na_2CO_3 1%	Na_2SO_4 4gpl
Medium	pH neutral	Alkaline medium	Alkaline medium
Temperature	60° C	Room temp	50 °C
Time	30 min.	30 min.	60 min.

Table 7.4 Effect of Weave, Pick Density and Type of Dye on Mass of Fabric

Type of Weave	Sample Code	Bleached (gsm)	Direct Dye (gsm)	Reactive Dye (gsm)	Vat Dye (gsm)
Plain	P30	35.00	36.00	37.00	41.67
	P40	43.66	41.23	46.00	48.67
	P50	47.00	51.33	52.00	53.67
	P60	52.66	52.66	53.67	55.33
Matt	M30	35.66	36.00	37.66	39.67
	M40	45.66	47.00	47.33	47.66
	M50	51.66	52.00	53.33	53.67
	M60	54.33	56.67	57.07	57.33
	M70	58.00	59.66	60.33	61.00
Twill	T30	36.33	37.00	37.33	40.00
	T40	44.00	45.00	46.33	47.67
	T50	51.00	52.66	52.67	54.33
	T60	54.33	53.30	55.66	58.67
	T70	57.33	56.00	58.33	61.67
Satin	S30	37.67	39.00	39.33	40.33
	S40	44.67	46.33	47.33	47.68
	S50	51.66	54.33	54.67	55.33
	S60	52.33	55.20	56.67	57.00
	S70	56.66	60.66	59.00	62.33

Table 7.5 Effect of Weave, Pick Density and Type of Dye on Burning Behaviour of Fabric

Fabric Weave	Sample Code	Flame propagation Time (second)				Burning Time (second)			
		Bleached	Direct Dye	Reactive Dye	Vat Dye	Bleached	Direct Dye	Reactive Dye	Vat Dye
Plain	P30	04.61	05.06	07.43	07.08	06.10	14.17	19.14	18.37
	P40	04.24	08.46	08.79	08.15	10.94	17.58	22.16	16.30
	P50	05.25	10.66	11.08	10.00	13.52	21.33	22.16	20.00
	P60	05.29	11.83	12.32	10.82	14.42	23.67	24.64	21.64
Matt	M30	04.74	08.69	09.28	07.48	13.58	17.39	18.57	14.97
	M40	05.96	09.67	09.78	08.53	15.31	19.34	19.56	16.94
	M50	06.73	10.19	11.33	09.72	18.43	20.38	22.67	19.44
	M60	08.32	10.61	13.15	11.50	21.64	23.92	26.29	22.09
	M70	09.28	12.81	14.28	11.77	24.85	23.81	28.48	23.81
Twill	T30	04.25	06.72	07.81	07.14	11.85	13.44	15.63	14.29
	T40	05.44	08.98	10.35	08.42	14.18	17.96	20.71	17.06
	T50	06.25	11.15	11.47	09.71	17.35	22.30	22.94	19.42
	T60	07.73	11.23	11.76	11.34	19.14	22.46	23.53	21.89
	T70	07.90	12.26	12.36	11.90	21.51	24.54	24.72	23.23
Satin	S30	04.52	07.72	08.21	07.20	12.52	14.24	15.93	14.54
	S40	05.64	09.18	10.35	08.43	14.88	18.66	21.11	18.46
	S50	06.25	11.15	11.47	09.71	17.85	22.42	22.94	19.42
	S60	07.93	11.76	12.20	11.38	19.34	23.60	25.64	21.90
	S70	08.90	12.36	13.26	11.80	22.18	24.82	26.41	22.36

Table 7.6 Effect of Fabric Weave, Pick Density and Type of Dye on AIHF Values of Fabric

Fabric Weave	Sample Code	Bleached (cal/cm^{2}s)	Direct (cal/cm^{2}s)	Reactive (cal/cm^{2}s)	Vat (cal/cm^{2}s)
Plain	P30	0.33	0.34	0.35	0.40
	P40	0.41	0.42	0.43	0.48
	P50	0.45	0.49	0.53	0.54
	P60	0.50	0.51	0.53	0.55
Matt	M30	0.40	0.46	0.48	0.49
	M40	0.43	0.46	0.45	0.45
	M50	0.49	0.51	0.52	0.52
	M60	0.52	0.54	0.54	0.55
	M70	0.58	0.59	0.59	0.60
Twill	T30	0.34	0.35	0.35	0.37
	T40	0.42	0.43	0.44	0.45
	T50	0.49	0.51	0.53	0.54
	T60	0.52	0.51	0.53	0.57
	T70	0.52	0.53	0.56	0.60
Satin	S30	0.37	0.37	0.37	0.38
	S40	0.42	o.44	0.45	0.46
	S50	0.49	0.52	0.52	0.53
	S60	0.50	0.53	0.54	0.54
	S70	0.54	0.58	0.56	0.60

Also it is seen from the Table 7.5 that the burning time value increases as per the Pick density. Plain weaves P30 sample shows 6.10 s, P40 shows 10.94 s, P50 shows 13.52 s, P60 shows 14.41 s. Similarly, Twill weave T30 sample shows 11.85 s, T40 shows 14.18 s, T50 shows 17.35 s, T60 shows 19.14 s and T70 shows 21.51 s. Satin S30 sample shows 12.52 s, S40 shows 14.88 s, S50 shows 17.85 s, S60 shows 19.34 s and S70 shows 22.18 s. Matt weave, M30 sample shows 13.58 s, M40 shows 15.31 s, M50 shows 18.43 s, M60 shows 21.64 s and M70 shows 24.85 s. These values indicate that as the pick density increases, the burning time also increases for all the plain, twill, satin and matt weaves. Increase in pick density lead to increase in weight per unit area i.e gsm as seen in Fig.7.1 to Fig.7.4, there by more amount of mass to burn, which requires more time to burn the particular mass.

Also it is reveled from the Table 7.6 that the average incident heat flux values increases as per the Pick density. Plain weaves P30 sample shows 0.33, P40 shows 0.41, P50 shows 0.45, and P60 shows 0.50. Matt weaves, M30 sample shows 0.40, M40 shows 0.43, M50 shows 0.49, M60 shows 0.52 and M70 shows 0.58. Similarly, Twill weaves, T30 sample shows 0.34, T40 shows 0.42, T50 shows 0.49, T60 shows 0.52 and T70 shows 0.52. Satin S30 sample shows 0.37, S40 shows 0.42, S50 shows 0.49, S60 shows 0.50 and S70 shows 0.54. These values indicate that as the pick density increases the AIHF values also increases for all the plain, twill, satin and matt weaves, as seen in Fig. 7.5 to Fig.7.8. Increase in pick density lead to increase in weight per unit area, they're by more amount of mass to burn releasing more amount of energy.

The result shows that as the pick density increased the weight per unit area also increased in all the four different types of Weaves. A flame propagation time decrease with increase in gsm, Increase in gsm is due to increase in threads per inch, which prepares tight fabrics and less air space between the threads. Less airspace leads to less oxygen fuel, due to more threads per inch. It means that more mass available to burn in a given area. The flame resistance is directly proportional to mass per unit area. Actually flame propagation, burning and incident heat flux depends on air permeability (i.e. porosity), which provides more air oxygen for combustion of fabric.

7.3.2 Effect of Weave

The analysis of thermal properties of all the weaves gives an idea of different thermal parameters tested. It was found that The Flame Propagation time, FPT and the Burning time BT for matt weave for all samples M30, M40, M50, M60 and M70 is height, followed by satin, twill and plain weaves. It is seen from the Table 7.5 that the FPT value varies as per the weave. Matt weave shows longest time for flame propagation, M30 sample shows 4.74, M40 shows 5.96, M50 shows 6.73, M60 shows 8.32 and M70 shows 9.28 as these samples shows maximum increase in gsm as compared to other weaves. Plain weaves shows least time for flame propagation P30 sample shows 4.61, P40 shows 4.24, P50 shows 5.25 and P60 shows 5.29 s due to low gsm in plain weave. Satin and twill shows intermediate rise in gsm of samples and there by show intermediate values of flame propagation as seen in the Table 7.5 , but values of satin weave are higher than twill weave in all 30, 40, 50, 60, and 70 samples.

Similarly burning time varies as per the weave. Matt weave shows longest time for burning, M 30 sample shows 13.58, M40 shows 15.31, M50 shows 18.43,M60 shows 21.64 and M70 shows 24.85 as these samples shows maximum increase in gsm as compared to other weaves. Plain weaves shows least time for burning 30 sample shows 6.10, P40 shows 10.94, P50 shows 13.52 and P60 shows 14.42 s due to low gsm in plain weave. Satin and twill shows intermediate rise in gsm of samples and there by show intermediate values of burning as seen in the Table 7.5, but values of satin weave are higher than twill weave in all T30, T40, T50, T60, and T70 samples.

Satin and twill weave lies in intermediate values of matt and twill, but satin takes more time for flame propagation and burning as compared to twill and this trend is observed in all S30, S40, S50, S60 and S70 samples. This trend signifies that flame propagation time and burning time depends upon the weight per unit area of the fabric. it is observed for all the samples of a particular weave and between the weaves, that as the weight per unit area increases the flame propagation time and burning time also increases

Similarly, the incident heat flux for matt weave is seen highest between all the other weaves, and it is significantly higher than other weaves. M30 show a value of 0.40, M40 show 0.43, M50 shows 0.49, M60 shows 0.52 and M70 shows 0.58, highest between all the other weaves. Satin weaves shows less incident heat flux values compared to matt, but more than twill and plain. Plain weave shows least incident heat flux values, P 30 show a value of 0.33, P40 show 0.41, P50 shows 0.45 and P60 shows 0.50, lowest among all the other weaves as seen in Fig. 7.5 to Fig.7.8.

The result shows that AIHF60 values depends on the weight per unit area of samples i.e. gsm, it can be seen that due to different weaves the gsm of fabric sample changed as per the displacement of warp and weft in a particular weave structure. Matt weaves showed maximum rise in gsm, followed by satin, twill and plain.

Moreover it also seen that AIHF values also depends upon the amount of air available for combustion, more the open structure of weave, more will be air available for combustion.

From the above table the matt, satin twill and plain weaves are in descending order of flame resistance. As we know that flammability depends on gsm and air permeability is explained in effect of density same reason followed in this case also. The increase in the gsm in matt is due to grouping of threads which gives more crimp % and also due to more shrinkage during bleaching because of loose structure compare to other weave. While in case of twill more gsm compare to twill and plain because of more float length I e. more crimp percentage.

7.3.3 Effect of Dye

From the result, it is observed that, dyeing influences some of the thermal properties of the fabric sample. Dyeing process brings physical as well as chemical changes in the fabric samples. This physical and chemical changes the flame propagation, burning time significantly.

Dyeing process brought resistance to the propagation of flame and even burning of sample. From the above results from Table 7.5 most of the cases in plain, matt, twill and satin weave the reactive dye shoes more flame resistance as compared to direct and vat dyes. Reactive dye molecules forms covalent bonds with fibre where in case of Vat and direct dye, dye molecules attach to fiber due to polar attraction, which need less energy to break, and burning will be similar to that of bleached sample. But the direct dye and Vat dye shows more flame resistance then bleached fabric. This is may be because of dyeing process, involved in swelling of yarns leading to shrinkage of fabric, thus more mass per unit area available for combustion as seen in Fig. 7.9 to Fig. 7.12. Even most of dye molecules are attached to the outer surface of the fibre. This dye molecule contains Sulphonate groups, Phosphate and nitrogen atoms get liberated when they burn and from a non-combustible gas, which stops the flame, spreading thus gives flame resistance to the dyed fabric samples, which can be seen from the results shown in Table 7.5.

But results of average heat incident flux when compared with bleached samples do not show significant change in the values indicating no influence of direct, reactive and vat dye on AIHF values as seen in Fig. 7.13 to Fig. 7.16. These results may be attributed to the fact that all above dyes having anthraquinonoid groups in chromophores. These groups does not support combustion and nor involved in any exothermic or endothermic reactions during burning process and thus there is not a prominent effect of these dyes on heat release property. The smoke liberated by the dyed fabric was not that much of heavy as in case of vat and reactive. The smoke liberated by direct dye is more irritating than the reactive and vat dye and thus liberation of smoke results in reducing oxygen content in testing chamber influencing the burning behaviour of fabric samples.

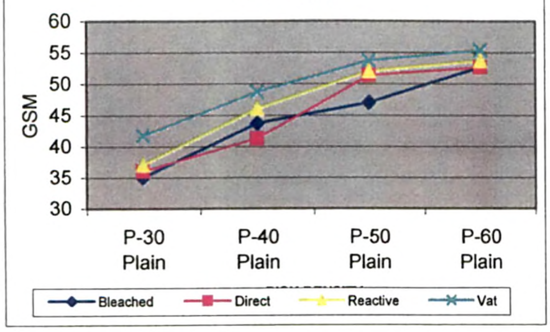

Fig. 7.1 Effect of Pick Density on GSM for Plain Weave

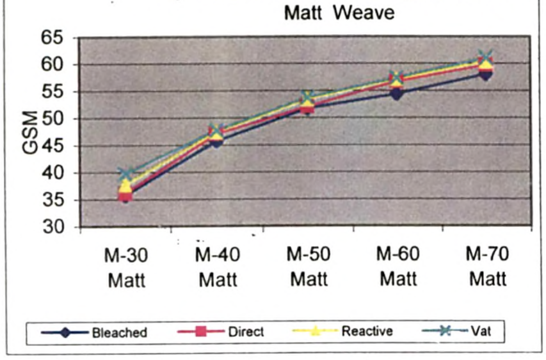

Fig. 7.2 Effect of Pick Density on GSM for Matt Weave

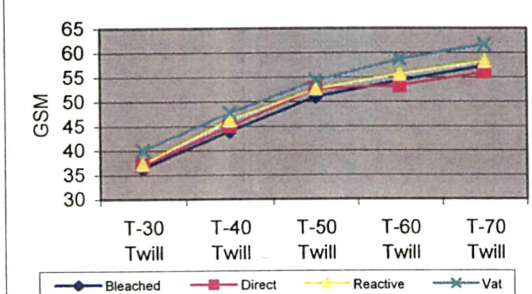

Fig. 7.3 Effect of Pick Density on GSM for Twill Weave

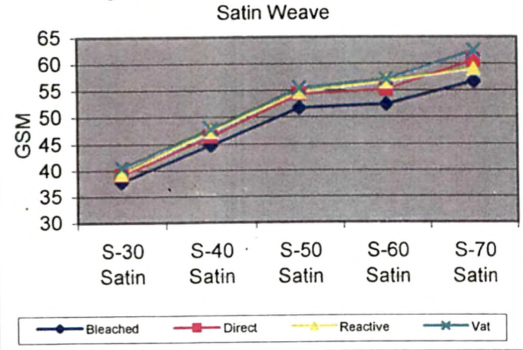

Fig. 7.4 Effect of Pick Density on GSM for Satin Weave

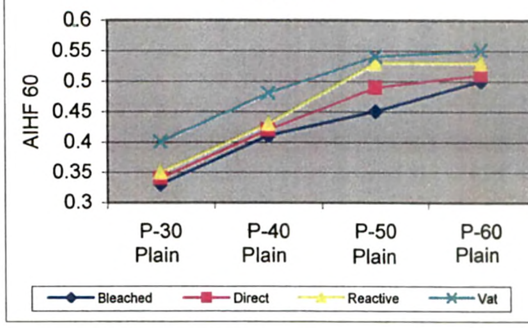

Fig. 7.5 Effect of Pick Density on AIHF60 for Plain Weave

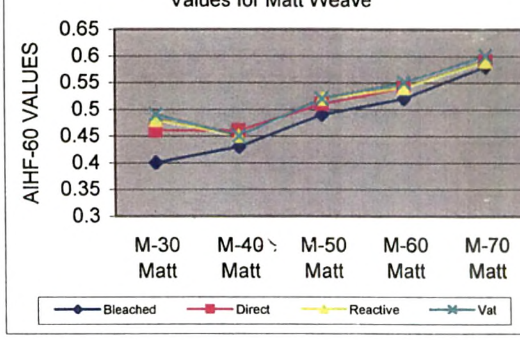

Fig.7.6 Effect Of Pick Density on AIHF-60 Values for Matt Weave

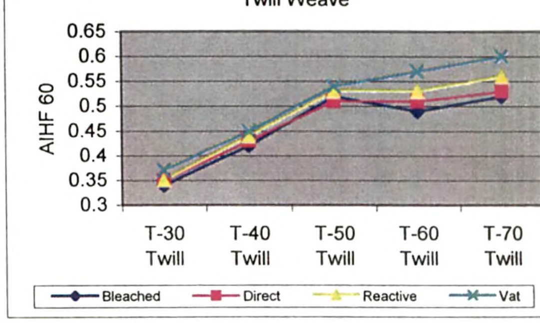

Fig. 7.7 Effect of Pick Density on AIHF60 for Twill Weave

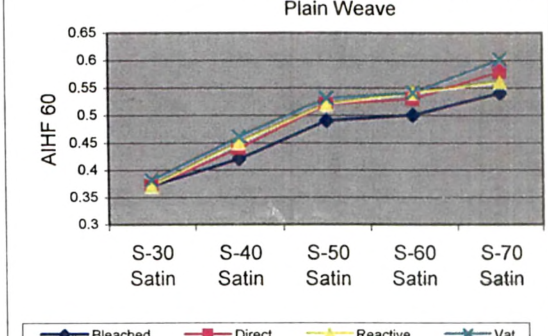

Fig. 7.8 Effect of Pick Density on AIHF60 for Plain Weave

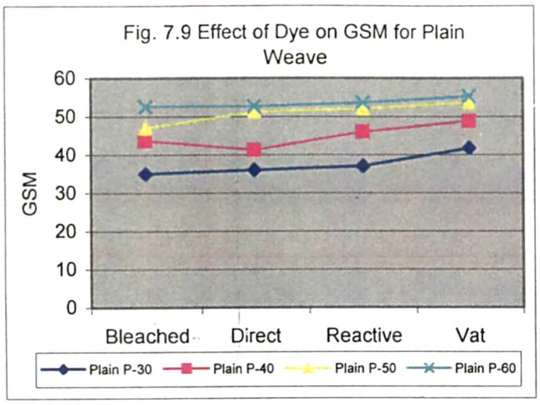

Fig. 7.9 Effect of Dye on GSM for Plain Weave

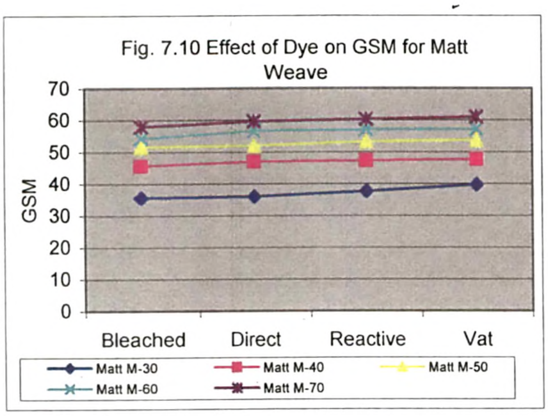

Fig. 7.10 Effect of Dye on GSM for Matt Weave

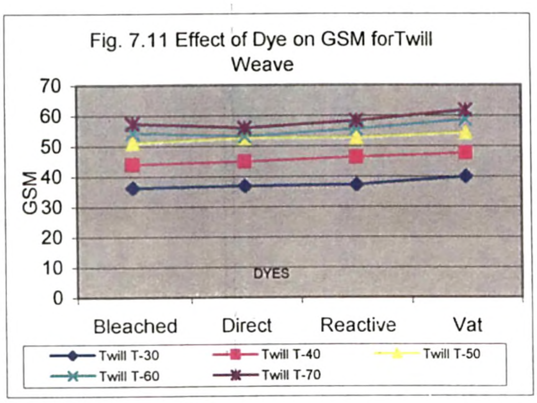

Fig. 7.11 Effect of Dye on GSM forTwill Weave

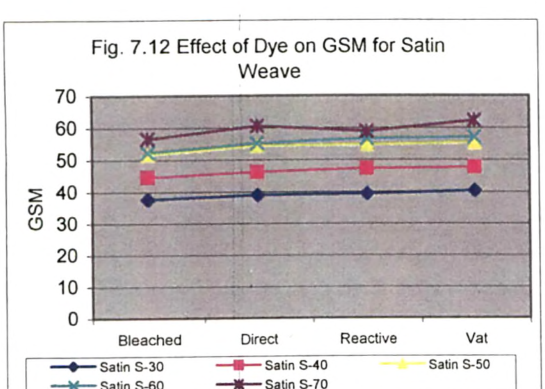

Fig. 7.12 Effect of Dye on GSM for Satin Weave

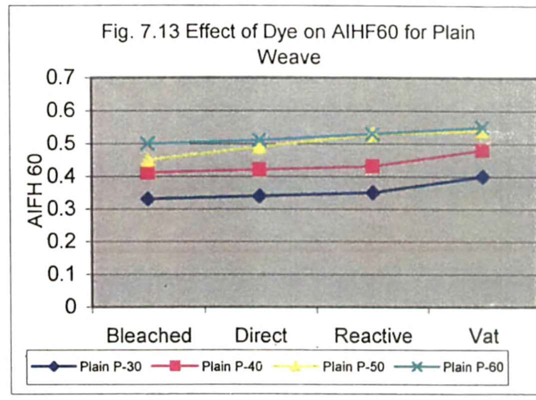

Fig. 7.13 Effect of Dye on AIHF60 for Plain Weave

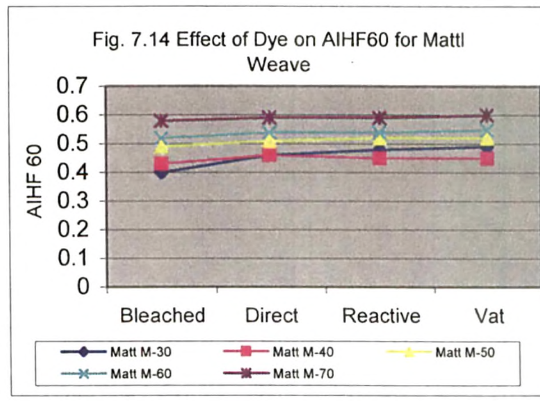

Fig. 7.14 Effect of Dye on AIHF60 for Mattl Weave

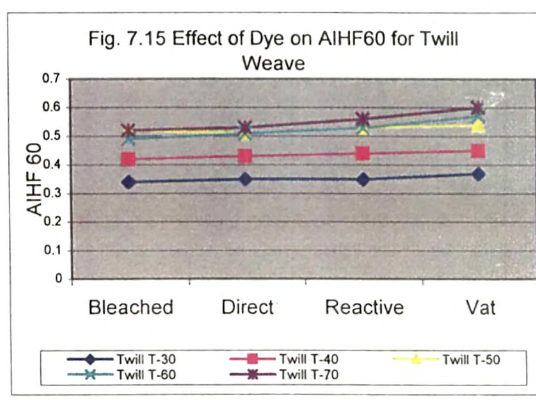

Fig. 7.15 Effect of Dye on AIHF60 for Twill Weave

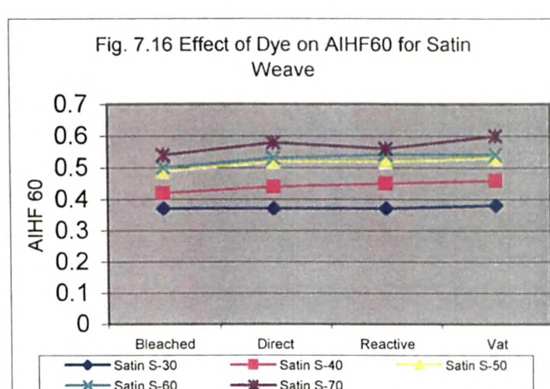

Fig. 7.16 Effect of Dye on AIHF60 for Satin Weave