International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 1 Issue 5, July - 2012

Practical Aspects of Imparting Sun Protective Coating on Cotton Textiles

S.K.Chinta*, Yogesh Wanere

D.K.T.E.S.Textile & Engg. Institute,
Ichalkaranji.

Abstract

The incidence of skin cancer has been rising for years worldwide. Elevated exposure to UV radiation is considering one of the main factors causing neoplasm of the skin. The risk to outdoors workers of exposure to solar ultraviolet radiation (UVR) has been known for some time. Textiles are a simple and effective means of protecting the skin against UV radiation. The UV protection depends on fiber type, yarn and fabric construction, square weight, moisture content, and finishing. To protect from any adverse affects due to exposure to ultraviolet light, a study was planned to provide protection for clothing using UVR absorbers. In the present study, cotton fabric in plain weave was coated with UV absorber by using titanium dioxide (TiO_2), to develop sun protective textiles. The coating is carried out by using two different recipes by varying temperature and concentration. The coated fabrics were tested for

UPF testing using AATCC 183/2000 and AS/NZS:4399/1996 methods and also certain physical properties like crease recovery, bending modulus, crease recovery angle etc were tested using conventional procedures. The results indicated that the coating of TiO_2 on cotton fabric improved the UV protection and also UPF values after washing do not alter noticeably.

Keywords: Ultraviolet Radiation (UVR), Titanium Dioxide (TiO_2), Ultraviolet Protection Factor (UPF).

1. Introduction

Sunlight is the prime energy source and essential element for survival of human race. Sun radiation has a continuous energy spectrum over wavelength range of about 0.7 nm to 3000 nm and the effective spectrum of the solar radiation reaching on the surface of earth spans from 280 nm to 3000 nm [1], where the wavelength of ultraviolet spectrum lies between 290 nm to 400 nm. Ultraviolet radiation constitutes to 5% of the total incident sunlight on earth surface (visible light 50% and IR radiation 45%). Even though, its proportion is quite less, it has the highest quantum energy compared to other radiations. This energy of ultraviolet radiation is of the order of magnitude of bond energy of organic molecules; hence, it has tremendous detrimental effect on human skin [2, 3]. The intensity and distribution of ultraviolet radiation depends closely on the angle of incidence; hence they vary with the location of the place, season and time of the day. The incidence of skin cancer has been increasing at an alarming rate over the past several decades. Thought there are many factors involved in the onset of melanoma and non-melanoma skin cancers, overexposure to ultraviolet radiation has clearly been identified as an important factor [4-6]. The long wavelength (320 nm-400 nm) ultraviolet rays (UV-A) causes a transformation of melanin precursors in the skin, leading to so-called rapid pigmentation, which sets in within a period of a few hours, but this is only a very minimal and of short duration. However, it penetrates deeply into the dermis or true skin, leading to premature ageing, showing up in the form of loss of elasticity accompanied by lines and wrinkles. The shorter wavelength (290 nm-320 nm), but higher energy ultraviolet rays (UV-B) penetrate to a depth of a few millimeters into the skin, causing the formation of a relatively stable pigment in the cells of the outer layer of the skin. This can lead to acute chronic reactions and damages; such as skin reddening (erythema) or sunburn. The shortest wavelength (10 nm-290nm) ultraviolet rays (UV-C), which are highly damaging to human skin are filtered out by the ozone layer and do not reach on the surface of earth [7-11].

The risks posed by ultraviolet radiation have become more dangerous in recent years as the whole world is suffering from all kinds of pollution. Clothing has the ability to protect the skin from incident solar radiation because the fabric from which it is made can reflect, absorb and scatter solar wavelengths. Each fabric must be tested to determine its ability to protect from solar radiation, as this cannot be known from visual observation nor calculated from descriptions of the fabric’s composition and structure. To determine this so called Ultraviolet Protection Factor (UPF), special test standards and methods are required as offered by different associations. Care labeling similar to fabric and garment care labels has

Vol. 1 Issue 5, July - 2012
ISSN: 2278-0181

been developed for UV protection, and standard procedures have been established for the measurement, calculation, labeling methods and comparison of label values. [12]

Ultraviolet Protective Factor Ratings [7]

UVR Protection Category	UV Protection Factor	Mean %UVR Transmission
Moderate	UPF 10 to 19	10 to 5.1
High	UPF 20 to 29	5.0 to 3.4
Very High	UPF 30 to 49	3.3 to 2.0
Maximum UPF	≥50	≤2.0

Thus in this study, coating of titanium dioxide (TiO_2) was carried out on plain woven cotton fabric, using two different recipes by varying temperature and concentration. The UPF of coated samples were measured by using AATCC 183/2000 and AS/NZS: 4399/1996 methods.

2. Material and methods

2.1 Fabric

For this study 100% cotton plain woven shirting fabric was used.

30^sx30^s
--------- 82”
106 × 106

GSM – 140 gm/sq mtr,

Thickness – 0.29mm.

2.2 Pretreatment of fabric

The raw fabric was desized by using enzyme desizing then scouring was carried out at boil temperature for 4hrs. After that bleaching is carried out using 4% H_2O_2 of 50% concentration for 4hrs followed by H_2O_2 killer, the fabric is then washed and dried.

2.3 Fabric Treatment: coating of fabric with titanium dioxide (TiO_2)

The cotton fabric was coated with titanium dioxide as UV absorber by using three different concentration (1%, 2%, and 4%) gpl and two different recipes.

Coating recipes of titanium dioxide for cotton fabric**.**

Recipe A:

UV absorber TiO_2	- (1%, 2%, 4%) gpl
Ammonium sulphate	- 1.0 gpl
Formic acid	- 1.0 gpl
Synthetic thickener	- as per requirement

Recipe B:

UV absorber TiO_2	- (1%, 2%, 4%) gpl
Sodium bicarbonate	- 4 gpl
Urea	- 60 gpl
Synthetic thickener	- as per requirement

The coating was carried out on Mathis Continuous Coating Mathis Type KTF-S-500. The fabric was

ISSN: 2278-0181
Vol. 1 Issue 3, May - 2012

then dried at 80^0c for 2min and curing was carried out at three different temperatures, i.e. at 120^0c, 140^0c and 160^0c for 4min.

2.5 Testing

2.5.1 Determination of UPF of fabric samples [13]

The UPF of fabric samples were tested by using standard AATCC 183/2000 and AS/NZS: 4399/1996 on Spectrophotometer.

2.5.2 UPF after Washing [14]

For washing treatment the 5gpl soap solution was used and washed in launder Ometer meter machine for 90 min at 40^0c and then check the UPF values of washing samples were checked by using standard AS/NZS: 4399/1996.

2.5.3 Tearing strength [15]

Fabric samples were evaluated for tearing strength on tearing tester as per the IS 6359:1971SP-15 the test specimen was according to template.

2.5.4 Bending Modulus [16]

Fabric samples were evaluated for Bending Modulus on stiffness tester as per the IS 6359:1971SP-15 methods, the test specimen was according to template.

2.5.5 Crease recovery angle [15]

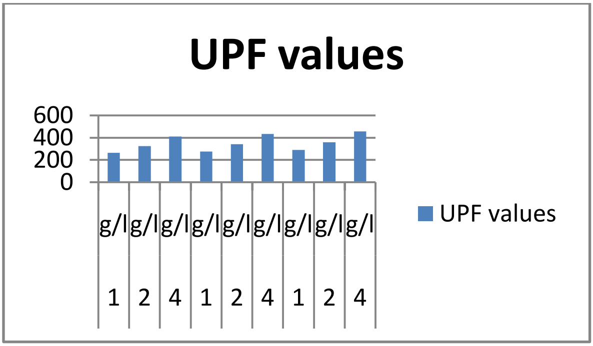
Fabric samples were evaluated for Crease recovery angle on Crease recovery tester as per the IS 6359:1971SP-15 methods, the test specimen was according to template.

2. Results and Discussion

Recipe-A

Table 1:- Effect of temperature and concentration of recipe-A on UPF values

	Values of UPF								
	120 ^{0}C			140 ^{0}C			160 ^{0}C		
	1	2	4	1	2	4	1	2	4
	g/l	g/l	g/l	g/l	g/l	g/l	g/l	g/l	g/l
UPF values	262.81	325.19	410.54	276.18	341.22	433.16	290.72	359.23	455.39



Graph 1:- Effect of temperature and concentration of recipe-A on UPF values

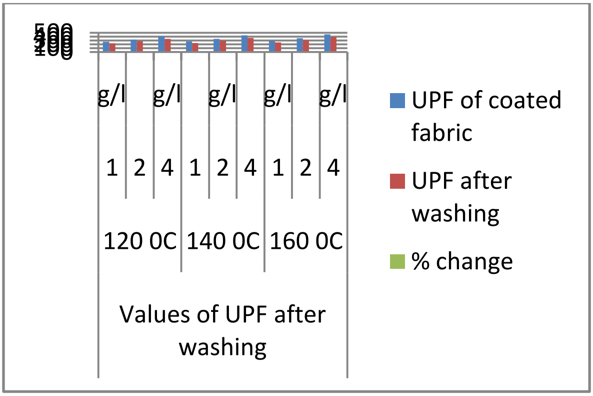
Results of Table 1 and Graph 1 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of UPF also increases from 262.81 to 410.54 respectively. As the temperature of curing increases from 120^{0}c to 160^{0}c, the trend of UPF is of

Vol. 1 Issue 5, July- 2012
ISSN: 2278-0181

increasing order and the maximum UPF value was found to be 455.39 for 4gpl TiO_2 concentration at 160^0c. The increase in UPF values may be due to the presence TiO_2 which reduced the UV transmission. Also increasing the curing temperature may attribute to higher cross linking efficiency of coated fabrics.

Table 2:- Effect of temperature and concentration of recipe-A on values of UPF after washing

	Values of UPF after washing								
	$120\ ^0$C			$140\ ^0$C			$160\ ^0$C		
	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
UPF of coated fabric	262.81	325.19	410.54	276.18	341.22	433.16	290.72	359.23	455.39
UPF after washing	226.18	279.5	340.3	237.36	292.76	370.18	250.26	309.11	391
% change	13.93	14.05	17.1	14.05	14.2	14.53	13.91	13.95	14.13



Graph 2:- Effect of temperature and concentration of recipe-A on values of UPF after washing

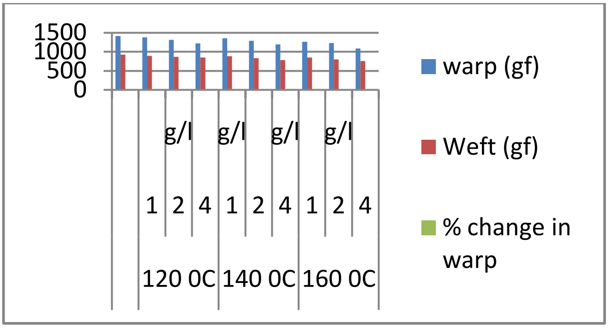
Results of Table 2 and Graph 2 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of UPF after washing increases from 226.18 to 340.3 respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of values of UPF after washing are of increasing order and the maximum UPF value was found to be 391.0 respectively for 4gpl TiO_2 concentration at 160^0c. The UPF value was found to be decreased up to 14.53% after application. UPF values before and after indicates average reduction in UPF of about 14% which indicates the stability of the coating during washing. The reason behind this may be higher cross linking efficiency.

Vol. 1 Issue 5, July - 2012
ISSN: 2278-0181

Table 3:- Effect of temperature and concentration of recipe-A on tearing strength values

	un-treated sample	Values of Tearing strength(gram force)								
		120 ^{0}C			140 ^{0}C			160 ^{0}C		
		1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
warp (gf)	1418.66	1380	1312.66	1226	1360	1290.33	1194.33	1262.66	1226.66	1088
Weft (gf)	928	896	864	853.3	885.33	838	784	848	800	755
% change in warp		2.72	7.47	13.58	4.13	9.04	15.81	13.53	10.99	23.3
% change in weft		3.44	6.89	8.04	4.59	9.69	15.51	8.62	13.79	18.64

Vol. 1 Issue 5, July - 2012
ISSN: 2278-0181

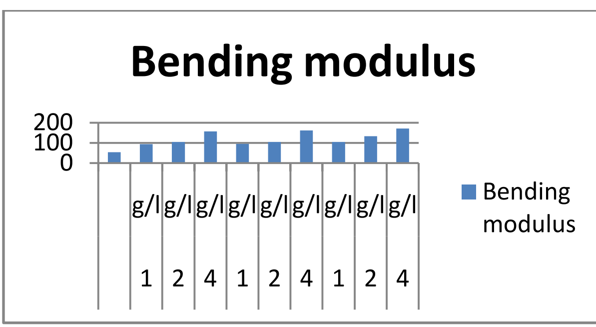


Graph 3: - Effect of temperature and concentration of recipe-A on tearing strength values

Results of Table 3 and Graph 3 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of tearing strength (in gram force) decreases from 1380 to 1226 and 896 to 853.33 in both warp and weft directions respectively. As the temperature of curing increased from 120^0c to 160^0c, the trend of tearing strength values were of decreasing order and the minimum tearing strength (in gram force) values were found to be 1088 and 755 in both warp and weft directions respectively for 4gpl TiO_2 concentration at 160^0c. The tearing strength values were found to be decreased by 23.30% and 18.64% respectively after application. The reason may be attribute to the cross linking efficiency. More the cross linking more will be reduction in strength.

Table 4:- Effect of temperature and concentration of recipe-A on values of bending modulus

	Un-treated sample	Values of Bending modulus								
		120 ^{0}C			140 ^{0}C			160 ^{0}C		
		1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
Bending modulus	54	93.06	104	157.88	94.45	105.34	162.44	105.17	133.82	171.58



Graph 4:- Effect of temperature and concentration of recipe-A on values of Bending modulus

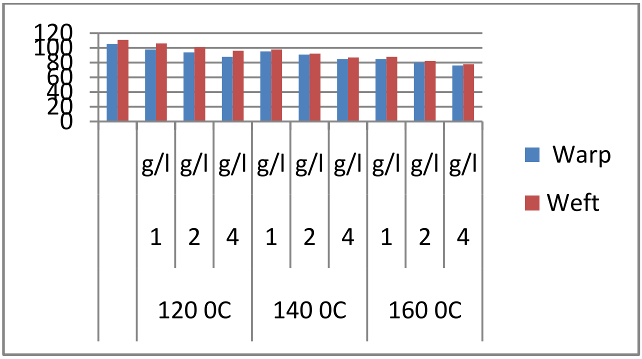
Results of Table 4 and Graph 4 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of bending modulus increases from 93.06

Vol. 1 Issue 5, July - 2012 ISSN: 2278-0181

to 157.88 respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of Bending modulus values were of increasing order and the maximum Bending modulus value was found to be 171 respectively for 4gpl TiO_2 concentration at 160^0c.

Table 5:- Effect of temperature and concentration of recipe-A on values of Crease recovery angle

	Un-treated sample	Values of Crease recovery angle								
		120 ^{0}C			140 ^{0}C			160 ^{0}C		
		1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
Warp	105	98	94	88	95	91	87	85	80	76
Weft	111	106	101	96	98	92	85	80	82	78



Vol. 1 Issue 5, July- 2012
ISSN: 2278-0181

Graph 5: - Effect of temperature and concentration of recipe-A on values of Crease recovery angle

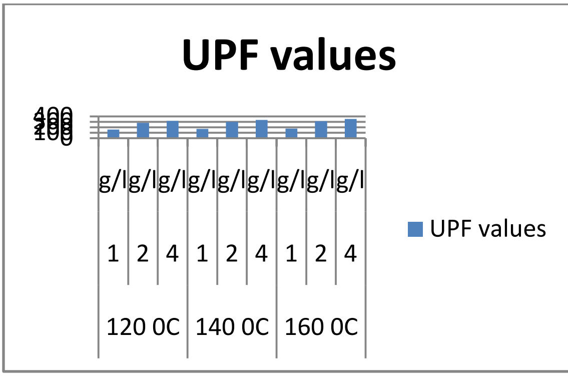
Results of Table 4 and Graph 4 indicate that as concentration of TiO_2 increases from 1gpl to 4gpl, the values of Crease recovery angle decreases from 98 to 88 and 106 to 96 in both warp and weft directions respectively. As the temperature of curing increased from 120^0c to 160^0c, the trend of Crease recovery angle values are of decreasing order and the minimum Crease recovery angle values were found to be 76 and 78 in warp and weft directions respectively for 4gpl TiO_2 concentration at 160^0c. The reduction in crease recovery angle may be due to stiffness of the fabric after coating and cross linking.

Recipe-B

Table 6:- Effect of temperature and concentration of recipe-B on UPF values

	Values of UPF								
	120 ^{0}C			140 ^{0}C			160 ^{0}C		
	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
UPF values	159.73	282.44	317.	168.15	297.83	334.42	176.46	313.14	355.18

			7						

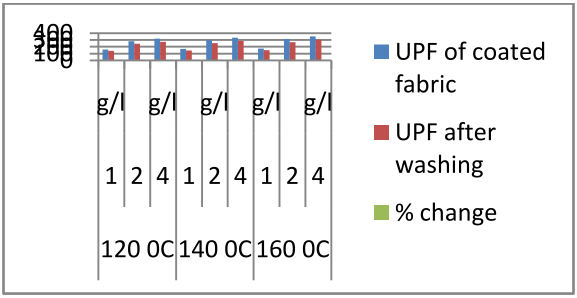


Graph 6:- Effect of temperature and concentration of recipe-B on UPF values

Results of Table 6 and Graph 6 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of UPF also increases from 169.73 to 317.7 respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of UPF is of increasing order and the maximum UPF value was found to be 355.18 for 4gpl TiO_2 concentration at 160^0c. The increase in UPF values may be due to the presence TiO2 which reduced the UV transmission. Also increasing the curing temperature may attribute to higher cross linking efficiency of coated fabrics.

Table 7:- Effect of temperature and concentration of recipe-B on values of UPF after washing

	Values of UPF after washing								
	120 ^{0}C			140 ^{0}C			160 ^{0}C		
	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
UPF of coated fabric	159.73	282.44	317.7	168.15	297.83	334.42	176.46	313.14	355.18
UPF after washing	140.6	242.45	272.52	146.16	256.3	287.24	151.36	270.18	305.3
% change	11.97	14.15	14.22	13.07	13.94	14.1	14.22	13.71	14.04



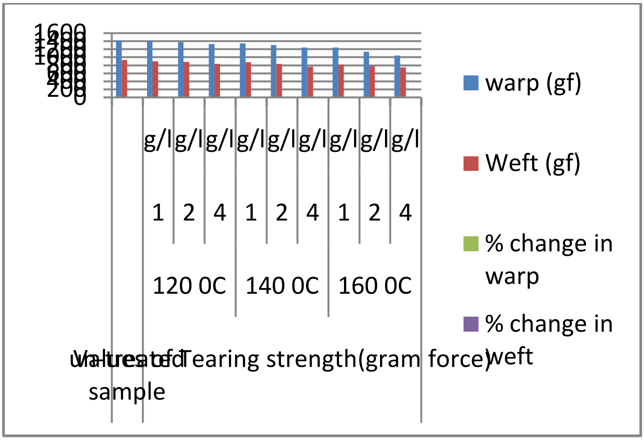
Graph 7:- Effect of temperature and concentration of recipe-B on values of UPF after washing

Results of Table 7 and Graph 7 indicate that as concentration of TiO_2 increases from 1gpl to 4gpl, the values of UPF after washing increases from 140.6 to 272.52 respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of values of UPF after washing are of increasing order and the maximum UPF value was found to be 305.3 respectively for 4gpl TiO_2 concentration at 160^0c. The UPF value was found to be decreased up to 14.22% after application. UPF values before and after indicates average reduction in UPF of about 14% which indicates the stability of the coating during washing. The reason behind this may be higher cross linking efficiency.

Table 8:- Effect of temperature and concentration of recipe-B on tearing strength values

	un-treated sample	Values of Tearing strength(gram force)								
		$120\ ^0C$			$140\ ^0C$			$160\ ^0C$		
		1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
warp (gf)	1418.66	1411.25	1376	1333.33	1344	1302	1240	1238	1136	1040
Weft (gf)	928	896	882	832	874.	832	768	816	784	752

					66					
% change in warp		0.51	2.49	6.01	5.26	8.22	12.59	12.73	19.92	26.69
% change in weft		3.44	4.95	10.34	5.74	10.34	17.24	12.06	15.51	18.96



Graph 8: - Effect of temperature and concentration of recipe-B on tearing strength values

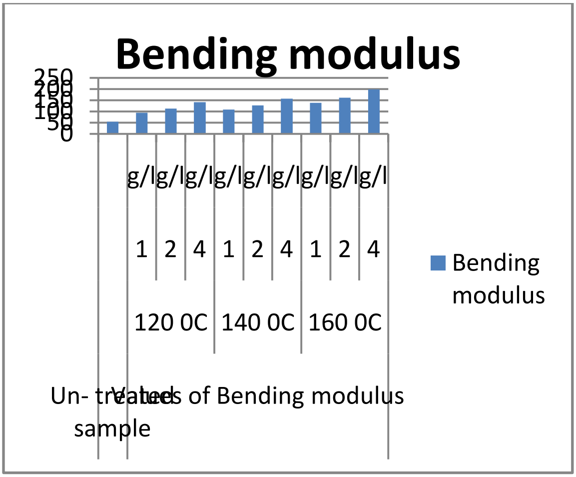
Results of Table 8 and Graph 8 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of tearing strength decreases 1411.25 to 133.33 and 896 to 853.33 in both warp and weft

Vol. 1 Issue 5, July - 2012 ISSN: 2278-0181

directions respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of tearing strength values are of decreasing order and the minimum tearing strength values were found to be 1088 and 755 in both warp and weft directions respectively for 4gpl TiO_2 concentration at 160^0c. The tearing strength values were found to be decreased by 26.69% and 18.96% respectively after application. The reason may be attribute to the cross linking efficiency. More the cross linking more will be reduction in strength.

Table 9:- Effect of temperature and concentration of recipe-B on values of Bending modulus

	Un-treated sample	Values of Bending modulus								
		$120\ ^0C$			$140\ ^0C$			$160\ ^0C$		
		1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
Bending modulus	54	94	112.39	140.79	108.22	127.8	157.24	138.02	162.03	199.25



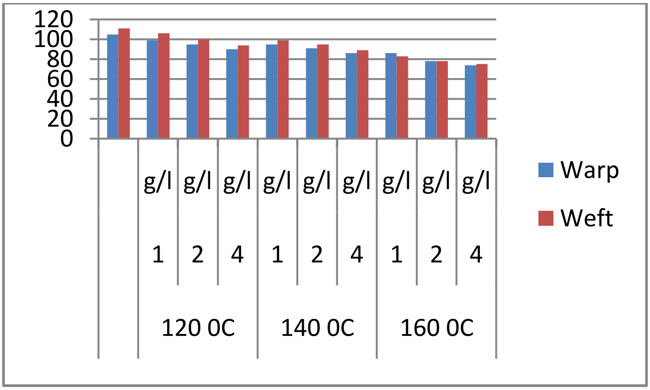
Graph 9:- Effect of temperature and concentration of recipe-B on values of Bending modulus

Results of Table 10 and Graph 10 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of bending modulus increases from 94 to 140.79 respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of Bending modulus values are of increasing order and the maximum Bending modulus value was found to be 199.25 respectively for 4gpl TiO_2 concentration at 160^0c.

ISSN: 2278-0181 Vol. 1 Issue 5, July - 2012

Table 10:- Effect of temperature and concentration of recipe-B on values of Crease recovery angle

	Un-treated sample	Values of Crease recovery angle								
		120 ^{0}C			140 ^{0}C			160 ^{0}C		
		1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l	1 g/l	2 g/l	4 g/l
Warp	105	99	95	90	95	91	86	86	78	74
Weft	111	106	100	94	99	95	89	83	78	75



Graph 10: - Effect of temperature and concentration of recipe-B on values of Crease recovery angle

Results of Table 10 and Graph 10 indicate that as the concentration of TiO_2 increases from 1gpl to 4gpl, the values of Crease recovery angle decreases from

Vol. 1 Issue 5, July- 2012 ISSN: 2278-0181

99 to 90 and 106 to 94 in both warp and weft directions respectively. As the temperature of curing increases from 120^0c to 160^0c, the trend of Crease recovery angle values are of decreasing order and the minimum Crease recovery angle values were found to be 74 and 76 in warp and weft directions respectively for 4gpl TiO_2 concentration at 160^0c. The reduction in crease recovery angle may be due to stiffness of the fabric after coating and cross linking.

Conclusions

From the results and discussion it was found that

- Due to the coating of TiO_2 on cotton fabric, it increases UPF values. At 4% concentration and 160^0c temperature, UPF value is higher.i.e. 455.39 of Recipe A.
- Recipe-A provided better UPF values as compare to Recipe-B.
- UPF values after washing reduced up to 14.33% in recipe-A and 14.22% in recipe-B and which indicates the durability of sun protective coating.
- Recipe-A was found to be slightly better as against Recipe-B as far as tearing strength and bending modulus are concerned.

References:-

1. UV radiation protective clothing, available at http://www.benthamscience.com/open/totextilej/articles/V003/14TOTEXTILEJ.pdf
2. F. Palacin, “Textile finish protects against ultraviolet radiation”, Melliand Int., vol. 3, pp. 169-172, 1997.
3. Akaydin, M., Research of UV Permeability Properties of Basic Weft Knitted Structures,

ISSN: 2278-0181
Vol. 1 Issue 5, July - 2012

Scientific Research and Essays, **5**, 2169-2178(2010).
4. Kursun, S., and Ozcan G., Investigation of UV Protection of Swimwear Fabrics, Textile Research Journal, **80**(17), 1811-1818(2010).
5. Saravanan, D., UV Protection Textile Materials, AUTEX Research journal, **7**, 53-62(2007).
6. Saxen, A., and Srivastava, A., Sun Screen Shelter Fabric, Textile Review, **5**, 16-21, (2010).
7. Menezes, E., UV Protective Finish, Man-Made Textile in India, **52,** 59-61, (2009).
8. Pai, S. R., and Paul, R., UV Absorber and Their Importance In Industry, New Cloth Market, **18**, 79-82(2003).
9. Bajaj, P., Kothari, V. K., and Gosh, S.B., Some Innovations in UV Protective Clothing, Indian Journal of Fibre and Textile Research, **25,** 315-329(2000).
10. Elhendawy, A. G., EL-Nagar, K., and EL-Ttahlawy, K., Cyclodextrin-4 Hydroxy Benzophenone Inclusion Complex for UV protective Cotton Fabric, Journal of Textile Institute, **98**, 453-462, (2007).
11. Nishkam, A., Sahu, H. C., Gupta, k. k., and Kasturiya, N., Snow Camouflage, Man-Made Textile In India, **10**, 402-408(2002).
12. Hussain, A., and Dr. Jahan, S., Protective Textiles: Protection Against UV Radiation, available at: www.fibre2fashion.com.
13. Richard A. Scott, Textile for Protection, first Edition, Woodhead publication , 2005.
14. Pradip V. Mehata and Satish K. Bhardwaj, Managimg Quality in the Apparel Industry, first Edition, New Age International(P), 1988.
15. B. P. Saville, physical Testing of Textile, first Edition, Woodhead publication, 1999.

16. J. E. Booth, Principle of Textile Testing, frist Edition, CBS publication, 1996.

*To whom the correspondence is made

Prof (Dr.) S.K. Chinta

Textile and Engineering Institute, D.K.T.E

Rajwada, Ichalkaranji, Maharashtra