International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.960

Study of the dyeing behaviour of acrylic microfiber i.e. a miyabi fibre with cationic dyes

Dr S R Shah and R. Mishra
Department of Textile Chemistry, Faculty of Technology & Engineering,
The Maharaja Sayajirao University of Baroda, Vadodara

Received: 10 April **Revised: 18** April **Accepted: 26** April

Abstract

Miyabi is the new innovative developed micro acrylic fibre which is thinner, lighter and warmer compared to normal acrylic fibre. The fibre was dyed with two structurally different cationic dyes using various process parameters and optimal conditions were derived. The dyeing profile of the said fibre is then studied in depth at these optimal conditions and finally, the fastness properties was also analysed to complete the dyeing behaviour. The derivation of the optimal conditions and the study of dyeing profile of fibre with cationic dye reveal many important characteristics. The results are quite energetic and can be tried at pilot scale and / or commercially.

Key words : Miyabi fibre, cationic dye, exhaustion percentage, dyeability

1. Introduction:

Microfibers are extra-fine synthetic fibres, having wonderful hand and drape, ultrafine linear density (< 0.1 dtex), high strength, hypoallergenic, non electrostatic, dry easily and environmental friendly[1-4]. The said fibre is explored in areas of applications of apparel textiles and technical textiles. Due to their fineness, the total surface area of the yarn or fabric of the fibre is higher than ordinary fibres and therefore special precautions should be considered during processing [5-7]. Miyabi, the recently developed fibre by Mitsubishi Rayon, is the micro-fine acrylic fibre with soft, lighter, anti – pilling and anti bacterial quality and warm feel. Miyabi fibre offers more smoothness compared to modal, viscose and silk and thinner, lighter and warmer as compared with wool and modal and is extremely comfortable to wear (figure – 1). The fibre has potential applications in area like sportswear, functional work wear, knitwear, hosieries and technical textiles [8-9].

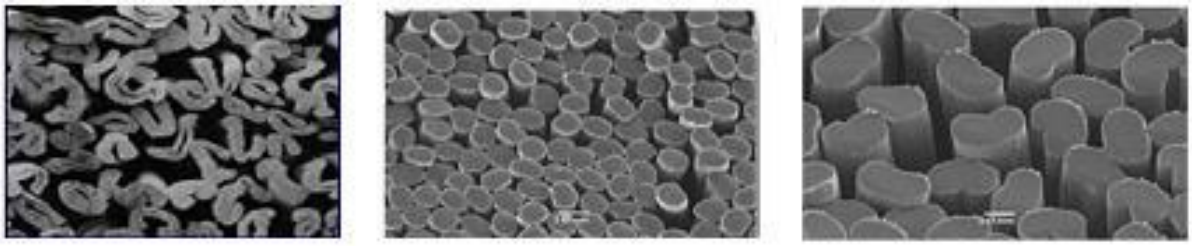


Figure – 1 : The cross sectional views of (a) Cotton, (b) Miyabi (c) Acrylic fibers

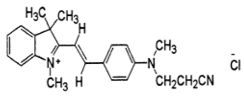
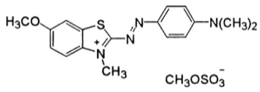
Being an acrylic and microfiber, its processing in general and dyeing required special precautions to get uniform and consistent end products. No literatures pertain to processing of the said fibre in general and dyeing in specific are available. In the present research, the dyeing behaviour of the miyabi fibre has been investigated and for this purpose the fibre is dyed with cationic dye under various process parameters and optimal process conditions was derived. The dyeing profile of the said fibre is then studied in depth at this optimal condition and evaluated in terms of fastness properties also.

2. Materials and methods :

2.1 Materials : Miyabi fibre, in the yarn form, has been procured from local supplier, was pre-treated with 1% (owf) non-ionic detergent at 70^0 C for 20 minutes, washed, dried & used throughout the present investigation (table – 1). Two structurally different cationic dyes in their commercial available form are used in the present investigation (table – 1). All the chemicals used for present research were obtained from local suppliers and of analytical reagent grade.

International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.960

Table – 1 : Details of miyabi yarn and dye used

Fibre	Dye
Denier : 150 Whiteness (ASTM 313) : 82 Absorbency : < 3 Sec Fineness : Ultrafine	1. Cationic Red C4G (C.I.Basic Red – 14)  Mol Wt = 380 2. Cationic Blue CGNX (C.I. Basic Blue – 54)  Mol Wt = 439

2.2 Dyeing procedure :

Firstly, the dye stock solution of suitable strength was prepared and used for the subsequent dyeing procedures. Two gram of miyabi fibre was dyed with two structurally different cationic dyes under different process parameters as prescribed table – 2. After stipulated dyeing period, the dye aliquot was used for spectral analysis after suitable dilution if required. The dyed sample was washed, soaped with non-ionic detergent, washed to neutral pH and used for further spectral assessment.

Table – 2 : Dyeing conditions of miyabi fibre with cationic dye

Parameter	Values	Parameter	Values
Dye (%, owf)	1%	Time (minutes)	60
pH	3,4,5 & 6 (with suitable buffer)	M:L Ratio	1:50
Temperature (^{0} C)	70,80,90 & 100	Machines used	(i) Open bath hank dyeing machine (ii) HT/HP beaker dyeing machine

2.3 Determination of λmax of dye :

One milligram of dye was dissolved in 100 ml of distilled water (1 ppm solution) and used for measurement of optical density. The instrument was calibrated with distilled water and absorbency (optical density) was determined at different wavelengths (between 400 to 700 nm) of both dyes. The values of optical densities, obtained in visible wavelength range are plotted as absorbency against wavelength and values of maximum wavelength were determined (figure – 1) [10]. It has been found that the maximum wavelength of absorbency of C I Blue – 54 and C I Red – 1 are 570 and 520 nm respectively.

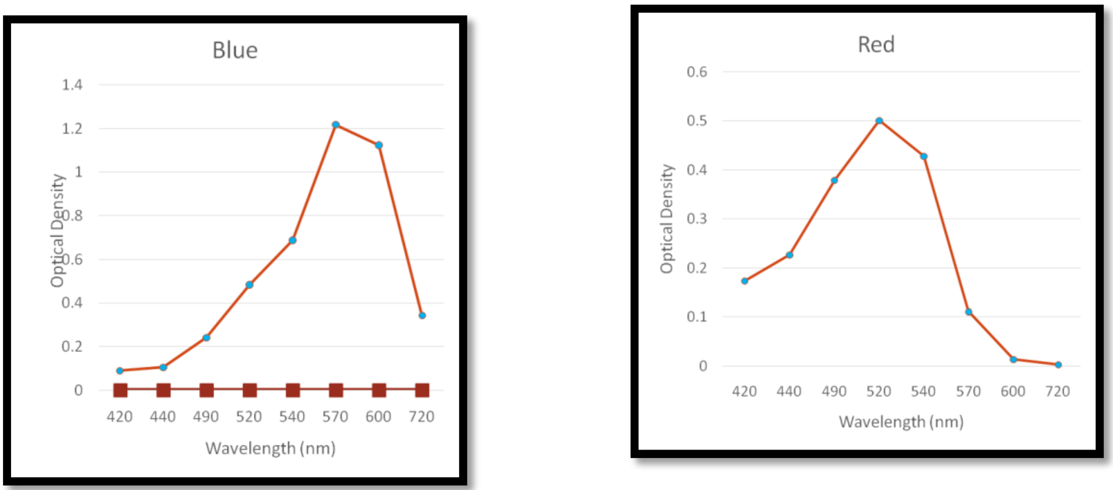


Figure – 1 : Absorbency curve of cationic dyes

2.3 Analytical procedures:

2.3.1 Determination of exhaustion percentage:

The percentage exhaustion of dyeing was determined by measuring the absorbency of initial dye bath (E_1) and final dye bath (E_2) at maximum wavelength of respected dye and using equation [11-12].

$$\text{Exhaustion } (\%) = \frac{E1-E2}{E1} \times 100 \qquad \text{....................... Equation – 1.}$$

2.3.2 Determinations of colour strength (K / S) :

Strength of any colorant (dyestuff) is related to absorption property. It is known that when reflectance is more, absorbance is less and when reflectance is less, absorbance is more. The reflectance values of coloured sample are converted into colour strength using Kubelka – Munk equation (K/S Equation – 2)[13].

$$K / S = (1-R)^2 / 2R \qquad \text{-------------- Equation – 2.}$$

Where,

K = Absorbance coefficient,

S = Scattering coefficient

R = Reflectance values of coloured sample at maximum wavelength.

International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.960

2.3.3 Determination of fastness properties:

ISO - 105 – C10 : 2006 test method was used for determination of wash fastness of dyed samples[14]. A yarn specimen was knotted between two undyed yarn samples, namely, miyabi yarn and cotton yarn, to form a composite specimen. Washing solution containing 5 gm/lit soap and 2 gm/lit sodium carbonate was taken in to Launder-o-meter and the specimen was treated for 30 minutes at 60 ± 2^{o}C. After stipulated time, the sample is removed, rinsed, knotting was opened and dried in shadow. The change in colour and degree of staining (on both the yarns) was evaluated using geometric gray scales.

ISO 105 X 12 1993 rubbing fastness test method was used and the coloured samples are determined using crock meter instrument and in dry as well as in wet conditions[15]. The rubbing was performed by fixing the white cloth on glass knob and to and fro strokes are applied. After fix number of rubbing the white cloths from glass knob is removed and staining was assessed with reference to gray scale of staining.

ISO 105 E04 2013 test method was used to determine perspiration fastness properties of dyed samples[16]. The dyed and undyed specimen after knotting is thoroughly wet in a solution of alkaline pH (0.5g l-histidine mono-hydrochloride mono-hydrate, 5g sodium chloride, and 2.5g disodium hydrogen o- phosphate per litre) at the liquor ratio of 20:1 for 30 minutes. After through wetting, the composite sample is placed between two glasses plates measuring about 7.5×6.5cm under a force of about 4.5kg. Simpilar test has been performed for acidic perspiration solution also. The change in colour of the specimen and the staining of the white cloth was assessed against standard gray scales.

3. Results & discussion:

3.1 Dyeing of miyabi fibre with cationic dyes:

The miyabi fibre (2.0 gm), was dyed with two structurally different cationic dyes, namely, C. I. Basic Red-14 and C. I. Blue-54 at various process parameters. The effects of pH (3, 4, 5 & 6) and temperature (70, 80, 90 & 100^0 C) on miyabi fibre with two dyes is reported in table – 3 and graphically represented in figure – 2 and 3.

International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.960

Table – 3 : Dyeing of miyabi fibre with cationic dyes at various process parameters

pH of dye bath	Temp. of dye bath (^{0}C)	Exhaustion (%)		K / S value	
		C.I.Red-14	C.I.Blue-54	C.I.Red-14	C.I.Blue-54
3	70	24.0	21.6	0.28	0.09
	80	44.0	44.3	0.60	0.24
	90	79.8	77.4	0.83	0.40
	100	89.0	91.2	1.10	0.48
4	70	28.9	10.9	0.25	0.12
	80	43.8	37.6	0.49	0.23
	90	83.5	71.3.	0.88	0.46
	100	90.0	92.0	1.20	0.55
5	70	24.4	30.0	0.35	0.10
	80	45.9	45.2	0.62	0.24
	90	85.8	79.8	0.87	0.42
	100	**91.0**	**93.0**	**1.22**	**0.57**
6	70	12.5	18.8	0.28	0.12
	80	42.6	42.6	0.38	0.23
	90	80.1	74.0	0.84	0.49
	100	88.0	91.0	0.92	0.51

It can be seen that the dye exhaustion percentage values of cationic dye red and blue on miyabi fibre at pH – 3 are 24, 44, 80 and 89 and 22, 44, 77 and 91 at 70, 80 90 and 100^{o}C temperatures respectively. Similar trends can be seen for other i.e. 4, 5 and 6 also. The colour strength values (K / S) also increases with that of temperature from 70 to 100^{o}c and at each pH values in the silmilar trends. This indicates the dye exhaustion of cationic dyes on miyabi fibre increase slowly at lower temperatures (< 80^{o}C) and than increases at and above 80^{o}C significantly. The maximumdye percentage exhaustion is observed at a temperature of 100^{o}C and at all pH values i.e. 3 to 6.

International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.960

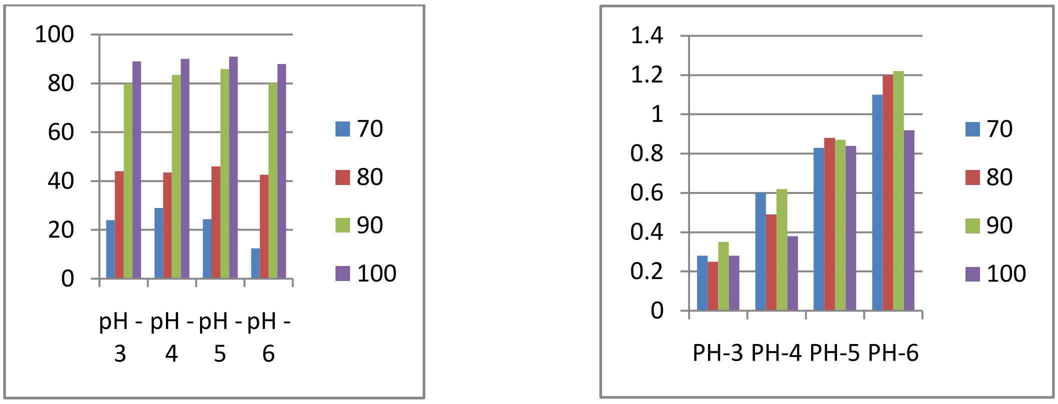


Figure – 2 : Effects of temperature & pH on dyebility of miyabi fibre with C. I. Basic Red – 14.

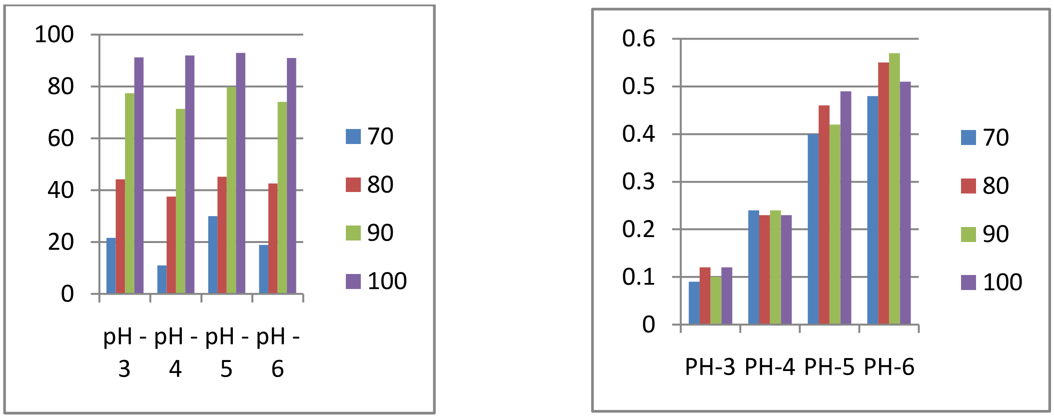


Figure – 3 : Effects of temperature & pH on dyebility of miyabi fibre with C. I. Basic Blue – 54.

The increase in dye exhaustion at and above 80^{o}C is due to the glass transition temperature (Tg) of miyabi fibre which is around 80^{o}C and the formation of more open structure. Further, at nearer to boil allmost 100 % exhaustion can be observed and therefore no trials at above the said temperature is conducted.

The percentage exhaustion values at pH values of 3, 4, 5 and 6 with cationic dyes red and blue on miyabi fibre at temperature of 90^{o}C are 80, 84, 86 and 80 and 77, 71, 80 and 74 respectively. The behavior of colour strength (k/s) was also observed in the similar trends of percentage exhaustion at various pH. The results indicate that dyeability of miyabi fibre with cationic dyes were improving with increases of pH from 3 to 5 and than decreases with increases of pH. The best results of dyeing in terms of percentage exhaustion (and colour strength) was observed at pH values of 5. The dyeing behavior shows that miyabi being, microfibre acrylic the dye bath pH should be betwee 5 – 5.5 for cationic dyes. It may postulates that at the said pH, the negative dye site on fiber can interact better with positive dye cation (Figure – 4).

(i) Fiber : F --- A (M) === F --- A^- + $(M)^+$

(ii) Dye : D --- X === D^+ + X^-

||

(iii) Dye-fibre bond : F --- A---D + $(M)^+$ + X^-

Where : FA → Acrylic fibre anion, M → Metallic cation, D → Dye cation, X → Dye anion

Figure – 4 : Ionic interaction of acrylic fibre and cationic dye

3.2 Optimal conditions of dyeing of miyabi fibre with cationic dye:

From the foregoing experiments the optimal conditions of miyabi fibre dyeing with cationic dyes with respect to the prime evaluation factor i.e. percentage exhaustion (table – 4).

Table – 4 : Optimal conditions of miyabi fibre dyeing with cationic dye

Name of dye	Temperature of dye bath (^{0}C)	pH	Time (Minutes)	Exhaustion (%)	K/S values
C.I. Basic Red-14	100	5	60	91	0.991
C.I.Basic Blue-54	100	5	60	93	0.564

Miyabi, a new innovative micro acrylic fibre can be dyed successfully with cationic dyes. However to get effective dyeing in terms of the highest percentage exhaustion and level dyeing, the optimal conditions should be very important. In the present investigation an optimal conditions of the said new innovative fibre dyeing with cationic dyes has been derived. It has been found that the best conditions of dyeing will be temperature of 100^{o}C and pH will be 5 to 5.5. The time of dyeing will be depends on the depth of dyeing. In present study the depth of shade will be 1 %, the ideal time will be 60 minutes for the said depth. Further, the sudden increase in rate of dye exhaustion from 80 to 100^{o}C indicates the slow heating rate is required in the said interval of temperature to get uniform dyeing results.

International journal of basic and applied research
www.pragatipublication.com
ISSN 2249-3352 (P) 2278-0505 (E)
Cosmos Impact Factor-5.960

3.3 Dyeing profile of miyabi fibre with cationic dye:

The dyeing profile of any system is an important tool to control the dyeing in terms of uniformity, exhaustion percentage, temperature and time of dyeing. Dyeing behaviour of normal acrylic fibre (mono and bi-component) has been studied by many technocrats but that of micro fibre has not been evaluated and no literatures are available. Dyeing profile of two cationic dyes on miyabi fiber indicate that dye uptake of cationic dye on miyabi fibre was very slow from room temperature (40^{o}C) to 80^{o}C (figures – 4 & 5). It means heating rate can be increased to higher rate (2 to 4 ^{o}C/min) from room temperature to 80^{o}C to reduce production cycle. However, dye exhaustion percentage increase to significant level from temperature of 80 to 100^{o}C. This can be observed in figures 2 and 3 for two cationic dyes. Therefore, to get level dyeing, the heating rate should be kept low (0.5 to 1 ^{o}C/min) in this temperature range. This may be because the glass transition temperature ranges of micro acrylic fibre. At 100^{o}C temperature the dye exhaustion percentage is all most 100 % and therefore there is no need to further increase in temperatures.

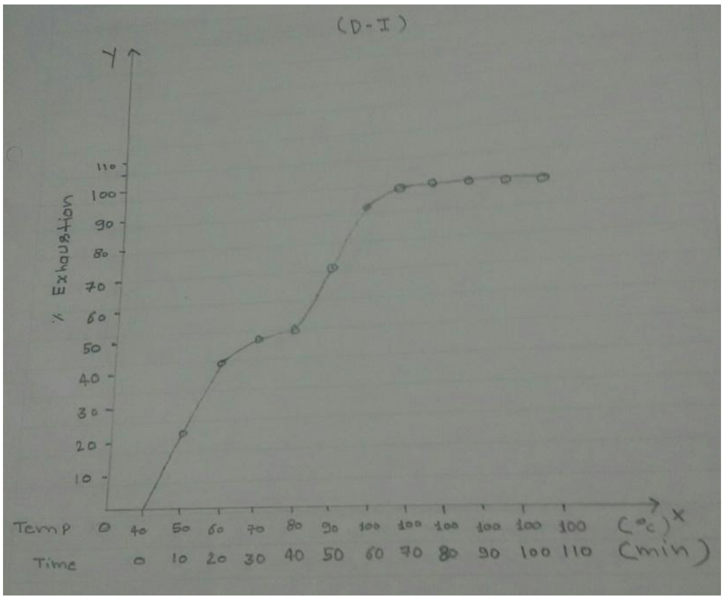


Figure – 4 : Dyeing profile of C.I. Basic Red-14

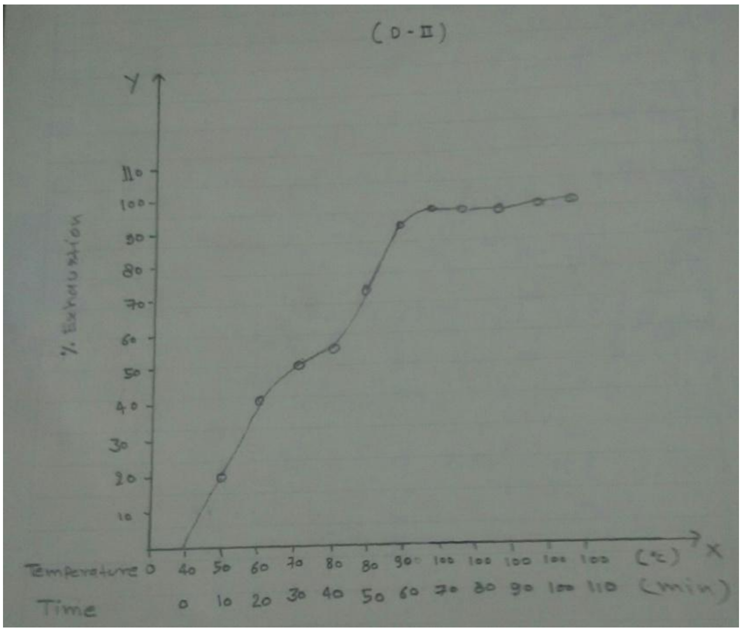


Figure – 5 : Dyeing profile of C.I.Basic Blue-54

3.4 Fastness properties of cationic dyes on miyabi fibre :

Fastness properties of any dyeing are important for post application of the materials in textiles. Therefore, the important fastness properties, namely, washing, rubbing and perspiration fastness properties of the optimum conditioned dyed miyabi fibre with two cationic dyes are determined (table – 5).

Table – 5: Fastness properties of miyabi fibre dyed with cationic dyes

Dye name	Wash fastness		Rubbing fastness		Perspiration fastness	
	CS	CC	Dry	Wet	Alkaline	Acidic
C.I. Basic Red-14	4/5	5	4/5	4	4/5	5
C.I.Basic Blue-54	5	4/5	4/5	4	4/5	4/5
CS : Colour stain, CC : Colour change						

It has been observed that the ratting of wash fastness in terms of colour stain and colour change are about 4/5 to 5. This indicates the wash fastness of cationic dye on miyabi fibre is very good. This is because of the strong ionic bonds between cationic dye and miyabi fibre.

The rubbing fastness ratings of cationic dyes on miyabi fibres are also good to very good i.e. 4 to 4/5. The good rubbing fastness is the characteristics of cationic dye in general on acrylic fibre and particularly on miyabi fibre.

The perspiration fastness, alkaline and acidic, is also very good of cationic dyed miybi fibre. Both alkaline and acidic perspiration ratings are very good (4/5 to 5) and therefore, the dyed material can be successfully used for the textile garments, next to skin because of the feel, and softness.

4. Conclusions:

Miyabi, the innovative micro acrylic fibre, can be dyed effectively with cationic dyes after certain precautions during dyeing. The rate of heating from start temperature to 80^{o}C can be kept higher (2 – 4^{o}C per min). However, the rate of heating should be very slow to get even dyeing between 80 – 100^{o}C. Percentage exhaustion cannot increases above 100^{o}C and therefore, the maximum temperature of dyeing is kept at this level. Effects of pH on dyeing of miyabi fibre was studied (3 – 6 pH) and found that the best dyeing obtained at pH values of 5 to 5.5. The optimal conditions of dyeing of miyabi fiber with cationic dye were derived and dyeing profile was established for pilot and / or commercial use. Fastness properties of dyed fibres, namely, washing, rubbing and perspiration are observed good to very good of cationic dyes.

5. References :

1. S. Purane, N. Panigrahi, ‘Microfibres, microfilaments & their applications’, Autex Res. J., 7 (3) (2007) Pages 148-158.
2. S . Pal ‘Microfibre – Production, Properties & Application’, Textile Asia, 24 (1) (1993) Pages 53-58.
3. M. Dagang, Z. Hongmei, J. Shouxiang, S. Songmin & C. Zhuoming, ‘Preparation of antibacterial microfibre’, Indian Journal of Fibre & Textile Research 41 (6) (2016) Pages : 145-149.

4. D L Smith, S Gillanders, J T Holah & C Gush, 'Assessing the efficacy of different microfibre cloths at removing surface micro-organisms associated with healthcare-associated infections' J. Hosp. Infect, 78 (2011) 182.
5. F Mohamed, Al Elkadyand & A Elmetwally 'Microfibre technology & its applications The Indian Text J., Feb (2012) Pages : 15-21.
6. B. Von Falki, 'Production and Properties of Microfibres and Microfilaments' The Indian Text J., Feb (1991) Pages : 62-70.
7. S Pal, R Gandhi & V Kothari, 'Draw texturing of microfibre polyester yarn', Textile Res. J., 66, (12), (1996) Pages : 770-776.
8. G. Ertekin & A. Marmaralı Ege, 'Performance and thermal comfort properties of knitted fabrics produced by cotton, acrylic and miyabi yarns', XIIIth International Izmir Textile and Apparel Symposium April 2-5 (2014) Pages : 237 – 243.
9. T Hussain, F. Akhtar, Inam-ul-Haq, I. Toqeer & H. Farooq, 'Usability of aqueous solutions of commercial reactive dye for gamma dosimetry', Academic Res. Int., 5(1) (2004) Pages : 32-36.
10. M. Zakerhamidi, A. Ghanadzadeh & M. Moghadam, 'Solvent effects on the UV/Visible absorption spectra of some aminoazobenzene dyes', Chem Sci Trans., 1(1) (2012) Pages : 1-8.
11. A. Gedamu, A. Sendek & S. Libsu, 'Optimizing dyeing parameters of remazol golden yellow G dye upon cotton fabric', International Journal of Advanced Research 2 (10) (2014) Pages : 234-240.
12. M. Shak Sadi, & M. Jakir Hossain, 'Measurement of the relationship between shade (%), reflectance (%) and colour strength (K/S)', Textile Today, January (2017) Pages : 12-18.