International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Dyeing of Polyester Fabrics Using Microwave Irradiation Technique

M. M. El-Molla[1], K. Haggag[2], K. A. Ahmed[3]

Textile Research Division, National Research Centre El- Bohouth St., Dokki, Giza, Egypt. P.O.12622

Abstract: ***Dyeing of polyester with disperse dyes, red 60 and blue 56 was done using microwaves irradiation technique. Different parameters such as dyeing time, dye concentration, power of microwave used and Liquor ratio were studied. Compared the results obtained upon using conventional technique and microwave technique was done. From the results obtained, the microwave technique save about 40 min. in the dyeing time, addition of carrier and dispersing agent, this means that save in time, energy and money. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent.***

Keywords: Dyeing, Disperse dyes, Microwave irradiation, Polyester Fabrics

1. Introduction

The main difference between conventional heating and microwave heating is the way in which heat is generated. In conventional processing, energy is transferred to material through convection, conduction and radiation of heat from the surface of the material. In contrast, microwave energy is derived directly to materials through molecular interactions with the electromagnetic waves. The uniqueness of the microwave is to process materials with selective energy, higher rate, uniform heating and energy conservation [1-6]. The utilization of green chemistry techniques is dramatically reducing chemical waste and reaction times as has recently been proven in several organic syntheses and chemical transformations [7]. Methods to lower the curing temperature have received the most attention because the high temperature cure process not only wastes energy but also creates the risk of destroying substrates that cannot endure high temperature processes. Radiation curing technologies (UV and microwave) are used in much industrial applications as well as in the textile area [8, 9] because of low energy consumption, short start-up period, fast and reliable curing, low environmental pollution, fixation at room temperature, space saving, etc. Microwave irradiation is a well-known method for heating and drying materials and is utilized in many private households and industrial applications. It offers a number of advantages over conventional heating**,** such as noncontact heating (circumventing the decomposition of molecules close to the walls of the reaction vessel), instantaneous and rapid heating (resulting in a uniform heating of the reaction liquor), and highly specific heating (with the material selectivity emerging from the wavelength of microwave irradiation that intrinsically excites dipolar oscillation and induces ionic conduction) [10]. The purpose of this work is dying of polyester fabrics with disperse dyes using microwave irradiation to save time energy and money.

2. Materials and Methods

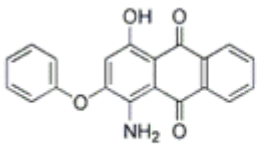
2.1. Materials

Polyester

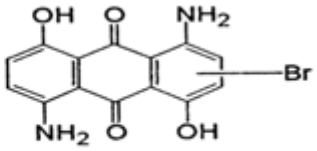
100% polyester knitted fabric of 150 g/m², supplied by a private sector was used.

Dyestuffs

Disperse red (C.I. Red 60) and Disperse blue dyes (C.I. Blue56), supplied by Clarinet Co.



Disperse Red 60



Disperse blue 56

Chemicals

Carreir , dispersing agent, acetic acid, were of laboratory grade chemicals were used.

2.2. Methods

2.2.1. Dyeing Procedure

Samples of polyester fabrics were dyed using disperse dye 0.5- 3% owf,1g/l carrier,1g/l dispersing agent, with L: R 1: 20. The temperature was slowly raised to 100°C and dyeing continued farther for 1 hours, another samples of polyester fabrics were dyed using disperse dye 0.5- 3% owf,1g/l carrier,1g/l dispersing agent, with L: R1:5 to 1: 20.(another samples were dyed without using ,1g/l carrier,1g/l dispersing agent), using microwave (Milestone Start synthesis Microwave Synthesis Lab station, USA) irradiation with power 200 Watt, for 10-20 min., hot rinsing and air-dried. Finally the samples were dried and assessed for color strength and over all fastness properties.

2.3. Measurements and Analysis

2.3.1. Color measurements

Color strength expressed as K/S was measured according to a previously reported method [11] by the light reflectance technique, and the relative color strength was calculated by applying the kubetka-Munk equation: Color strength (K/S) =

$$\frac{(1-R)^2}{2R} - \frac{(1-R°)^2}{2R°}$$

Where R and R° are the decimal fraction of the reflectance of the colored and uncolored fabrics, respectively. K is the absorption coefficient and S is the scattering coefficient.

2.3.2. Fastness Properties

Fastness properties to washing, rubbing and perspiration were measured according to a standard method [12].

3. Results and Discussion

3.1. Dyeing of polyester fabric using conventional heating technique.

Normal polyester does not contain any ionic groups, the fiber crystalline is very high, only suitable dye is disperse dye, either temperature > 100C required or special auxiliary (carrier) required for dyeing. Figure 3.1 show the effect of dye concentration on the color strength of dyed polyester fabrics at Liquor ratio 1:20, Temperature of dyeing 100°C, dyeing time 60 minute, carrier 1 g/l, dispersing agent 1g/l at PH=4.5, using disperse dye red 60. It is noticed that the increase in the dye concentration this is lead to increase in the color strength, for example the increase the dye concentration from 0.5, 1, 2 and 3% the K/S increase from 4.5, 8.9, 11.5 and 13.6 respectively.

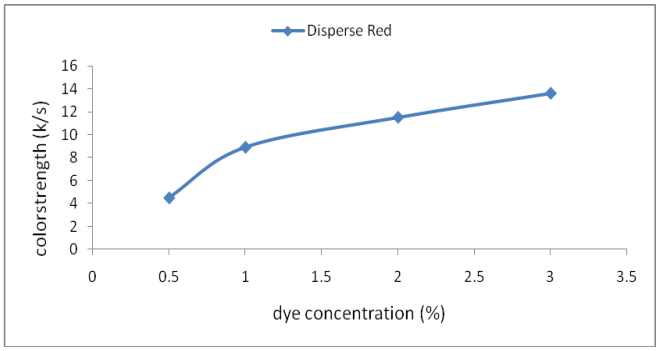


Figure 3.1: The effect of dye concentration on the color strength of dyed polyester* fabric with disperse dye red 60 using conventional method

* Liquor ratio 1:20, Temperature 100°C, dyeing time 60 minute, Carrier 1 g/l, dispersing agent 1g/l PH=4.5.

Table3.1, show the effect of dye concentration on the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye red 60 using conventional heating technique**.** Generally speaking, the fastness properties to rubbing, either wet or dry, washing, light fastness and color fastness properties to both acidic and alkaline perspiration for the dyed samples their values ranging from very good to excellent.

Table 3.1: Effect of dye concentration on the color strength and the overall fastness properties of dyeing* polyester fabric using disperse dye Red 60 using conventional technique**.**

Dye conc. (%)	*K/S*	*Light fastness*	*Rubbing fastness*		*Washing fastness*			*Perspiration*			
			dry	*wet*	*St cotton*	*St wool*	*Alt.*	*Acidic*		*Alkaline*	
								Alt	*St*	*Alt*	*St*
0.5	4.5	5	5	4-5	4	4-5	4-5	4-5	4-5	4-5	4-5
1	8.9	5	5	4-5	4	4-5	4-5	4-5	4-5	4-5	4-5
2	11.5	5	4-5	4	4-5	4-5	4	4-5	4-5	4-5	4-5
3	13.6	5	4-5	4	4-5	4-5	4	4-5	4-5	4-5	4-5

* Liquor ratio 1:20, Temperature 100°C, dyeing time 60 minute, Carrier 1 g/l, dispersing agent 1g/l PH=4.5

3.2. Dyeing polyester fabric Using microwave irradiation technique.

3.2.1. Effect of dyeing time on the color strength

Figure 3.2 shows the effects of dyeing time on the color strength of the dyed polyester fabrics upon using disperse dye red60 and using microwave irradiation. From Figure3.2 we noticed that increase the time up to 10 min. this is lead to increase the K/S, after that increase the time of dyeing this is lead to either constant or slightly increase in the K/S, so we recommended that the time of dyeing not more than 10 min. Comparing between the conventional and microwave technique as shown in Table 3.1 & 3.2, for example, the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye Red60 using conventional technique i.e. (Liquor ratio 1:20, Temperature 100°C, dyeing time 60 minute, Carrier 1 g/l, dispersing agent 1g/l , PH=4.5 and dye concentration 0.5 & 3%) and the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye Red60 using microwave irradiation technique i.e.(Microwave power 200, Liquor ratio 1:20, Temperature 100°C, dyeing time 10 minute , Carrier 1 g/l, dispersing agent 1g/l, PH=4.5, and dye concentration 0.5 & 3%) are 4.5&13.5 and 4.6 &12.9 respectively. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent. From the data we found that upon using microwave irradiation technique save about 50 min. and this is also means that save in time and energy used for complete dyeing process.

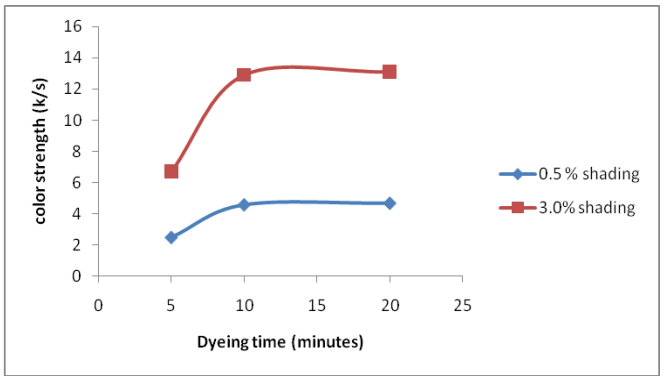


Figure 3.2: Effect of dyeing time on the color strength of dyed polyester* fabrics using disperse red 60 using microwave irradiation technique.

* Microwave power 200, Liquor ratio 1:20, Temperature 100°C, Carrier 1 g/l, dispersing agent 1g/l PH=4.5

Table 3.2: Effect of dyeing time on the color strength and the overall fastness properties of dyeing* polyester fabric using disperse Red60 using microwave irradiation technique.

Dye Con.	Dyeing time	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
				dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
									Alt	St.	Alt	St.
0.5% Shading	5	2.5	5	4	3-4	4	5	4	4	4	4	4
	10	4.6	5	4-5	4	5	4-5	4-5	4-5	4-5	4-5	4-5
	20	4.7	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
3% Shading	5	6.7	5	4	4	4	4	3-4	4	3-4	4	4
	10	12.9	5	4-5	4	4-5	4	4-5	4-5	4-5	4-5	4-5
	20	13.1	5	5	4-5	4-5	4-5	4-5	4-5	4-5	4-5	4-5

* Microwave power 200, Liquor ratio 1:20, Temperature 100°C, Carrier 1 g/l, dispersing agent 1g/l PH=4.5

Figure 3.3 shows the effect of dyeing time on the color strength of dyed polyester fabrics using disperse red 60 using microwave irradiation technique, without addition of carrier and dispersing agent. From Figure3 we noticed that increase the time of dyeing, this is lead to increase the K/S. Comparing between the dying using microwave technique with & without addition of carrier and dispersing agent as shown in Fig.3.2 & 3.3, it is noticed that the K/S obtained upon using carrier and dispersing agent is higher than obtained without added carrier and dispersing agent. For example, the color strength of dyeing polyester fabric using disperse dye Red60 and using (Microwave power 200, Liquor ratio 1:20, dyeing time10 minute, Carrier 1 g/l, dispersing agent 1g/l , PH=4.5 and dye concentration 0.5 & 3%) and the color strength of dyeing polyester fabric at the same conditions but without addition of carrier and dispersing agent are 4.5&13.5 and 4.2 &10.1 respectively, increasing the time of dyeing up to 20 minutes this is lead to increase the K/S values nearly to K/S values obtained using carrier and dispersing agent, but at dyeing time 10 minutes i.e. the addition of carrier and dispersing agent save about 10 minutes. Table 3.3 shows the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples without added carrier and dispersing agent, their values ranging from very good to excellent.

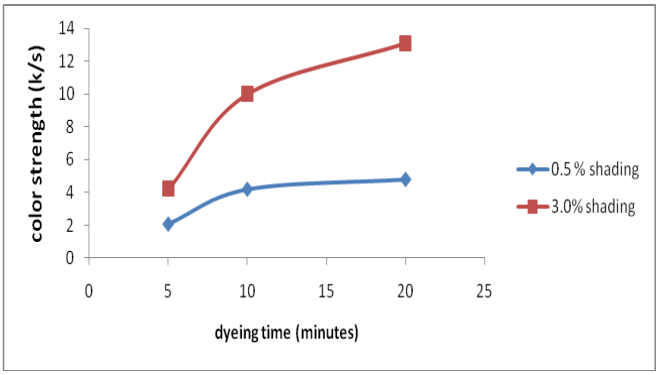


Figure 3.3: Effect of microwave dyeing time on the color strength of polyester fabric dyed with microwave irradiation (without addition of Carrier and dispersing agent).

Table 3.3: The effect of microwave dyeing time on the color strength and fastness properties of polyester fabric using microwave irradiation without addition of Carrier and dispersing agent

Dye Con.	Dyeing time	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
				dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
									Alt	St.	Alt	St.
0.5% Shading	5	2.1	5	4-5	4	4	4	4	4	4	4	4
	10	4.2	5	4-5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
	20	4.8	5	4	4	5	4	4-5	4-5	4-5	4-5	4-5
3% Shading	5	4.1	5	4	4	4	4	4	4	3-4	4	4
	10	10.1	5	4	4	4-5	4	4-5	4-5	4-5	4-5	4-5
	20	13.2	5	4-5	4-5	4-5	4	4-5	4-5	4-5	4-5	4-5

* Microwave power 200, Liquor ratio 1:20, Temperature 100°C, Carrier 0 g/l, dispersing agent 0 g/l PH=4.5

3.2.3. Effect of liquor ratio on the color strength

Figure 3.4 show the effect of liquor ratio on the color strength of the dyed polyester fabrics upon using dispersed dye red 60 using microwave irradiation. From Figure4 we noticed that increase the liquor ratio from 1:5 to 1:20, this is lead to slightly decrease in the K/S. For example increase the liquor ratio from 1:5, 1:10, and 1:20 the K/S is 14, 13.6, and 13.1. Table3.4 shows that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranging from very good to excellent

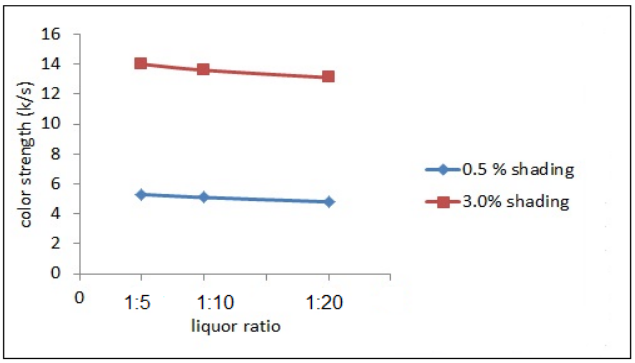


Figure 3.4: Effect of liquor ratio on the color strength of dyeing* polyester fabric using disperses dye red 60 using microwave irradiation technique.

* Microwave power 200, dyeing time 20 minute, Carrier 0 g/l, dispersing agent 0 g/l PH=4.5

Table3.4. Effect of liquor ratio on the color strength and the overall fastness properties of dyeing* polyester fabric using disperse red 60 using microwave irradiation technique**.**

Dye Con.	*Dyeing time*	*K/S*	*Light fastness*			*Washing fastness*			*Perspiration*			
				dry	*Wet*	*St. on cotton*	*St. on wool*	*Alt.*	*Acidic*		*Alkaline*	
									Alt	*St.*	*Alt*	*St.*
0.5% Shading	**1:20**	4.8	5	5	4-5	4	3-4	4	4	4	4	4
	1:10	5.1	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
	1:5	5.3	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
3% Shading	**1:20**	13.1	5	4	4	4	4-5	4	4-5	4-5	4-5	4
	1:10	13.6	5	4-5	4	4-5	4	4	4-5	4-5	4-5	4-5
	1:5	14.0	5	4	4-5	4-5	4	4-5	4-5	4-5	4-5	4-5

* Microwave power 200, Temperature 100^{o}C, dyeing time 20 minute, Carrier 0 g/l, dispersing agent 0 g/l PH=4.5

3.2.4. Effect of power of microwave used on the color strength

Figure 3.5 shows the effect of power of microwave used on the color strength of the dyed polyester fabrics upon using disperse dye red 60. From Figure 5 we noticed that increases the power from 200 to 600 watt, this is lead to slightly increase in the K/S. For example increasing the power from 200,400, and 600, the color strength (K/S) increasing from 14.1, 14.2, and 14.4 respectively. So we recommended that the power used in case of dyeing polyester fabric not exceed 200 watt. From Table3.5 we show that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranging from very good to excellent

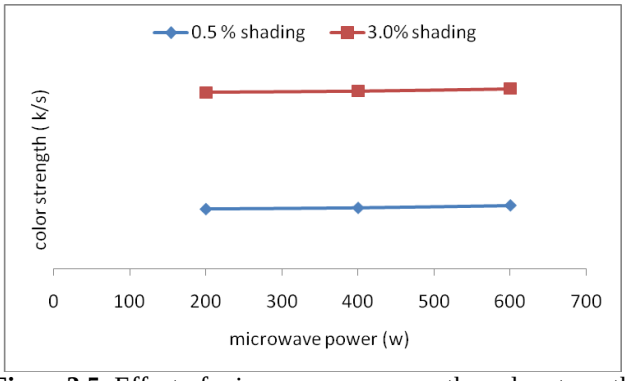


Figure3.5: Effect of microwave power on the color strength of dyed polyester* fabrics using disperse dye Red 60 using microwave irradiation technique.
* Liquor ratio 1:5, Temperature 100^{o}C, dyeing time 20 minute, Carrier 0 g/l, dispersing agent 0 g/l PH=4.5

Table3.5. Effect of microwave power on the color strength and the overall fastness properties of dyeing* polyester fabric using disperse red 60 using microwave irradiation technique**.**

Dye Con.	*Power (Watt)*	*K/S*	*Light fastness*	*Rubbing fastness*		*Washing fastness*			*Perspiration*			
				dry	*Wet*	*St. on cotton*	*St. on wool*	*Alt.*	*Acidic*		*Alkaline*	
									Alt	*St.*	*Alt*	*St.*
0.5% Shading	200	4.8	5	4-5	4	4	4-5	4	4-5	5	4-5	5
	400	4.9	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
	600	5.1	5	5	4-5	5	4	4-5	4-5	4-5	4-5	4-5
3% Shading	200	14.1	5	3	4	4	4-5	4-5	4	4-5	4-5	4-5
	400	14.2	5	4-5	4	4-5	4-5	4-5	4-5	4-5	4-5	4-5
	600	14.4	5	5	4-5	4-5	4	4-5	4-5	4-5	4-5	4-5

* Liquor ratio 1:5, Temperature 100^{o}C, dyeing time 20 minute, Carrier 0 g/l, dispersing agent 0 g/l PH=4.5

3.3. Dyeing of polyester fabric using convention and optimum condition of microwave irradiation using Disperse blue 56

3.3.1. Dyeing of polyester fabric using conventional heating technique.

Figure3. 6 shows the effect of dye concentration on the color strength of dyed polyester fabrics at Liquor ratio 1:20, Temperature of dyeing 100^{o}C, dyeing time 60 minute, carrier 1 g/l, dispersing agent 1g/l at PH=4.5, using disperse dye blue 56. It is noticed that the increase in the dye concentration this is lead to increase in the color strength, for example the increase the dye concentration from 0.5, 1, 2 and 3% the K/S increase from 3.5, 7.9, 12.37 and 14.6 respectively.

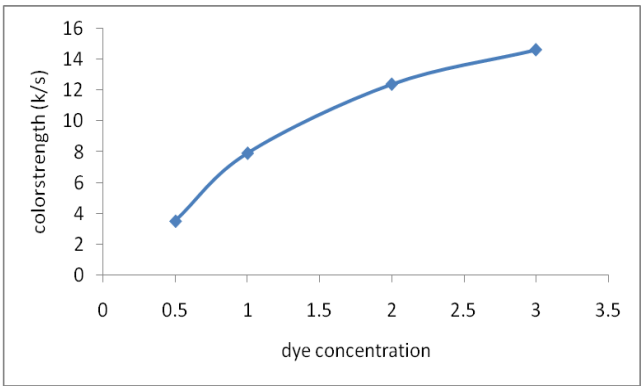


Figure3.6: The effect of dye concentration on the color strength of dyed polyester* fabric with disperse blue 56 using conventional method

* Liquor ratio 1:20, Temperature 100°C, dyeing time 60 minute, Carrier 1 g/l, dispersing agent 1g/l PH=4.5

Table3.6, shows the effect of dye concentration on the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye blue 56 using conventional heating technique**.** Generally speaking, the fastness properties to rubbing, either wet or dry, washing, light fastness and color fastness properties to both acidic and alkaline perspiration for the dyed samples their values ranging from very good to excellent.

Table3.6: Effect of dye concentration on the color strength and the overall fastness properties of dyeing* polyester fabric using disperse dye blue56 using conventional technique.

Dye conc. (%)	K/S	Light fastness	Rubbing fastness		Washing fastness			Perspiration			
			dry	wet	St. on cotton	St. on wool	Alt.	Acidic		Alkaline	
								Alt	St	Alt	St
0.5	3.5	5	4-5	4	4-5	4	4	4-5	4-5	4-5	4-5
1	7.9	5	4-5	4	4	4	4	4-5	4-5	4-5	4-5
2	12.37	5	4-5	4	4	4	4-5	4-5	4-5	4-5	4-5
3	14.6	5	4-5	4	4	4-5	4	4-5	4-5	4-5	4-5

* Liquor ratio 1:20, Temperature 100°C, dyeing time 60 minute, Carrier 1 g/l, dispersing agent 1g/l PH=4.5

3.3.2. Dyeing of polyester fabric using microwave irradiation technique

Table3.7 shows the effects of dye concentration on the color strength of the dyed polyester fabrics upon using disperse dye blue 56 and using microwave irradiation. From Table3.7, we noticed that increases the dye conc. this is lead to increases in the K/S, for example increase the dye conc. , from 0.5, 1, 2 and 3% the K/S increase from 4.2, 9.3, 12.8 and 15.1 respectively. From Table 3.7 we show that the overall fastness properties to rubbing, washing, light and perspiration for the dyed samples and their values ranging from very good to excellent.

Comparing between the conventional and microwave technique as shown in Table3. 6 & 3.7, for example, the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye blue 56 using conventional technique i.e. (Liquor ratio 1:20, Temperature 100°C, dyeing time 60 minute, Carrier 1 g/l, dispersing agent 1g/l , PH=4.5 and dye concentration 0.5 & 3%) and the color strength and the overall fastness properties of dyeing polyester fabric using disperse dye blue 56 using microwave irradiation technique i.e. (Microwave power 200, Liquor ratio 1:20, Temperature 100°C, dyeing time 20 minute, Carrier 0 g/l, dispersing agent 0g/l, PH=4.5, and dye concentration 0.5 & 3%) are 3.5&14.6 and 4.2 &15.1 respectively. The overall fastness properties to rubbing, washing, light and perspiration for the dyed samples their values ranging from very good to excellent. From the data we found that upon using microwave irradiation technique save about 40 min., carrier and dispersing agent, this is also means that save in time and energy used for complete dyeing process.

Table3.7: Effect of dye concentration on the color strength and the overall fastness properties of dyeing* polyester fabric using disperse dye blue 56 using microwave irradiation technique. (Optimum condition)

Dye conc.%	*K/S*	*Light fastness*	*Rubbing fastness*		*Washing fastness*			*Perspiration*			
			dry	*wet*	*St. on cotton*	*St. on wool*	*Alt.*	*Acidic*		*Alkaline*	
								Alt	*St.*	*Alt*	*St.*
0.5	4.2	5	5	4	4	4-5	4-5	4-5	5	5	5
1	9.3	5	5	4-5	5	4-5	4-5	4-5	4-5	4-5	4-5
2	12.8	5	4-5	4	5	4-5	4-5	4-5	4-5	4-5	4-5
3	15.1	5	4-5	4	4	4	4	4	4-5	4-5	4-5

*Liquor ratio 1:5, Microwave power 200w, Temperature 100°C, dyeing time 20 minute, Carrier 0 g/l, dispersing agent 0g/l PH=4.5

4. Conclusions

The time of dyeing polyester fabric using dispersed dyes not more than 10 min. using microwave irradiation technique. The power used in case of dyeing polyester fabric using dispersed dyes not exceed 200 watt. The liquor ratio used in case of dyeing polyester fabric using dispersed dyes and microwave technique method must be 1:5 which save water. The microwave technique save about 40 min. in the dyeing time and the dyeing process without carrier and dispersing agent used, this means that save in time, energy and money, this is true irrespective the dye used

5. Acknowledgements

The authors of this article gratefully acknowledge the Science and Technology Development Fund, Academy of Scientific Research and Technology, Cairo, Egypt, for financially support this work through funding the project ID 3561. Project PI: Prof. Dr. Karima Haggag.

References

[1] C.Y. Cha, Y. Kong, *Carbon*; **34**(8):1035–40, 1996.
[2] L.S. Clark, W.R. Tinga, J.R. Laia In: Ceramic transaction, vol.**36**, Ohio: *The American Ceramic Society*, pp. 3–18, 1993.
[3] J.A. Menendez, E.M. Menendez, A. Garcia, J.B. Parra, J.J. Pis ,*Microwave Power Electromagnet Energy* ;**34**(3):137–43, 1999.

[4] J.A. Menendez, E.M . Menendez, M.J. Iglesias, A. Garcia, JJ. Pis , NMP-based carbon; (b) PFO-based carbon. *Carbon*; **37**(8):1115–21,1999.
[5] F. Langa, P.Cruz, E. Espildora, J.J. Garcia, M.C. Perez , A . Hoz ,*Carbon* ;**38**(11–12):1641–6, 2000.
[6] D.S. Kim , J.Y., J.Y. Kim, D.K. Lee ,*Carbon Sci*. ; **1**(3–4):143–7, (2001).
[7] K.A. Ahmed , M.M. El-Molla, M.S.A. Abdel-Mottaleb ,Mohamed S. Attia and S. El-Saadany, *Research Journal of Chemical Science*, Vol. **3**(4), April 3-18, 2013.
[8] M. M. El-Molla, K. Haggag , N. O. Shaker & F. N. El-Shall, *Indian Journal of Fiber & Textile Research*, Vol. **38,** March, pp. 57-65, 2013.
[9] S. Li, H. Boyter & Neil Stewart, *AATCC Revi*. **4**(8), 44-9, 2004.
[10] J.G. Belton, *Int Dyers Text Printer*, 43(5), 662, 1980.
[11] D.B. Judd,G. Wyszenki, "Color in Business, Science and Industry" 3rd Ed., John Wiley and Sons, New York 1975.
[12] J.S.D.C., "Standard Methods for the Assessment of Colour Fastness of Textile", third report of the fastness tests coordinating committee, Yorkshire, England, P. 24 1995.