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SciVerse ScienceDirect

Energy Procedia 14 (2012) 424 – 431

Energy Procedia

2011 2nd International Conference on Advances in Energy Engineering (ICAEE 2011)

Usage of Microwave Energy in Turkish Textile Production Sector

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Abstract

Application areas of microwave energy which has been used for many years in science and technology are increasing. The studies about the usage in textile industry are recent and open to improvements. It is known that usage of microwave energy provides advantages in whole processes in textile industry like pre-treating, dyeing, bare finishing and drying. In this study microwave energy in Turkish textile finishing applications are researched and its advantages, process efficiencies and contributions to energy gain are given. Microwave energy has not been efficiently used in Turkish textile sector. Promotion of microwave technology is expected to contribute to Turkey's economy especially in terms of energy and time conservation.

Keywords: Textile sector; microwave; textile finishing; energy; electricity

1. Introduction

Textile and apparel sector has a vital role in England, North America and Japan which are propellants of developing industries in the world throughout the history [1]. But since seventies the manufacture and exportation of textile products has been shifting from developed countries to developing countries.

Textile sector that has an important role in economic growth period in Turkey as textiles is one of the industries which Turkey is in leader position in terms of manufacture, employment, export volume, created by added value and technology used. Further development is expected within the next years. Energy consumption of this sector is gradually increasing corresponding to the new developments in the textile industry. According to 2008 TEDAŞ (Turkey Electricity Distribution Company) data, textile

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doi:10.1016/j.egypro.2011.12.953

industry has used the most energy after iron and steel production and processing industries [2]. Also in textile industry reduction of energy expenditure is crucial for promoting competitive power as in all branches of industry.

Microwave (MW) energy has been successfully applied in many low-temperature (<500°C) applications, such as rubber pretreatment and vulcanization, food processing, wood curing, textiles, polymers and biochemistry. In most of these areas the technology has been successfully commercialized, and low-temperature industrial microwave furnaces are now available worldwide [3].

In this study microwave energy and its properties are discussed for increased applications of MW in textile sector. The information relative too textile finishing applications, advantages, processing efficiency and contribution to energy gain are given.

2. General Structure of Textile Sector

Textile is covering the processes which start from fibers such as spinning, weaving, knitting and dyeing. And apparel industry covers transformation of this processes to the user stuffs. From fiber to finished fabric all processes are assessed as textiles and the process from finished fabric to garment is assessed as confection sector.

Textile and apparel are important building blocks for industrialization period and this is the leading labor intensive sector which makes major contributions to recovery of developing countries.

Turkish textile and apparel sector is a strong position of Turkey's economy as both provided employment and in excess of one billion dollar export revenue. According to January 2010 data of Social Security Institution, while 687 441 insured people are determined as working in textile and apparel sector, in general 2,5 million people is estimated to be employed. Additionally 40320 offices have been registered in textile and apparel sector according to social security institution. On the other hand, there are approximately 11 000 manufacturing and exporting companies within and around the city of Istanbul.

According to the published statistical study of International Textile Manufacturers Federation (ITMF) about the sales of textile machinery in the world, as of 2008 in terms of machinery park, 3% of the short fiber spindle capacity, 5% of the long fiber spindle capacity, 7.3% of open end (OE) rotor capacity, 3.5% of cotton system shuttleless loom, 1.3% of cotton system gripper shuttle loom, 0.6% of silk/filament weaving loom and 5.1% of wool woven fabrics are located in Turkey. According to the same study, for the European part of the study, 43.5% of the short fiber spindle capacity, 12% of the long fiber spindle capacity, 19% of the OE rotor capacity, 19.2% cotton system shuttleless loom, 46.3% of the cotton system gripper shuttle loom, 7.2% of the silk/filament weaving loom and 12.2% of the wool woven fabrics are located in Turkey.

3. Energy Usage in Textile Sector

Textile industry is one of the industries which use intensively water and energy. Very high amount of energy and water is being consumed and long lasting process is required during wet processing, especially washing off, dyeing, rinsing, desizing, being hydrophilic and bleaching [4]. In addition, technological improvements in textile industry increase energy consumption ratios. According the results of a survey made by Turkish Textile Finishing Industry Association, energy costs (16%) have the biggest share after human resources (26%) in expenditure [5]. In reference to 2010 general energy balance, approximately 40% of energy- and 47% of electricity consumption originates from the textile industry in Turkey [6]. Power usage values in Textile industry are shown in Table 1. Electricity consumption (in terms of tone equivalent to petroleum TOE) indicates the maximum value for all textile industry as shown in Table 1. Similar results are also seen in textile finishing sector that uses the most energy (Table 2).

Table 1. Energy Distributions Used in the Textile Sector

	Quantity	TOE
Total		29885
Electricity (MWh)	187290	16107
Natural gas (000 m3)	9666	7558
Diesel oil (liter)	1916149	1629
Fuel oil (ton)	736	707
Gasoline	764755	585
Acetylene	-	-
LPG	55	60
Others (Acetylene; Kerosene ;Geothermal Energy (MWh); Central heating fuel; Coking coal; Lignite 2000; Steam; Wood; Petroleum coke; Prina olive-pomace oil; Propane; Hard coal)		3239

TÜİK 2005 (Turkey Statistical Institute)

Increasing expenditure of energy and electricity consumption values indicate a requirement for productive usage of energy in Turkey. For this reason the use of MW radiation in especially textile finishing processes, is expected to decrease electricity consumption and make a favorable contribution to the Turkish economy in a very short period of time.

Table 2. Energy Distributions Used in the Field of Textile Finishing (TÜİK 2001)

Fuel type	Quantity(Tons)	TOE	Value(1000$)
Total		921 889	236 375 641 191
Acetylene	4	5	4 81 411
Gasoline	793	825	599 334 520
Steam	509 438	30 547	3 860 623 532
Natural gas (000 m^3)	300 163	247 634	364 111 196 64
Electricity (MWh)	3 359 318	288 901	151 086 606 168
Fuel oil	188 076	185 443	21 648 504 454
LPG	31 064	33 860	10 599 854 668
Lignite (2000 / 3000 / 4500)	178 877	63151	4 408 170 547
Central heating fuel	21 929	21 929	3 273 501 778
Diesel oil	7 218	7 362	2 273 578 764
Others (Kerosene; Coking coal; Hard coal; Petroleum coke; Naphtha; Prina; Propane)	668 843	42 232	2 209 765 683

4. The Use of Microwave Energy in Textile Sector

Electricity used in each process of textile industry, is also used to enhance the take up in dying process and to provide adsorption of chemical finishing agent on textile materials in textile finishing especially in the warm up operation.

Textile finishing industry is one of the principal branches of textile industry. Finishing industry provides the special fabric to fulfill the requirements of trends in the world depending on the place of use, quality, sales appeal and added values to the raw clothing from weaving loom. All of the whitening, coloring and chemical finishing are referred to as textile finishing processes. Textile finishing is separated into three main sections with regard to structure of the applied processes and its purposes as pre-finishing, dye-press and finish processes.

Researches about MW radiation have been aimed to shorten processing time because conventional warm up resources used in textile finishing processes may constitute the reason for the loss of time and energy. MW energy is observed to be used in heating, drying, condensation process, dyeing and pressing, finishing process, surface modifications of textile materials. It is determined that the duration of the applied method is shortening, while protecting the product quality and the efficiency of applied method is increasing by virtue of the uniform heating provided by microwave [7]. Despite these advantages microwave energy has not yet found a widespread application in Turkey.

4.1. Microwave energy

Microwaves which have broad frequency spectrum are electromagnetic waves that are used in radio, TV and radar technology. Since the beginning of the twentieth century this technology has made significant contributions to scientific and technological developments. Also due to its initial intend to be used in telecommunications, very important progresses has been made in this area. Nevertheless from the second half of twentieth century, MW energy is finding increased number of application area in other industrial processes and these applications are surpassing telecommunication applications [8]. MW was first used in radar systems during second world war in a controlled manner and in 1946 the effect of MW heating on materials has first been studied by Dr. Spencer. In 1947 first MW oven is designed for home appliances market [9]. Nowadays MW energy is being used in various sectors like food, chemistry, textile, metallurgy, ceramic and furniture.

4.1.1. Basic characteristics of microwave radiation

Microwave has a wavelength ranging between 1cm and 1m and frequencies between 30GHz and 300MHz. MW covers the infrared (IR) radiation and radio frequencies in electromagnetic spectrum [10]. Microwaves can be absorbed, diffracted and reflected. Electromagnetic waves can be absorbed and be left as energy units called photon. The energy carried by photon is depended on the wavelength and the frequency of radiation. Energy of MW photons is 0.125kJ/mol. This value is very low considering the necessary energy for chemical bonds. Therefore MW rays can not affect the molecular structure of the material directly and change the electronic structures of atoms. MW absorption is assumed to increase kinetic energy in stimulating molecules [11-15].

4.1.2. Working principle of microwave

MW heat systems consists of three main units; magnetron, waveguide and applicator. Magnetron is used as a microwave energy source in industrial and domestic type of microwave ovens. One of the oscillator tube, magnetron consists of two main parts as anode - cathode, and it converts the continuous current - electrical energy to MW energy. Circulator transmits approximately all of the waves that are sent from magnetron and shunts transmitted waves to water burden. Thus magnetron is protected. Electromagnetic waves are transmitting to the applicator by waveguides [16]. Applicators are parts of the matter MW applied on. MW energy produced in generator is affected directly on the material in applicators in MW heating systems. Type of applicators used in practice can be divided into three groups as multi-mode (using 80% of the industrial systems), single-mode and near field MW applicators.

4.1.3. Heating with microwave energy

MW radiation provides more uniform heating in a reaction mixture unlike the ordinary methods of heating. The sample of a reaction mixture is heated more efficiently inside of it. This minimizes the wall effect due to internal heating. Therefore a super heating occurs.

In normal heating methods the outer wall heats up at first. Then the outer surface of the liquid heats up and this warming up moves to the center. In this kind of heating method, a continual temperature difference occurs between outer surface and central. In case of MW heating, every point of the solvent regularly warms up. Thus it becomes possible to reach higher temperatures faster than normal heating methods (Fig. 1) [17].

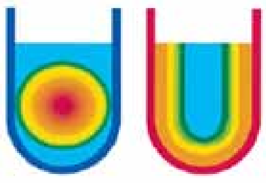
a-MW heating  b- conventional heating

Fig. 1. Microwave heating and conventional heat dissipation

5. Usage of Microwave Energy in Textile Finishing Process

Microwave radiation is presented as an alternative to conventional heating techniques because it provides fast, uniform and effective heating by enabling the heating of all particles at the same time with its easy penetration property into the particles of the matter. Microwave energy is becoming gradually preferred especially due to its shorter time of application, heating and drying, convenience of the change in process time for heating in different volumes, and energy conservation. This has been proved by various academic studies. But these studies are limited.

MW energy which is used in dying of various types of textile staple and fixation processes [18,19] has brought positive results. Microwave energy that used in synthetic fiber dyeing like wool fiber coating and cooling process[20], acrylic fiber[21], polyamide[22] and nylon6 [23] is seen as a performance booster fort he dyeing processes. Microwave energy increases the diffusion of dye molecules in dyeing process when applied to Polyamide fibers [22]. It is also used in pre finishing of silk yarns [24].

MW radiation is applied to fabrics in various conditions and thermal stability and its morphological structure is investigated to determine the effect of microwave energy on cellulosic structure of cotton. While crystallinity of cellulosic fabric is increased, the physical properties are improved [25].

As a result of MW energy use in dyeing polyester fiber, rate of dye extraction and dyeing increases [19, 26-29, 30, 31]. Addition of urea also increases dye extraction when polyester is dyeing with MW energy [32]. In consequence of polypropylene dyeing with MW energy, the fastness and strength properties of dyed material is determined as very well and it is proposed that this method has more advantageous in terms of time and energy conservation according to conventional method [33-35]. If cotton fabric is dyed directly with dyestuff with the help of MW, dye process becomes faster [36].

Besides MW is used to dry a linen cloth that is soaked in urea solution and under different energy power conditions to diffuse urea effectively into cloth. Then the cloth is dyed with reactive dyestuffs. This method is highly effective in dyeing of linen cloth. The method has a promising future [37].

MW energy is accepted as more efficient than conventional methods for cotton fabric finishing, drying and curing processes, durable press finishing, incombustibility, water and oil repellent finishing [38]. High wrinkle recovery angel is achieved for cotton and viscose fabric as a result of curing and durable press finishing applied by the MW [39]. MW is observed to be successfully used in Poly-carboxylic acid application which provides wrinkle and deformation recovery to cotton fabric [40]. In a study of non-iron finishing process, it is applied to cotton drying and the curing is completed in one minute, and this method is proposed to provide higher stress and tearing strength according to conventional method [41]. Microwaves do not tend to cause a loss of high strength in application of antibacterial finishing process to cotton fabrics. The use of MW is determined as a more advantageous process than conventional methods [42].

On the other hand, MW energy is more effective technique in modification and grafting processes of protein-based fibers especially in terms of cost, time and energy conversation [43]. As a result of polyester modification by using MW, heating is observed in hydrophility and the dyeing properties and the desired physical properties are not lost [44]. Furthermore in another study, alkaline hydration is applied to polyester by using MW and it is determined that it hydrolyzes faster according to conventional methods [45].

Except these studies, MW radiation used in drying, fixing [46-50] and sanitization [51,52] processes applied to materials is examined to shorten the process time and affects positively the properties of material.

Considering the current studies, the increase in Microwave use is expected to provide contributions to Turkey's economy in terms of energy conservation and also would increase the performance of material. But microwave use in textile sector has not reached to a desired level in Turkey. The main reasons for the limited usage of microwave energy in Turkey can be listed as follows:

- The investor is greatly affected by the economic crisis and continues his work with outdated technology.
- Lack of laws and regulations in Turkey about the renewal of the technology used in the industry.
- Investors take a dim view of bids due to inaccurate or lack of information about microwave technology.
- Lack of trained personnel due to the limitations on training given about microwave technology.

6. Conclusion

The main conclusion, which may be drawn from the present study, can be listed as follows:

- The use of MW energy is more efficient than conventional method.
- To extend the use of microwave technology in textile sector will gain favor to facilities especially in terms of time and energy.
- It will pull down the production cost.
- About studied use of MW in textile sector is in an increasing trend.
- If various institutions, organizations and associations increase the awarenesses of their members and explain the advantages of microwave technology to investors for an increase use of microwave technology, this will contribute especially in terms of energy consumption and the corresponding costs to Turkish economy and hence increase the competitiveness of the Turkish industry.

Acknowledgements

I would like to thank Prof. Dr. E.Öner and Assoc. Prof. Dr. H.Küçük from Marmara University and Assoc. Prof. Dr. Z.Utlu from Istanbul Aydin University for their help and encouragement.

References

[1] Arslan K. Küresel Rekabet Baskısı Altında Tekstıl Ve Hazır Gıyım Sektörünün Dönüşüm Stratejılerı Ve Yenı Yol Harıtası, Müsiad Araştırma Raporları 2008).

[2] (TEVEM - Enerji ve Enerji Verimliliği Çalışmaları Raporu / 2010).

[3] Dinesh Agrawal, Jiping Cheng, Hu Peng, Larry Hurt and Kuruvilla Cherian; *Microwave Energy Applied to Processing of High-Temperature Materials;* American Ceramic Society Bulletin, Vol. 87, No. 3, 2004].

[4] Duran,K., Perincek, S., Körlü, A. E., Bahtiyari, M. İ.,2007, Ultrason Teknolojisinin Tekstilde Kullanın Olanakları,Tekstil ve Konfeksiyon.

[5] 2007-2013 Dokuzuncu Kalkınma Planı Tekstil, Deri ve Giyim Sanayii Özel İhtisas Komisyonu Raporu,60,http://ekutup.dpt.gov.tr/imalatsa/tekstil/öik668.pdf

[6] Türkiye Enerji ve Enerji Verimliliği Çalışmaları Raporu"Yeşil Ekonomiye Geciş" Temmuz – 2010

[7] http://www20.uludag.edu.tr/~aksel/KURUTMA.pdf.

[8] (Oktay A., "RF ve Mikrodalga Enerjisinin Endüstriyel Uygulamaları", http://www.ume.tubitak.gov.tr

[9] http://www.rsc.org/images/evaluserve_tcm18-16758.pdf.

[10] Strauss, C. R., Trainar, R. W., 1995. Developments in MW-Assisted Organic Chemistry. Aust. J. Chem, 48, 1665-1692.

[11] Collins, M. J., 2001. Drug Discovery at the Speed of Light. R&D Magazine,43, 12, 57-59.

[12] http://www.nap.edu/execsumm/0309050278.html.

[13] (J P Tierney, P Lidström (Eds.), Microwave Assisted Organic Synthesis, Blackwell Publishing Ltd.,2005.)

[14] Ahluwanlia, V. K. ve Aggarwal, R., (2001), Organic Synthesis: Special Techniques, Alpha Science Int. Ltd, UK.

[15] www.bilim/mikrofırın_pr/html (Erişim Tarihi:Mayıs2004)

[16] Regier, M. ve Schubert, H. (2005). Introducing MW processing of food: principles and technologies, in the MW processing of foods, pp. 3-21, Eds Schubert, H., Regier, M. CRC Press, Woodhead Publishing Limited, Cambridge, England.

[17] Larhed, M. ve Hallberg, A., (1996), "Microwave Promoted Palladium-Catalyzed Coupling Reactions", Journal of Organic Chemistry, 61(26):9582-9584

[18] N S E Ahmed, R M El-Shishtawy, The Use of New Technologies in Coloration of Textile Fibers, Journal of Material Science, **45** (5) (2010) 1231-1236.

[19] R S Berns, H L Needles, Microwave versus Conductive Heating Their Effect on the Solvent-Assisted Dyeing of Polyester Fibre with Anthraquinonoid Disperse Dyes, Journal of the Society of Dyers and Colourists, **95** (6) (1979) 207-211.

[20] M J Delaney, I Seltzer, Microwave Heating for Fixation of Pad-dyeings on Wool, Journal of the Society of Dyers and Colourists, 88 (2) (1972) 55-59.

[21] F Nourmohammadian , M D Gholami, An Investigation of Dyeability of Acrylic Fiber via Microwave Irradiation, Progress in Color, Colorants and Coatings, **1** (2008) 57-63.

[22] Y Yoshimura, T Ohe, M Ueda, T Kurokawa, F Mori, Effect of Microwave on Diffusion Behaviour of Dye Molecules, Sen'i Gakkaishi, **65** (9) (2009) 241-245.

[23] T Ohe, Y Yoshimura, Microwave Irradiation onto Nylon 6 Fibers in Organic Solvent, Sen'i Gakkaishi, **65** (1) (2009) 64-70.

[24] K Haggag, H El-Sayed, O G Allam, Degumming of Silk Using Microwave-Assisted Treatment, Journal of Natural Fibers, **4** (3) (2007) 1-22.

[25] Hou A, Wang X, Wu L, Effect of microwave irradiation on the physical properties and morphological structures of cotton cellulose, Carbohydrate Polymers (2008) 74, 934-937.

[26]Xu W, Yang C, Hydrolysis and dyeing of polyester fabric using microwave irradiation, Coloration Technology (2002) 118,211-214.

[27]Haggag K, Hanna HL, Youssef BM, El-Shimy NS, Dyeing Polyester With Microwave Heating Using Disperse Dyestuffs, American Dyestuff Reporter (1995) 84,3,22-36.

[28]Haghi AK, An experimental study on dyeing of polyester with microwave heating http://www.fibre2fashion.com/industry-article/9/824/an-experimental-study-on-dyeing-of-polyester-with-microwave-heating1.asp (2009).

[29] A K Haghi, M Valizadeh, K Mohammadi, The Effect of MW Radiation on Dyeing of Polyester Fibers: Studying the Effect of Pre-Treatment of Fibers in Organic Solvent, Iranian Journal of Polymer Science and Technology, (71) (2004) 151-156.

[30] J Chiao-Cheng, B M Reagan, Microwave Dyeing of Polyester with Disperse Dyes, Textile Chemist and Colorist, **15** (1) (1983) 12-19.

[31] S Kim, S Leem, N Lee, M Huh, M Lee, The Level Dyeing Technology of Polyester Fabric by Microwave, International Symposium in Wakayama on Dyeing and Finishing of Textiles (Proceedings), **1998** (1998) 246-247.

[32] Kim SS, Leem SG, Ghim HD, Kim JH, Lyoo WS, Microwave Heat Dyeing of Polyester Fabric, Fibers and Polymers (2003) 4,4,204-209.

[33] Büyükakıncı Y. Dyeing of PP Fibers with Special Methods, MSc Thesis, Marmara University, Istanbul, Turkey (2005).

[34] Y Buyukakıncı, N Sokmen, E Oner, Microwave Assisted Exhaust Dyeing of Polypropylene, 4th Central European Conference, 7-9 September 2005, Liberec, Czech Republic.

[35] Y Buyukakıncı, B Oktem, N Sokmen, E Oner, Exhaust Dyeing of Polypropylene, 5th International Istanbul Textile Conference, 19-21 May 2005, Istanbul, Turkey.

[36] M. Montazer, F. Alibakhshi, Microwave Assisted Dyeing of Cellulose with Direct Dyes, 9th Asian Textile Conference, Taiwan, 28-30 June 2007.

[37] Sun H, Lin L, Jiang X, Bai X, The improvement of dyeability of flax fibre by microwave treatment, Pigment & Resin Technology (2005) 34,4,190-196.

[38] Katovic D, Vukusic SB, Grgac SF, Application of microwaves in textile finishing processes, http://www.texmail-plus.ca/doc/Microwaves_textile%20finishing.pdf (2009).

[39] Katovic D, Vukusic SB, Application of Electromagnetic Waves in Durable Press Finishing with Polycarboxylic Acid, AATCC Review ,(2002) 39-42.

[40] Vukusic SB, Katovic D, Schramm C, Influence of Microwaves on Nonformaldehyde DP Finished Dyed Cotton Fabrics, Textile Research Journal (2003) 73,8,733-738.

[41] Purwar R, Joshi M, Effect of Microwave Curing on Easy Care Finishing of Cotton Using Glyoxal/Glycol, AATCC Review, (2005) 40-44.

[42] Fouda MGM, El Shafei A, Sharaf S, Hebeish A, Microwave curing for producing cotton fabrics with easy care and antibacterial properties, Carbohydrate Polymers, 77 (3) (2009) 651-655

[43]Tsukada M, Islam S, Arai T, Boschi A, Freddi G, Microwave Irradiatin Technique to Enhance Protein Fibre Properties, AUTEX Research Journal (2005) 5, 1, 40-47.

[44] Tai A, Solvent-Asisited Modification of Polyethylene Terephtalate, Doctora Thesis, University of California, Davis (1981)

[45] Nouri M, Labaff K, Eavazi B, Alkaline Hydrolisis of Poly (ethylene terephthalate) With The Use of Microwave Heating, http://research.guilan.ac.ir/research/doc/c1063.pdf (2009)

[46] J D Hatcher, K B Higgins, D W Lyons, Analytical Solutions to the Drying of Textile Materials with Microwave Heating, Textile Research Journal, **45** (3) (1975) 223-229.

[47] N V Bhat, M J Kale, A V Gore, Microwave Radiations for Heat-setting of Polyester Fibers, Journal of Engineered Fibers and Fabrics, **4** (2009) 1-6.

[48] B Neral, S S Turk, R Schneider, Efficiency of Microwave Fixation of Digital Prints of the Reactive Dyestuff CI Reactive Red 24, Tekstil, **56** (6) (2007) 358-367.

[49] A. Özerdem; A Özgüney I. Tarakçıoğlu; "The Use Of Mıcrowave Energy For The Fıxatıng of Reactıve Prınted Cotton Fabrıcs" Tekstil ve Konfeksiyon Dergisi, 18 (4) 2008 .

[50] D G Evans, J K Skelly, Application of Microwave Heating in Dye Fixation, Journal of the Society of Dyers and Colourists, 88 (12) (1972) 429-433.

[51] B M Reagan, A M Rolow, J E Urban, Microwave Sanitization of Polyester and Cotton, Textile Research Journal, **52** (3) (1982) 186-192.

[52] M Zielinski, S Ciesielski, A Cydzik-Kwiatkowska, J Turek, M Debowski, Influence of Microwave Radiation on Bacterial Community Structure in Biofilm, Process Biochemistry, **42** (2007) 1250-1253.