

Investigation of the Deposition Time of Electrospayed Textile Chemicals

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Abstract

Deposition time should be considered as an important parameter in the assessment of the electrospaying process as an application alternative because it would determine the treatment time and cost of the application. In this study, commercially available textile softeners and liquid repellents on electrospayed on a collecting ground to statistically investigate the effect of the intrinsic properties of the chemicals and set-up parameters of electrospaying on the deposition time and to find out the mathematical relation between the deposition time and selected parameters. The results showed that the process had a higher deposition time when the chemicals were poured in diluted emulsions. Also the chemical type and electric field intensity had a strong contribution.

Key words: electrospaying, softener, liquid repellent, deposition time.

Introduction

Electrospaying is a well-known technique of liquid atomisation employing electrical forces. The conventional configuration of the electrospaying set-up consists of a charged liquid/emulsion syringe and grounded collecting electrode plate (*Figure 1*). When the liquid in the syringe is subjected to an electric field of several kilovolts per centimeter, its meniscus elongates and forms a fine jet, which is atomised into fine droplets and collected on the grounded collecting surface. Electrospaying has been widely used for the production of micro- and nanoparticles, nanostructured composite substrates, thin films, and functional layers, with properties varying with the particle size and shape [1-3]. There are also various papers investigating the effect of the process parameters of electrospaying when applied for the preparation of solid dispersions, microparticles or thin coatings [4-6]. Some previous studies [7-9] also demonstrated the success of electrospaying in the application of a commercially available textile finishing chemical onto a textile surface with an acceptable

finishing performance at a very low amount of chemical consumption and with the avoidance of undesirable agglomeration. These findings revealed that the process should be well reviewed in order to consider it as a textile treatment alternative.

This study focuses on the effect of the intrinsic properties of widely used textile finishing chemicals and set-up parameters of electrospaying on the deposition time of chemical droplets on a collecting ground. The deposition time is considered as a key factor for the facile process, which affects the application (treatment) time and process cost. Therefore a statistical approach is also made to evaluate the contribution of selected parameters. Electrospaying was performed for commercially available chemicals, two types of softeners and two kinds of liquid repellents separately. The deposition time of the chemicals was recorded and a statistical analysis was made to evaluate the contribution of the parameters, selected as the chemical type, emulsion concentration and electric field intensity

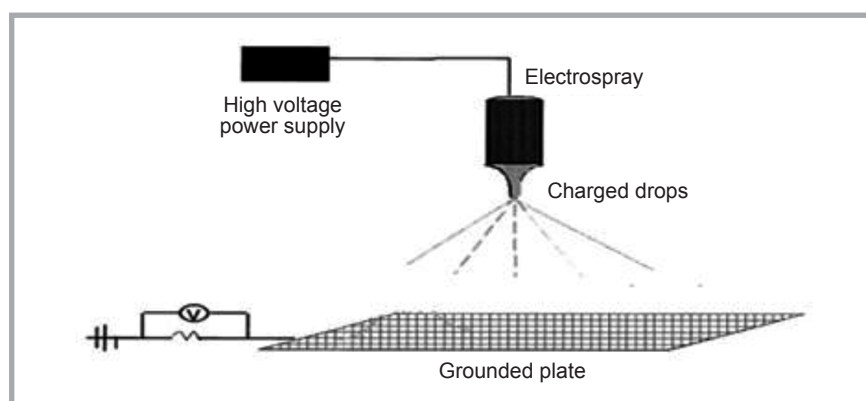


Figure 1. Electrospaying processes.

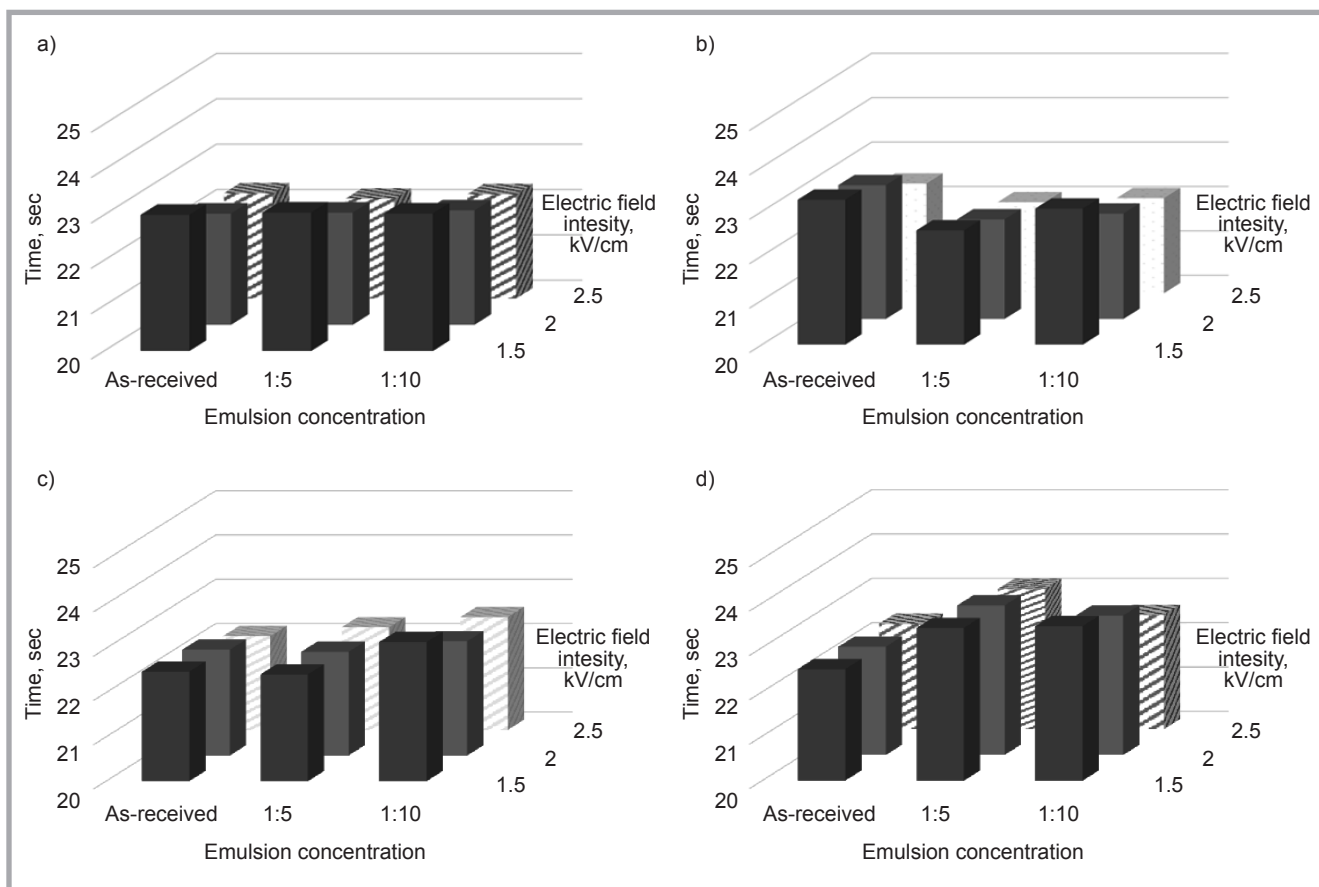


Figure 2. Deposition time for (a) MiS (b) MaS (c) F and (d) D.

ty. The chemicals were characterised by means of surface tension, electrical conductivity and viscosity measurements; then the relation between the deposition time and data measured were expressed in an equation.

■ Experimental

The commercially available micro softener *MiS*, macro softener *MaS* (poly-siloxane based nonionic), liquid repellent *F* (cationic fluorocarbon resin) and *D* (cationic dendrimer fluorocarbon and booster component in fluorocarbon) were kindly supplied by Rudolf-Duraner (Bursa, Turkey). The chemicals were electro-sprayed in as-received, 1:5 and 1:10 (v:v), dilutions in distilled water. The viscosity of the emulsions was investigated with a rheometer (Brookfield Eng., MA, USA) at room temperature and 200 rpm spindle speed. Conductivity measurements were performed with a portable pH/conductivity meter (Thermo Scientific, MA, USA) using a 2-probe electrode. Surface tension measurements were made by means of a Theta optical tensiometer/pendant drop analysis (KSV Inst., Finland).

Electrospray applications were carried out using a previously established set-up [6], where 4 mL of emulsion was poured into a charged syringe and sprayed at a 20 $\mu\text{L}/\text{min}$ flow rate on a flat aluminum foil as the ground, which enabled large contact with the bottom electrode. The distance between the syringe and foil was varied as 3 and 10 cm; hence the kV applied was also varied so that the electric field intensity of the set-up would have three levels (1.5, 2 and 2.5 kV/cm). The time for the deposition of 4 mL of emulsions was recorded by a simple chronometer: the less the time, the more facile the process is. The average of at least three measurements of

the deposition time was taken as the time data. The contribution of each factor was assessed using a completely randomised one-way analysis of variance (ANOVA), and the results were evaluated at a 5% significance level. The contribution of the variables were evaluated through the F-ratio and probability thereof. The lower the probability of the F-ratio, the stronger the contribution of the variation, and the more significant the variable. We also used the Student-Newman-Keuls (SNK) range test to decide which variable differs significantly from others. The treatment levels were marked in accordance with the mean values from the highest to the lowest, and any levels marked by

Table 1. Characterisation of chemicals studied.

Property	MiS			MaS		
	As-received	1:5	1:10	As-received	1:5	1:10
Viscosity, cP	35.40	2.77	2.56	35.60	2.56	2.13
Surface tension, dyn/cm	24.31	30.30	30.74	22.64	25.05	26.06
Conductivity, $\mu\text{S}/\text{cm}$	706.33	473.33	299.67	1336.33	594.33	290.67
Property	F			D		
	As-received	1:5	1:10	As-received	1:5	1:10
Viscosity, cP	3.40	2.35	2.13	28.60	2.56	2.35
Surface tension, dyn/cm	30.71	39.47	40.35	31.14	36.26	38.74
Conductivity, $\mu\text{S}/\text{cm}$	2195.33	721.33	396.67	936.67	583.33	406.33

Table 2. Deposition time values in seconds.

Electric field intensity, kV/cm	MiS			MaS		
	As-received	1:5	1:10	As-received	1:5	1:10
1.5	23.00	23.05	23.03	23.26	22.57	23.06
2	22.45	22.47	22.52	23.01	22.24	22.37
2.5	22.32	22.20	22.30	22.47	22.05	22.14
Electric field intensity, kV/cm	F			D		
	As-received	1:5	1:10	As-received	1:5	1:10
1.5	22.47	22.41	23.14	22.51	23.44	23.48
2	22.39	22.34	22.58	22.44	23.37	23.14
2.5	22.12	22.32	22.55	22.38	23.16	22.58

Table 3. ANOVA table for deposition time.

Source	F ratio	Probability of F ratio
Chemical type	2224.44	0.000
Emulsion concentration	536.56	0.000
Electric field intensity	5884.16	0.000

the same letter showed that they were not significantly different. Also regression relations between the deposition time, electric field intensity, surface tension, conductivity, and viscosity measurements were derived using Minitab software.

Results

The viscosity, surface tension and electrical conductivity of the chemicals are accepted as important intrinsic properties which have a large influence on electro-spraying [5]. **Table 1** gives the average results of three measurements of those properties. All measurements were made in a controlled laboratory environment, where the temperature was between 20-23 °C and the relative humidity 27-32%; and CV% values of all measurements was lower than 5%. The results showed that the chemicals selected had a wide range of values, which made it easy to monitor the contribution of the properties as a variation source; and diluting the emulsion changed the values as a function of the distilled water, as expected. It has been concluded before that a liquid cannot be electro-sprayed when its surface tension is higher than 50 dyn/cm and its conductivity does not fall within the range of 10⁻¹-10⁻¹¹ S/m [10], 10⁻⁵-10⁻¹¹ S/m [11], or 10⁻¹-10⁻⁹ S/m [12]; hence we did not meet with any failure in the electro-spraying of the emulsions, as expected.

The deposition time of the chemicals is given in **Figure 2** and **Table 2**. The results reveal that there was a certain decrease in the deposition time as the electric field intensity increased, and diluted emulsions had a tendency to have a longer deposi-

tion time due to the lowered conductivity. Furthermore liquid repellent chemicals gave lower deposition time values than softeners without dilutions.

The results of the statistical analysis of the study given in **Table 3** and **Table 4** show that the electric field intensity and chemical type had a more significant impact on the deposition time than the concentration. The statistical analysis also showed that electro-spraying had a longer deposition time when the chemicals were poured in diluted emulsions (as done in typical textile application), and the higher the electric field intensity, the lower the deposition time was. Among the chemicals, the lowest deposition time was achieved for *F*, which had the lowest intrinsic viscosity and highest electrical conductivity values. Also the softener type (micro or macro emulsion) had a non-significant impact on the deposition time.

The combined contribution of the parameters to the electro-spraying deposition time of the resin emulsion was established using Minitab software. The relation was determined after considering all the variables according to Best-subsets Regression method, and is given in **Equation (1)**:

$$t = 23.1 + 0.00763 \times \eta + 0.0217 \times \sigma - 0,000151 \times \kappa - 0,567 \times E$$

where, *t* is the deposition time, minutes; η the viscosity, cP; σ the surface tension, dyn/cm; κ the electrical conductivity, μ S/cm, and *E* is the electric filed intensity, kV/cm. The R² value for the equation was 73.1%, which shows that the model fits the data well.

Table 4. SNK ranking at 5% significance level.

Rank	Chemical type	Non-significant range
1	D	a
2	MiS	b
3	MaS	b
4	F	c
Rank	Emulsion concentration	Non-significant range
1	1:10	a
2	1:5	b
3	As-received	c
Rank	Electric field intensity	Non-significant range
1	1.5	a
2	2	b
3	2.5	c

Conclusions

This study investigated the deposition time of widely used textile finishing chemicals as a part of ongoing researches on the assessment of the electro-spraying process as an application alternative. The aim was to establish the basic relationships between the deposition time of chemicals and varying the process parameters. The results of the study showed that the process had a longer deposition time when the chemicals were diluted with distilled water. Moreover the chemical type had a strong impact on the deposition time.

The statistical analysis also showed that electro-spraying had a higher deposition time when the chemicals were poured into diluted emulsions (as done in typical textile application), and the higher the electric field intensity, the lower the deposition time. Among the chemicals, the lowest deposition time was achieved for *F*, which had the lowest intrinsic viscosity and highest electrical conductivity values. Also the softener type (micro or macro emulsion) had a non-significant impact on the deposition time.

It is possible to find studies in literature comparing electro-spraying with typical foulard or mechanical spraying units, but there is still a need to continue investigations on electro-spraying in terms of application set-up, fabric properties and performance after treatment to evaluate the possibility of industrial usage. Our early results for electro-spraying showed that this method had brief advantages for the pick-up value. This study will be followed by assessments of the performance

and mechanical properties of electrospayed fabric.



References

1. Wu Y, Clark RL. Controllable porous polymer particles generated by electrospaying. *Journal of Colloid and Interface Science* 2007; 310: 529-535.
2. Gupta D, Venugopal J, Mitra S, Giri Dev VR, Ramakrishna S. Nanostructured biocomposite substrates by electrospinning and electrospaying for the mineralization of osteoblasts. *Biomaterials* 2009; 30 (11): 2085-2094.
3. Burkater E, Saul CK, Thomazi F, Cruz NC, Roman LS, Schreiner WH. Superhydrophobic electrospayed PTFE. *Surface & Coating Technology* 2007; 202 : 194-198.
4. Smeets A, Clasen C, Van den Mooter G. Electrospaying of polymer solutions: Study of formulation and process parameters. *European Journal of Pharmaceutics and Biopharmaceutics* 2017; 119: 114-124.
5. Jaworek A, Krupa A, Lackowski M, Sobczyk AT, Czech T, Ramakrishna S, Sundarajan S, Pliszka D. Nanocomposite fabric formation by electrospinning and electrospaying technologies. *Journal of Electrostatistics* 2009; 67: 435-438.
6. Dasdemiir M, Ibili H. Formation and characterization of superhydrophobic and alcohol-repellent nonwovens via electrohydrodynamic atomization (electrospaying). *Journal of Industrial Textiles* 2017; 47 (1) : 125-146.
7. Gunesoglu C, Kut D, Orhan M. Performing the Electrospaying Process for the Application of Textile Nano Finishing Particles. *Textile Research Journal* 2010; 80 (2): 10-115.
8. Gunesoglu C, Gunesoglu S, Wei S, Guo Z. Electrical conduction investigation of stainless steel wire-reinforced cotton fabric composites by electrospaying of fluoropolymer. *Journal of the Textile Institute* 2011; 102 (5): 434-441.
9. Prabu GTV, Chattopadhyay SK, Patil PG. Moisture management finish on cotton fabric by electrospaying. *Textile Research Journal* 2017; 87 (17): 2154-2165.
10. Smith DPH. The electrohydrodynamic atomization of liquids. *IEEE Transactions on Industrial Applications* 1986; 22: 527-535.
11. Mutoh M, Kaieda S, Kamimura K. Convergence and disintegration of liquid jets induced by an electrostatic field. *Journal of Applied Physics* 1979; 50: 3174-3179.
12. Cloupeau M, Prunet-Foch B. Research on Electrohydrodynamic Spraying. Presented at: 4th International Conference on Liquid Atomization and Spray Systems; 1986 August 24-28; Sendai, Japan.

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