MATHEMATICAL MODELING OF PLASMA PARAMETERS PROCESSES FOR MULTIFUNCTIONAL TEXTILE

AILENI RALUCA MARIA, SURDU LILIOARA

National Research & Development Institute for Textiles and Leather, Lucretiu Patrascanu 16 Street, 030508, Bucharest, Romania, raluca.aileni@certex.ro, surdu.lilioara@certex.ro

This paper presents the mathematical modeling for plasma processes treatments used for textile materials functionalization. The subject fabric on this work was made by cotton. In this research it was started from initial known textile structural parameters and some parameters for oxygen plasma treatment. The goals of plasma treatment were to increase activation and cleaning textile material for adherence preparation of the colloidal silver. The main objective was to obtain a textile surface with reduced microbial charge for medical destination. For obtaining the optimal results are required plasma treatment parameters optimization. This optimization was done starting from analyzing the plasma processes parameters variation. This variation and experimental results was formed the start point for developing mathematical modeling presented in this papers.This variation and experimental results was formed the start point for developing mathematical modeling presented in this papers.

Keywords: mathematical, textile, plasma

INTRODUCTION

Plasma polymerization is a technique for obtain functional textile materials for any domain and for high performance clothing (Kilic *et al.*, 2009; Gulrajani *et al.*, 2011). By using air plasma treatments on cotton textile surfaces can occur surface modification (Bhat *et al.*, 2011) that conduct to improve the hydrophobicity and decrease contact angle (Karahan and Özdoğan, 2009). This surface functionalization can help in textile finishing and coating process by obtain the activated surface without using any else chemicals that are requiring wet process (Rauscher *et al.*, 2010). There are in situ experiments by using plasma nanotechnology (Haji *et al.*, 2013) and involving chemical modification of cotton fabrics by natural chitosan followed by incorporating silver nanoparticles in the fabrics (Thomas *et al.*, 2011).

EXPERIMENTAL PART

The experiment consisted in analyzing the cotton knit samples before and after 10 minutes plasma treatment. It is known from others experiments, developed in Multitexfunction Crosstexnet project, that for samples with 100% cotton composition the high values for resistances, pilling effect are obtained after 10 minutes oxygen plasma treatment, after this moment till 90 minutes experiment the natural polymer cellulose from cotton is supposed to accelerated depolymerization process.

The goal of plasma treatment was to activate the textile surface in order to make easier and durable chemical submission (colloidal silver, chitosan) by using foulard method, for obtaining medical bandages with antimicrobial properties.

For 20 samples analyzed were tested the tear and abrasion resistance to obtain the maximal pilling effect and tear force before and after 10 minute oxygen plasma treatment (Table 1).

Table 1. Experimental data

Sample No.	Pilling effect experimental 10 minutes plasma treatment	Pilling effect fitting approximate	String density experimental 10 minutes plasma treatment	Spring density fitting approximate
1	3.29	3.52	13.5	13.7808
2	3.325	3.51	13.6	23.6577
3	3.36	3.56	13.1	17.3394
4	3.395	3.54	13.6	13.7705
5	3.43	3.58	13.7	13.5635
6	3.465	3.57	13.2	14.002
7	3.5	3.59	13.8	13.8909
8	3.535	3.54	13.5	13.5229
9	3.57	3.56	13.5	13.4299
10	3.605	3.54	13.7	13.5618
11	3.64	3.29	13.8	13.5183
12	3.675	3.58	13.5	13.3027
13	3.71	3.68	12.9	14.0918
14	3.745	3.59	13.4	17.7966
15	3.78	3.44	13.9	25.2781
16	3.815	3.68	13.8	33.8494
17	3.85	3.69	13.5	35.3076
18	3.885	3.44	13.5	18.1836
19	3.92	3.89	13.8	-20.2942
20	3.955	3.98	13.2	-44.6882

RESULTS AND DISCUSSIONS

For experimental data from Table 1 was obtained an approximated mathematical model for pilling effect addicted to strings density for knitted samples. The approximated data from Table 1 for string density and pilling effect are obtained by using the next polynomial mathematical model (1).

We made the following notations for pilling effect and string density:

x- string density

f(x)- pilling effect

$$f(x) = 1.483 * x^9 - 4.812 * x^8 + 6.937 * x^7 - 5.832 * x^6 + 3.15 * x^5 - \\ - 1.134 * x^4 + 2.72 * x^3 - 4.192 * x^2 + 3.768 * x - 1.504 \quad (1)$$

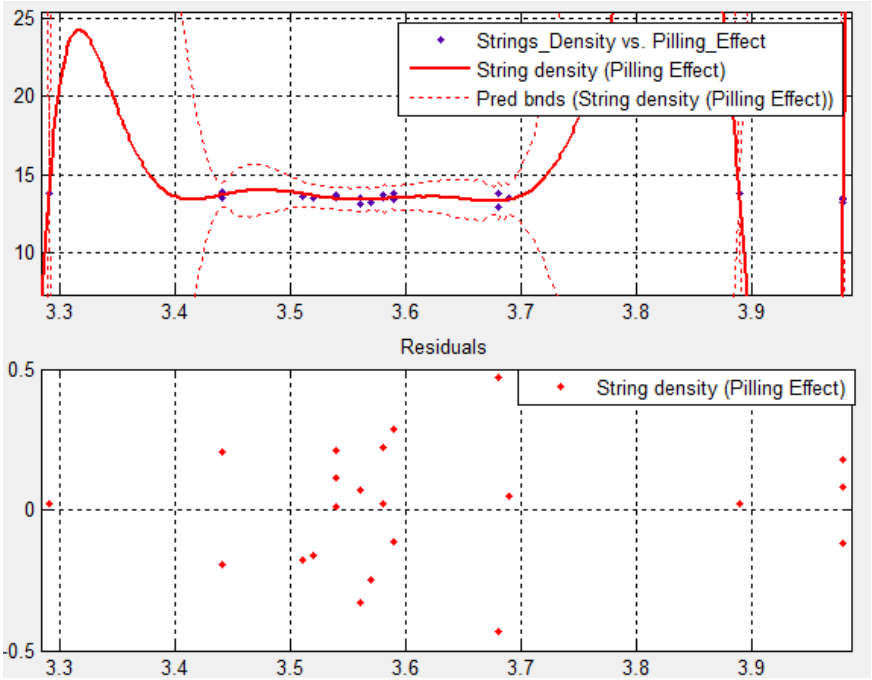

Figure 1. String density dependent on pilling effect model aproximation

In figure 1 is presented the string density addicted to pilling effect prediction and model approximation.

In figure 2 is presented the fitting string density dependent on pilling effect for dataset obtained by approximation.

The string density modification after 10 minutes plasma treatment can be computed by using cubic interpolation and explained in function of tear force and pilling effect modification (figure 3).

For contour data analyze (figure 4) we can see that the high values for pilling effect and tear force, after 10 minutes plasma treatment, are 199 N and approximate 3.7 values for pilling effect. By using plasma treatment the pilling effect can be reduced and this can conduct to increasing the textile surface elongation and indirectly decreasing the strings density.

For higher value of pilling effect we have elongation increasing. This means that elongation and electrostatic tension reduction is depending on pilling effect improvement after plasma treatment. String density is not influenced by tear force increasing, but can be indirectly proportional with pilling effect.

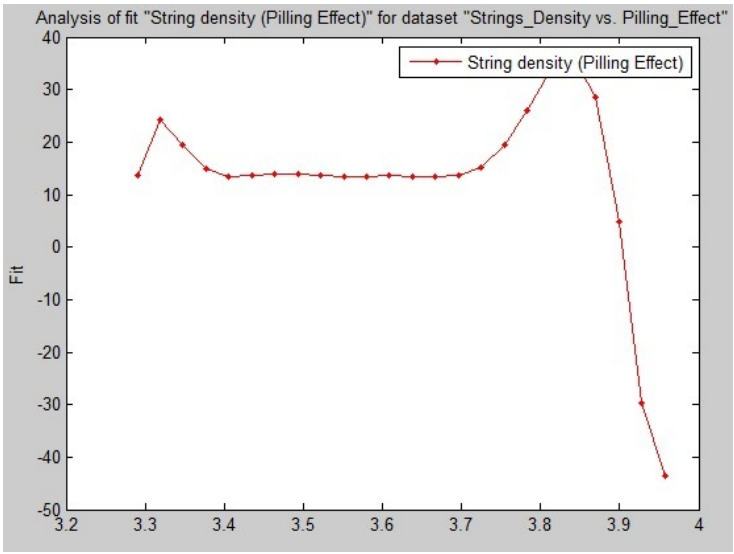

Figure 2. Fitting value analyzing for string density

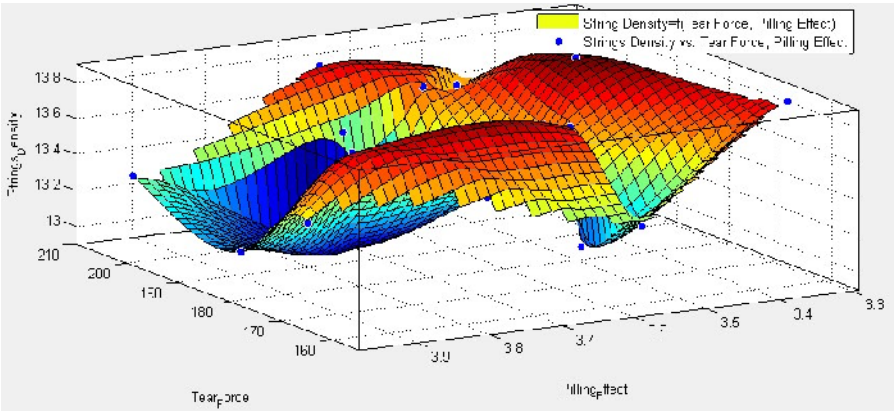

Figure 3. String density -3D analyze in function of tear force and pilling effect

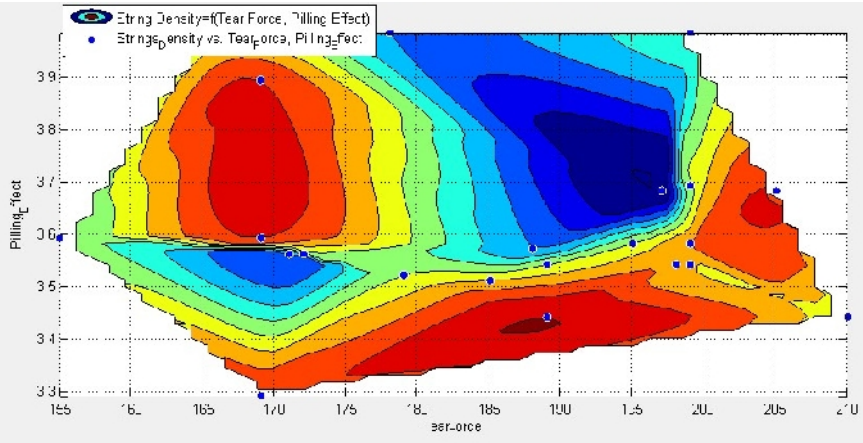

Figure 4. Contour analyzing –string density vs. tear force, pilling effect

By analyzing the residuals values can conclude that string density in function of tear force and pilling effect don't have residual values and respect the 3D fitting.

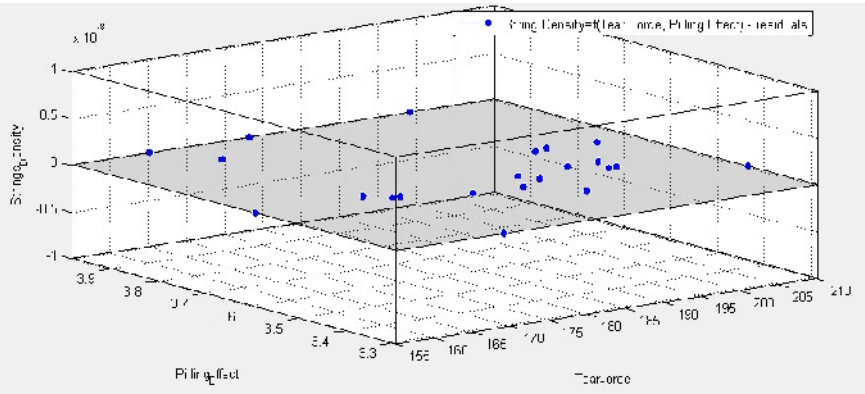

Figure 5. Residual values for model analyzed

CONCLUSIONS

From analyzed data can conclude that plasma nanotechnology treatment for knit samples made from cotton and having medical usage destination area is ecofriendly method for surface functionalization and conduct to:

- Reducing pilling effect
- Surface activation
- Traction resistance improvement
- Electrostatic tension reduction in knit surface
- Improvement finishing treatment and increasing the life cycle of treated surface

- Improvement of hydrophilic capacity
- Contact angle reduction
- Economy on chemicals used for finishing treatment
- Reduction of steps required for treat the materials used for medical area.

Acknowledgements

This paper presents experimental results obtained in *Innovative Production Chain For Textile By Plasma Nanotechnology*, Multitexfunction CrossTexNet project, 7-062/ 2012.

REFERENCES

Bhat, N. Netravali, A, Gore, A., Sathianarayanan, M., Arolkar, G., Deshmukh, R. (2011), "Surface modification of cotton fabrics using plasma technology", *Textile Research Journal*.

Crosstexnet Project, *INNOVATIVE PRODUCTION CHAIN FOR TEXTILE BY PLASMA NANOTECHNOLOGY*, MULTITEXFUNCTION, 7-062 / 2012.

Gulrajani, M.L. and Gupta, D. (2011), "Emerging techniques for functional finishing of textiles", *Indian Journal of Fibre & Textile Research*.

Haji, A., Barani, H., Qavamnia S. (2013), "In situ synthesis of silver nanoparticles onto cotton fibres modified with plasma treatment and acrylic acid grafting", *Micro & Nano Letters*.

Karahan, H.A., Özdoğan, E. (2008), "Improvements of surface functionality of cotton fibers by atmospheric plasma treatment", *Fibers and Polymers*, 9(1), 21-26.

Kilic, B., Dokuz Eylul, Aksit, A. C., Mutlu, M. (2009), "Surface modification and characterization of cotton and polyamide fabrics by plasma polymerization of hexamethyldisilane and hexamethyldisiloxane", *International Journal of Clothing Science and Technology*, 21(2/3).

Rauscher, H., Perucca, M., Buyle, G. (2010), *Plasma Technology for Hyperfunctional Surfaces: Food, Biomedical and Textile Applications*, WILEY-VCH.

Thomas, V., Bajpai, M., Bajpai, S.K. (2011), In Situ Formation of Silver Nanoparticles within Chitosan-attached Cotton Fabric for Antibacterial Property, *Journal of Industrial Textiles*.