THE EFFECTS OF HMDSO PLASMA POLYMERIZATION ON PHYSICAL, LOW-STRESS MECHANICAL AND SURFACE PROPERTIES OF WOOL FABRICS

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Abstract:

This work is mainly focused on the characterization of physical, low-stress mechanical and surface properties (such as bending rigidity, shear rigidity and air permeability) of plasma coated wool fabrics. A thin film was deposited on fabric samples by means of plasma polymerization of hexamethyldisiloxane (HMDSO) and differences between such plasma-treated and untreated fabrics were evaluated, analysing possible influences of operating conditions (particularly discharge power and deposition time) on the trends of the studied properties.

Keywords:

HMDSO; plasma polymerization; wool; bending rigidity; shear rigidity; air permeability

Introduction

Owing to the increasing awareness of ecological and economical restrictions imposed on the textile industry and to new needs of consumers and producers, today there is a great interest in the development of environmentally friendly and economical processes. One of the most interesting possibility is the application of plasma as a novel alternative finishing technology that significantly reduces toxic-chemical pollution, and could result in a powerful tool to fulfil environmental requirements and very specific functions; it is a dry process (i.e. it does not require water or wet chemicals and does not produce liquid effluents) and is an effective and versatile technique for modifying homogeneously the uppermost atomic layers of a material surface leaving the bulk characteristics unaffected, due to its very low penetration. It is well known that plasma is an ionized gas in which numerous active species coexist, from charged particles, such as electrons and ions, to neutral particles, chemically active, such as radicals and excited atoms and molecules. This state is reached spontaneously in the matter at thermodynamic equilibrium (temperatures higher than 10^4 K) when thermal agitation is sufficient to permit an high ionization; for non-equilibrium systems, plasma can be realized when excitation agents, with energy higher than the minimum energy for the ionization, exist. Non thermal (or low temperature) plasma, in which the ions and neutrals are at a much lower temperature respect to “hotter” electrons, are characterized by a sufficiently low temperature, thus resulting interesting for the treatment of textile materials. The most suitable way to produce such low temperature plasma (LTP) is through electrical discharges, either under atmospheric pressure or at low pressure.

Since the sixties there have been research studies regarding the application of plasma technology in the textile field: a lot of works have been reported concerning plasma grafting of chemical functions onto surface and plasma etching and activation of surface material by means of non-polymer forming feeds like oxygen, nitrogen, argon, helium, air and ammonia, and deposition of polymer-like products on the surface by plasma polymerization of fluorocarbon, hydrocarbon and organosilicon molecules [1-20]. In those works chemical, physical and mechanical properties and surface characteristics of plasma treated natural (wool [1-10], mohair [1], cotton [8-12], silk [13], linen [14]) or man-made (polyester [3, 8, 15, 16], polyamide [4, 15, 17], acrylic [16], polypropylene [8, 19], rayon [18]) fibres, yarns and fabrics were investigated, and the results pointed out that the plasma treatment could be properly used to achieve surface modifications affecting properties like shrink-resistance [1, 2, 5, 8], wettability [3, 5, 13, 15, 16, 19], dyeability [4, 7, 9, 15], wickability [9, 14], scourability [9], soiling [15] and desizing [18].

Instead, in previous works [21, 22] we investigated the plasma polymerization of hexamethyldisiloxane (HMDSO), a silicon-containing organic monomer, as an alternative, ecological finishing process for improving pilling performance of knitted wool fabrics. It was pointed out that treated fabrics showed a promoted pilling resistance respect to untreated ones, and that the plasma deposition of the silicon-based thin film was more effective in the enhancement of the pilling behaviour than a wet anti-pilling treatment [21].

In the textile finishing wet processes by silicone-based treatments are widely used to impart different surface effects to the fibre fabrics, including reduced fibre friction, water repellence, softness, anti-staining and anti-wrinkle effects [23]. Therefore, taking in consideration that silicone treatments are more and more widespread in the textile finishing, in this report the study of plasma polymerization of HMDSO was continued, and the effects on physical, low-stress mechanical and surface properties investigated. Wool fabrics were coated by a ultra-thin layer of plasma polymer obtained by feeding radio frequency (RF) glow discharges with HMDSO in mixture with argon and oxygen gases. After treatments some physical, low-stress mechanical and surface properties were investigated. Particularly, compression, bending, tensile and shear behaviour was characterized by means of FAST (Fabric Assurance by Simple

Testing) integrated set of instruments, and air permeability measured. The aim of this work was to present a comparative analysis of physical properties (e.g. thickness, bending rigidity, shear rigidity, air permeability) of treated and untreated wool fabrics. The results are presented graphically and discussed.

Experimental

Materials and plasma treatments

Fabric samples measured 30 cm x 30 cm and were cut from 138 g/m^2 standard undyed wool fabric (ISO 105-F01). In accordance with our previous works [21, 22], the samples were plasma coated by means of a Si:Ox:Cy:Hz thin film, from the precursor hexamethyldisiloxane (HMDSO, 98%, Sigma Aldrich), using argon (Ar, 99.9995%, Siad) and oxygen (O_2, 99.999%, Siad) as carrier and reactive gases.

In order to clean the substrate and remove materials from fibre surface, whose presence could affect the treatment in an undesired and uncontrolled way, before treatment samples were scoured with petroleum ether by means of a Soxhlet extraction for 3 hours, then rinsed twice with deionised hot (50 °C) and cool (room temperature) water for 1 hour, respectively, and finally dried in an oven at 105 °C for 4 hours to avoid water sorption by walls of plasma chamber.

The experimental equipment used for plasma treatments is schematized in Figure 1.

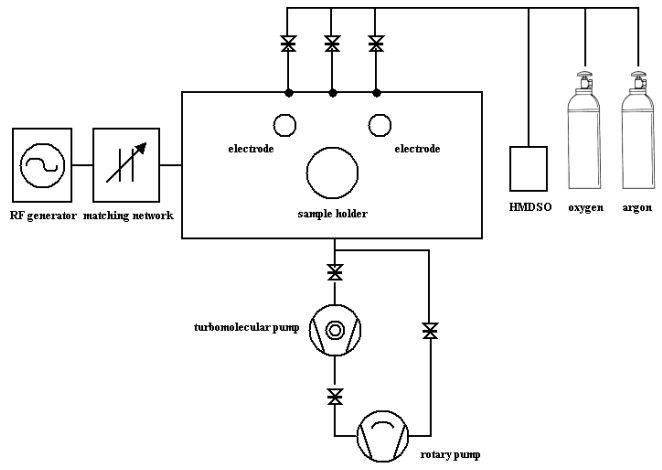

Figure 1. Schematic diagram of plasma system.

It consists of an aluminium reactor (inside dimensions about 250 mm H x 650 mm W x 400 mm D), equipped with a 13.56 MHz RF generator (PFG 600 RF, HÜTTINGER Electronic) tuned by means of an impedance matching network (PFM 1500 A, HÜTTINGER Electronic). The low pressure reactor is pumped by a turbomolecular pump (Turbo-V 301 Navigator, VARIAN Vacuum Technologies) and a dual stage rotary vane pump (DS 602, VARIAN Vacuum Technologies). The plasma is generated between two capacitively-coupled cylindrical electrodes (∅ 53 mm, 310 mm wide), distant 110 mm. Fabric specimen is fixed on a rotating roller (∅ 93 mm) below the electrodes, allowing homogeneous plasma irradiation on surface area; the distance between each electrode and the roller is 72 mm. The reactor is fitted with three inlets: one for the introduction of the monomer, and two for the processing gases. The flows of monomer vapour and feed gases are measured and controlled by means of mass flow controllers (Type 1179A, MKS Instruments), and the pressure is monitored by a capacitance manometer (Baratron Type 626A, MKS Instruments) and a gauge controller (senTorr CC2C, VARIAN Vacuum Technologies).

The surface of wool samples was covered by a ultra-thin layer of plasma polymer obtained from HMDSO by means of a two steps LTP process. An activation and etching of the substrate by a RF excitation of Ar (mantaining Ar flow rate at 20 sccm, discharge power at 50 W, chamber pressure at 20 Pa, for a treatment time of 3 minutes) was followed by the polymerization performed in a mixture of HMDSO vapour and feed gases (O_2 and Ar) at constant flows: HMDSO flow rate was maintained at 3 sccm, O_2 flow rate at 20 sccm, Ar flow rate at 20 sccm, chamber pressure at 2 Pa, while discharge power was varied between 20 and 60 W, and deposition time between 5 and 8 minutes. After treatment, RF power was switched off and the system returned to atmospheric pressure by introducing air into the plasma chamber. Table 1 summarizes all plasma processes and conditions tested in this study.

Table 1. Plasma treatment conditions tested.

		HMDSO-Ar-O_2 polymerization		
Plasma treatment	Ar activation	Pressure (Pa)	Power (W)	Time (min)
PT20_5	Yes	2	20	5
PT20_8	Yes	2	20	8
PT40_5	Yes	2	40	5
PT40_6	Yes	2	40	6
PT40_7	Yes	2	40	7
PT40_8	Yes	2	40	8
PT60_5	Yes	2	60	5
PT60_6	Yes	2	60	6
PT60_7	Yes	2	60	7
PT60_8	Yes	2	60	8

Low-stress mechanical and surface properties measurements

FAST (CSIRO, Australia) is a simple Fabric Objective Measurement (FOM) system for assessing aspects of the appearance, handle and performance properties of fabrics; it measures fabric properties that are closely related to the ease of garment making-up and the durability of worsted finishing, and represents an inexpensive, robust, and simple to use alternative to the more complex Kawabata Evaluation System for Fabrics (KES-F), whose use is hindered by the cost of test equipment, the complexity of test results, and the difficulty of their interpretation [24, 25]. Moreover, even though the KES-F and FAST systems employ somewhat different principles for measuring low-stress fabric mechanical properties, there are highly significant correlations between the test parameters measured [26]. FAST system consists of three instruments, that permit to fully describe tensile, shear, bending and compression behaviour of fabric; the deformations involved are presented in Figure 2.

FAST-1 [27] is a compression meter that provides a direct measure of fabric thickness at selected loads (2, 20 and 100 gf/cm^2). This is achieved by positioning fabric samples on the reference surface of the instrument and lowering appropriate weights onto the fabric (Figure 3a).

FAST-2 [27] is a bending meter that provides a direct measure of fabric bending length, either in warp or weft direction. Fabric bending rigidity is calculated from the bending length and

fabric mass per unit area. The instrument is designed to measure the bending length of a 50 mm wide strip of fabric. The fabric is moved horizontally, and its leading edge is detected, first as it is moved across to the measurement cavity, initiating the length measurement, then as it cuts a light beam inclined at 41.5° degrees to the horizontal (the fabrics is left to bend under its own weight) (Figure 3b).

FAST-3 [27] is an extension meter that provides a direct measure of fabric extension under different loads (5, 20 and 100 gf/cm), chosen to simulate the level of deformation the fabric is likely to undergo during garment manufacture. Measurements are usually quoted in the warp and weft directions, and shear rigidity can be calculated from extension values measured on the bias (i.e. 45° to warp or weft direction). Rectangular specimens of fabric are gripped between two parallel sets of jaws and extended by a selected force. The instrument measures the increase of a 100 mm gauge length of the sample in millimetres, operating on a balance principle (Figure 3c).

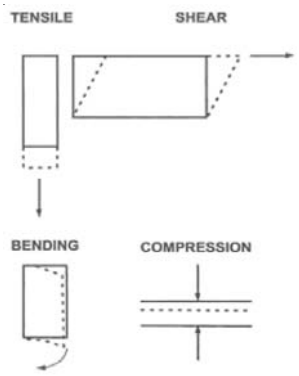

Figure 2. Schematic diagram of deformations involved in FAST measurements.

FAST instruments were used to measure and evaluate the properties summarized in Table 2. Each sample was conditioned under standard laboratory conditions (20 °C ± 2 °C and 65% ± 2% RH) at least for 24 hours before cutting and testing.

Air permeability measurements

The air permeability was measured by means of a FX 3300 air permeability tester (TEXTEST AG, Switzerland), according to ISO 9237 standard. A powerful, muffled vacuum pump draws air through an interchangeable test head with a circular opening. The air flow through the test specimen is measured with a variable orifice and the air permeability of the test specimen is determined from the pressure drop across this orifice [28]. The test pressure drop was set to 100 Pa and the air permeability of each sample was calculated as average of the values measured in 9 different sample zones (each of 20 cm^2). Samples were conditioned under standard laboratory conditions at least for 24 hours before testing.

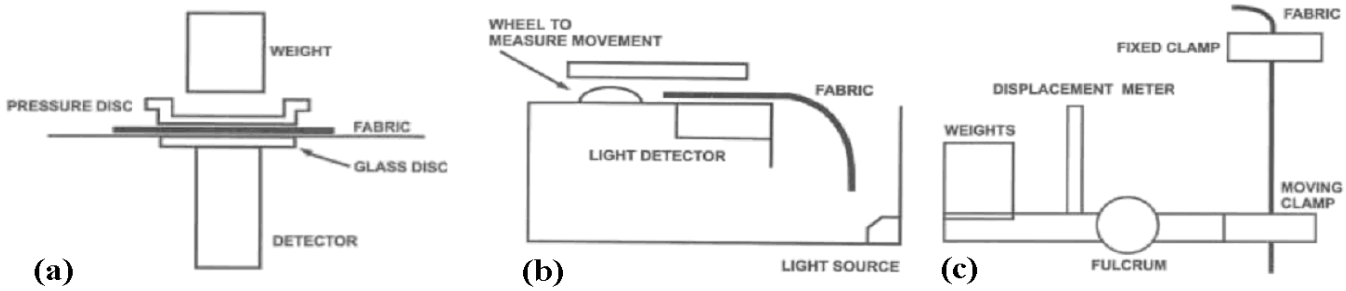

Figure 3. FAST-1 (a), FAST-2 (b) and FAST-3 (c) schematic diagrams.

Table 2. Fabric properties measured and calculated from FAST system.

Instrument	Property	Symbol/Formula	U.M.
	Weight (per unit area)	W	g/m^2
FAST-1	Thickness at 2 gf/cm^2 (0.196 kPa)	T2	mm
	Thickness at 20 gf/cm^2 (1.96 kPa)	T20	mm
	Thickness at 100 gf/cm^2 (9.81 kPa)	T100	mm
	Surface Thickness	ST=T2-T100	mm
FAST-2	Bending Length in warp	C1	mm
	Bending Length in weft	C2	mm
	Bending Length	C=(C1+C2)/2	mm
	Bending Rigidity in warp	$B1=W \times C1^3 \times 9.81 \times 10^{-6}$	μNm
	Bending Rigidity in weft	$B2= W \times C2^3 \times 9.81 \times 10^{-6}$	μNm
	Bending Rigidity	B=(B1+B2)/2	μNm
FAST-3	Warp Extensibility at 5 gf/cm (4.9 N/m)	E5_1	%
	Weft Extensibility at 5 gf/cm (4.9 N/m)	E5_2	%
	Warp Extensibility at 20 gf/cm (19.6 N/m)	E20_1	%
	Weft Extensibility at 20 gf/cm (19.6 N/m)	E20_2	%
	Warp Extensibility at 100 gf/cm (98.1 N/m)	E100_1	%
	Weft Extensibility at 100 gf/cm (98.1 N/m)	E100_2	%
	Bias Extensibility (at 5 gf/cm)	EB5	%
	Shear Rigidity	G=123/EB5	N/m

Results and Discussion

Effect of the plasma treatments on low-stress mechanical properties

FAST system had permitted to analyse low-stress mechanical properties regarding fabrics treated with different operating conditions, and to assess possible differences introduced by the plasma process.

First of all, it can be highlighted that the plasma process caused an increase in fabric thickness (Table 3) measured by FAST-1. The plasma polymerization was responsible for the deposition of a thin polymeric film: this film, according to a previous study, should be less than 100 nm thick [21], so it could not be the only answerable of the general increase in thickness

after the plasma process revealed by FAST measurements. In fact, for T2 there were increments from 4 μm to 33 μm in the thickness of treated samples respect of untreated ones, for T20 from 10 μm to 22 μm, for T100 from 15 μm to 23 μm. All these increments are at least one order of magnitude greater than the thickness of the plasma polymerized film deposited on wool fabrics. So the general thickening must be a consequence of the whole plasma process. As described above, prior to the deposition, Ar pre-treatment was carried out to clean, etch and activate the surface; besides, the polymerization step was carried out in a mixture of HMDSO, O_2 and Ar: in addition to Ar as neutral gas carrier for HMDSO vapour whose presence improves the decomposition of the monomer, O_2 was added to dilute the input gas mixture. It is known that O_2 and Ar plasma treatments lead to an increase in fabric thickness: the treated fabrics become fuller and a certain roughness on the surface is created, enhancing the inter-spaces between fibres and yarns and thus increasing the fabric thickness and compressibility [10, 17].

The differences between treated and untreated samples were more and more evident with the increase of load. At the lowest load (2 gf/cm^2) it seems to be an increase with the rising both in the discharge power and in the deposition time, even if there were some particular cases that did not respect these proportional increases (PT40_6 and PT60_7).

With the increase of load there was a more and more little gap between the lowest and the highest values of treated-sample thickness (390 m and 402 m for T20, 351m and 359 m for T100), and no relevant tendencies related to power and deposition time could be observed.

It is difficult to generalize, but it seemed that, for the same deposition time, thickness increased with higher discharge power: this is more evident for T2, while for T100 measured thickness values varied less and were very similar. Instead, it is not possible to state that, for the same power, thickness increased with higher deposition time, at least for the range of deposition time tested in this work.

Analysing FAST-2 measurements, it is possible to state that the plasma process induced an increase in bending length (Table 4), and consequently in bending rigidity: this means greater resistance to bending and minor flexibility of the fabric. Bending properties are important non only to aesthetic characteristics such as drape and hand, but also to the making up of an acceptable garment: a fabric of higher bending rigidity may be more manageable during sewing, resulting in a flat seam, but may cause problems during moulding [24, 29]. The evident increase in bending length, both in warp direction (C1) and in weft direction (C2), results in an increment of fabric bending length C (from 5% to 6.8%). Bending rigidity (B), defined as couple required to bend unit width of fabric to unit curvature, is calculated from bending length, as reported in Table 2. Table 4 and Figure 4 summarize all the calculated bending rigidities. Obviously, owing to the results regarding bending length, bending rigidity increased after the plasma process, both in warp (B1) and in weft (B2) direction; consequently, bending rigidity B, mean of B1 and B2, increased, going from a minimum of +16% (PT40_7 vs. Untreated) to a maximum of +22% (PT40_6 vs. Untreated). No particular trends related to changes in operating conditions were observed. Starting from the considerations made for thickness measurements, the enhance of bending rigidity could be explained, in accordance with Yip et al., with the rough surface that might impart more contact points between the fibres/yarns and thus enhance the fibre to fibre and yarn to yarn inter-friction; this increased friction develops a greater cohesive force among the yarns during the application of tensile, bending and shearing stresses [17].

The bending properties of a fabric depend, among other things, on the fabric structure and increase when the fabric thickness increases [10]: the results were consistent with the increase in fabric thickness reported above.

Finally, as reported in Table 5, from FAST-3 measurements it is possible to state that there were no key influences of the plasma process as regards fabric warp and weft extensibilities under different loads, also considering that the instrument has a sensor that monitors the position of the arm and values for extension are measured as percentage fabric extension, with a resolution of 0.1%. On the contrary, great influence of the plasma application was

Table 3. Measured fabric thickness at 2 gf/cm^2 (T2), 20 gf/cm^2 (T20), 100 gf/cm^2 (T100), and calculated fabric surface thickness (ST), for each condition.

Condition	T2 (mm)	T20 (mm)	T100 (mm)	ST (mm)
Untreated - TQ+SOX	0.473	0.380	0.336	0.137
PT20_5 - 20 W 5 min	0.479 (+1.3%)	0.394 (+3.7%)	0.358 (+6.5%)	0.121
PT20_8 - 20 W 8 min	0.487 (+3.0%)	0.394 (+3.7%)	0.355 (+5.6%)	0.132
PT40_5 - 40 W 5 min	0.477 (+0.8%)	0.393 (+3.4%)	0.357 (+6.3%)	0.122
PT40_6 - 40 W 6 min	0.496 (+4.9%)	0.398 (+4.7%)	0.357 (+6.3%)	0.139
PT40_7 - 40 W 7 min	0.484 (+2.3%)	0.390 (+2.6%)	0.351 (+4.4%)	0.133
PT40_8 - 40 W 8 min	0.494 (+4.4%)	0.396 (+4.2%)	0.357 (+6.3%)	0.137
PT60_5 - 60 W 5 min	0.489 (+3.4%)	0.397 (+4.5%)	0.358 (+6.5%)	0.131
PT60_6 - 60 W 6 min	0.496 (+4.9%)	0.396 (+4.2%)	0.354 (+5.3%)	0.142
PT60_7 - 60 W 7 min	0.506 (+7.0%)	0.402 (+5.8%)	0.359 (+6.8%)	0.147
PT60_8 - 60 W 8 min	0.500 (+5.7%)	0.399 (+5.0%)	0.358 (+6.5%)	0.142

Table 4. Measured fabric bending length in warp (C1), in weft (C2) and mean (C) and calculated fabric bending rigidity in warp (B1), in weft (B2) and mean (B), for each condition.

Conditions	C1 (mm)	C2 (mm)	C (mm)	B1 (μNm)	B2 (μNm)	B (μNm)
Untreated - TQ+SOX	16.56	14.63	15.60	6.15	4.23	5.20
PT20_5 - 20 W 5 min	17.69	15.13	16.41 (+5.2%)	7.49	4.69	6.09 (+17.1%)
PT20_8 - 20 W 8 min	17.69	15.25	16.47 (+5.6%)	7.49	4.80	6.15 (+18.3%)
PT40_5 - 40 W 5 min	17.50	15.38	16.44 (+5.4%)	7.26	4.93	6.10 (+17.3%)
PT40_6 - 40 W 6 min	17.81	15.50	16.66 (+6.8%)	7.65	5.04	6.35 (+22.1%)
PT40_7 - 40 W 7 min	17.56	15.19	16.38 (+5.0%)	7.33	4.74	6.04 (+16.2%)
PT40_8 - 40 W 8 min	17.69	15.38	16.54 (+6.0%)	7.49	4.93	6.21 (+19.4%)
PT60_5 - 60 W 5 min	17.56	15.25	16.41 (+5.2%)	7.33	4.80	6.07 (+16.7%)
PT60_6 - 60 W 6 min	17.56	15.50	16.53 (+5.9%)	7.33	5.04	6.19 (+19.0%)
PT60_7 - 60 W 7 min	17.56	15.50	16.53 (+5.9%)	7.33	5.04	6.19 (+19.0%)
PT60_8 - 60 W 8 min	17.75	15.31	16.53 (+5.9%)	7.57	4.86	6.22 (+19.6%)

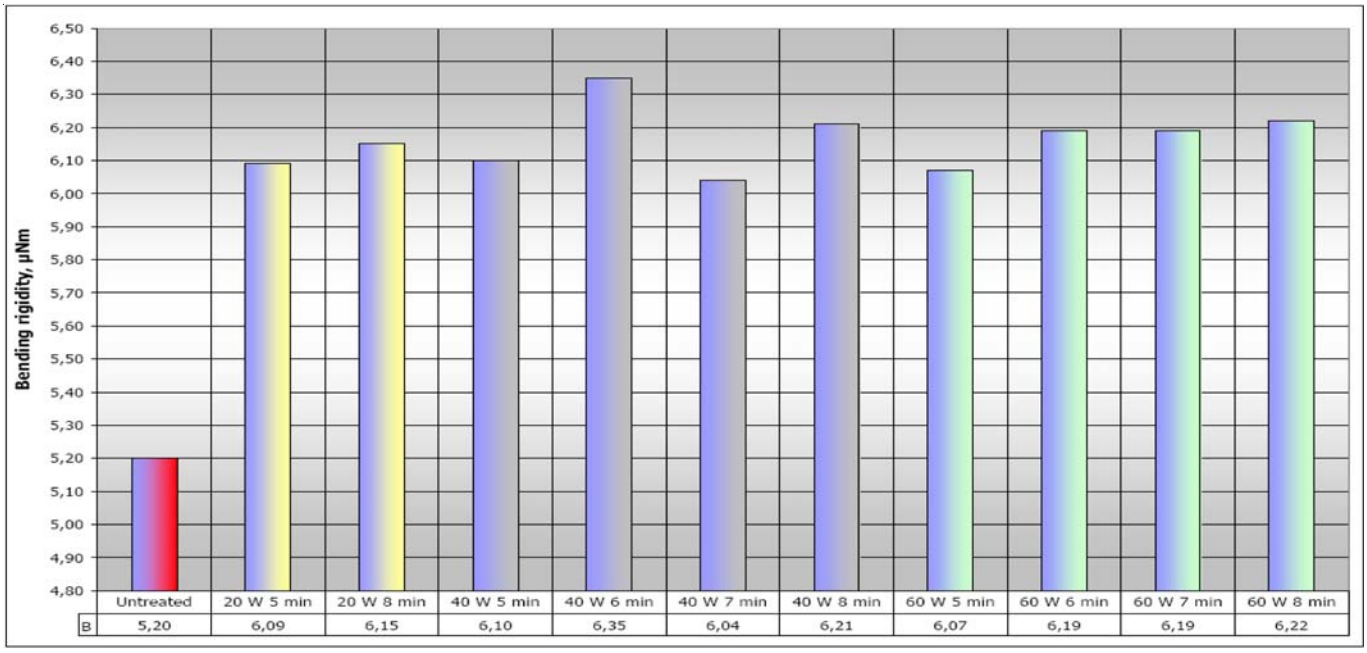

Figure 4. Calculated fabric bending rigidity (B) for each condition.

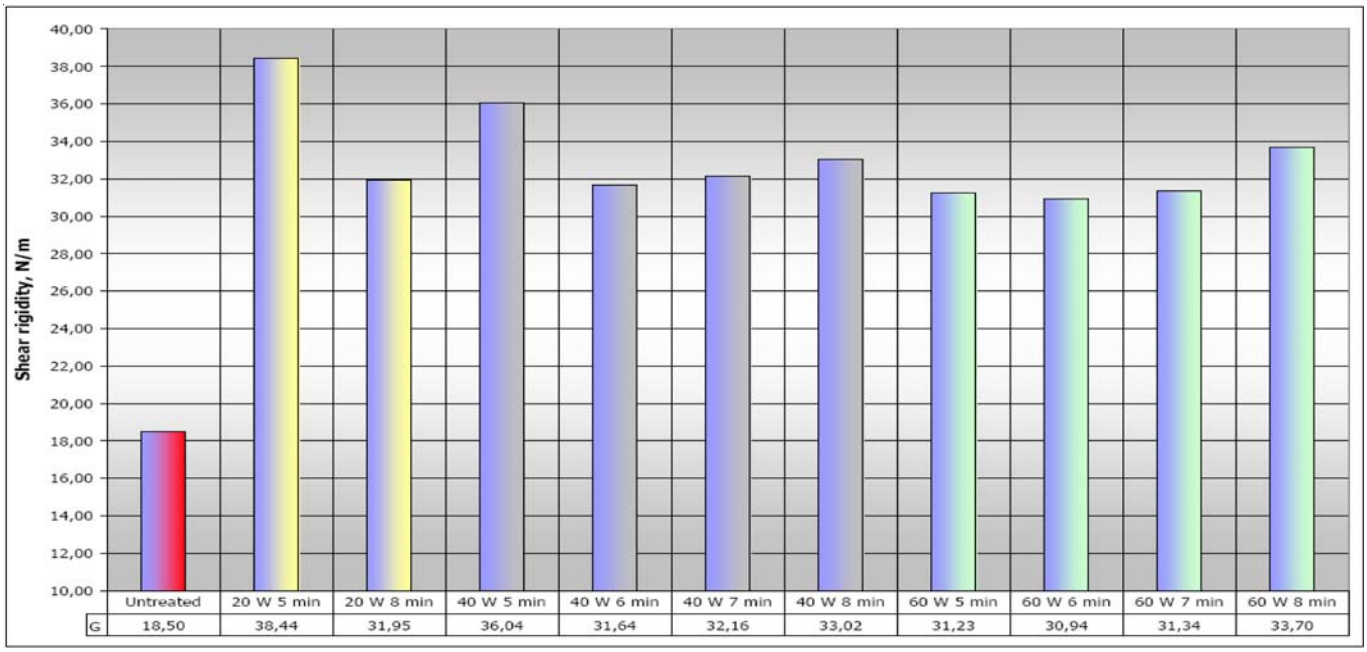

Figure 5. Calculated fabric shear rigidity (G) for each condition.

Table 5. Measured fabric warp extensibility at 5 (E5_1), 20 (E20_1) and 100 (E100_1) gf/cm, and fabric weft extensibility at 5 (E5_2), 20 (E20_2) and 100 (E100_2) gf/cm, and fabric bias extensibility (EB5) at 5 gf/cm, for each condition.

Conditions	E5_1 (%)	E20_1 (%)	E100_1 (%)	E5_2 (%)	E20_2 (%)	E100_2 (%)	EB5 (%)
Untreated - TQ+SOX	0.325	0.925	2.325	1.000	3.150	8.375	6.650
PT20_5 - 20 W 5 min	0.350	0.800	2.250	0.750	2.775	8.025	3.200 (-51.9%)
PT20_8 - 20 W 8 min	0.350	0.950	2.425	0.850	2.875	7.775	3.850 (-42.1%)
PT40_5 - 40 W 5 min	0.350	0.900	2.325	0.800	2.550	7.350	3.413 (-48.7%)
PT40_6 - 40 W 6 min	0.500	1.075	2.525	0.800	2.950	8.075	3.888 (-41.5%)
PT40_7 - 40 W 7 min	0.275	0.825	2.150	0.800	2.625	7.225	3.825 (-42.5%)
PT40_8 - 40 W 8 min	0.525	1.150	2.725	0.950	3.050	8.100	3.725 (-44.0%)
PT60_5 - 60 W 5 min	0.300	0.825	2.225	0.825	3.000	8.175	3.938 (-40.8%)
PT60_6 - 60 W 6 min	0.300	0.875	2.425	0.850	2.825	7.700	3.975 (-40.2%)
PT60_7 - 60 W 7 min	0.325	0.900	2.350	1.000	3.125	8.250	3.925 (-41.0%)
PT60_8 - 60 W 8 min	0.300	0.875	2.350	0.800	2.825	7.750	3.650 (-45.1%)

reported as concerns bias extensibility (EB5): the plasma process caused a drastic decrease in bias extensibility (from 40 to 52%), and consequently there was a great increase in shear rigidity (Figure 5), starting from +67% (PT60_6 vs. Untreated). In fact, shear rigidity (G) is defined as shear load required to deform unit width of fabric to unit strain, and is calculated as G = 123/

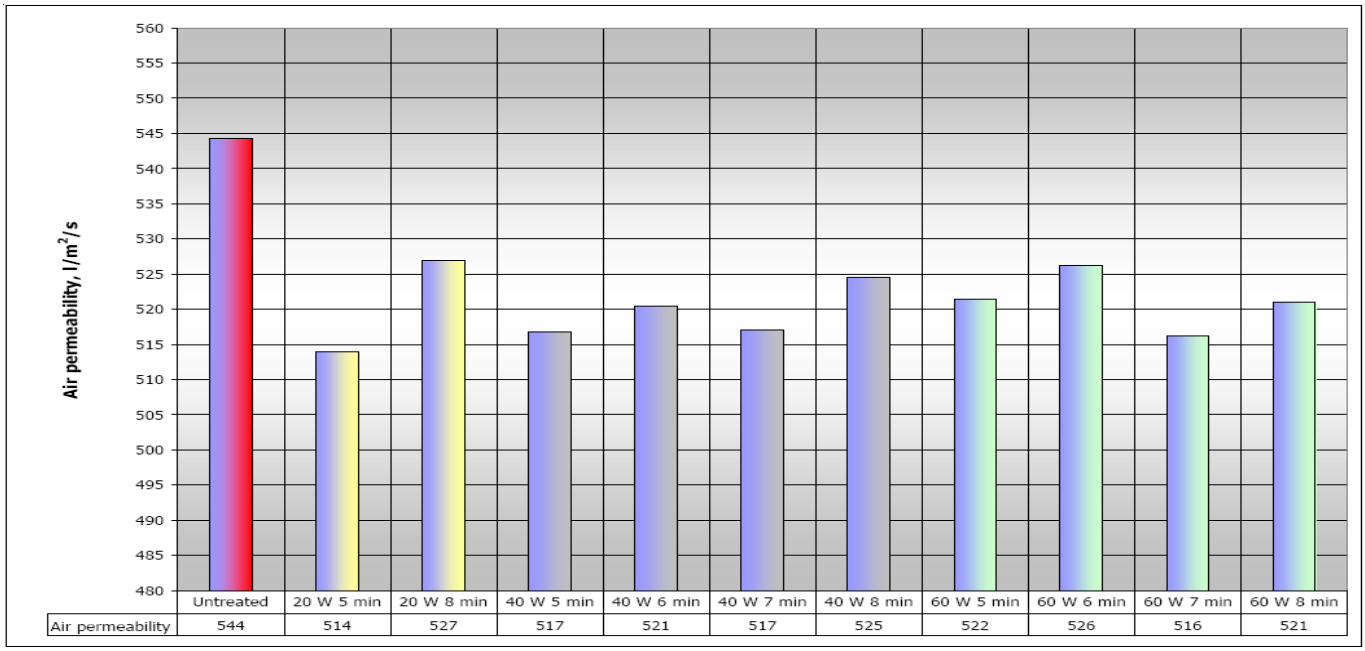

Figure 6. Air permeability for each condition.

EB5, thus resulting inversely proportional to bias extension. The same considerations said for explaining the enhance of bending rigidity after the plasma treatment might be used to understand the shear rigidity increase after the same process. No particular trends related to different operating conditions were observed. Shear rigidity gives a measure of the ease with which a fabric can be deformed into a three-dimensional shape. With low shear rigidity the fabric easily distorts, giving rise to difficulties in laying up, marking and cutting; on the other hand, a high value of shear rigidity means a fabric that is difficult to mould and where there are problems with sleeve insertion [29].

Effect of the plasma treatments on air permeability

Air permeability is a property of textiles which influences the flow of gas from the human body to the environment and the flow of fresh air to the body. It depends mainly on fabric porosity, which means the number of canals in the textile fabric, its cross-section and shape, and has great influence on thermal properties [30].

The air permeability of a textile fabric is determined by the rate of air flow through a material under a differential pressure between the two fabric surfaces. Figure 6 reports air permeability values for treated and untreated fabrics. It can be seen how the plasma process caused a lowering in air permeability of fabrics, in comparison with untreated ones (from 3.1 to 5.5%). For plasma-treated fabrics, no particular trend and influences correlated to power input and deposition time can be pointed out, at least for conditions tested in this work. All averaged values are quite similar and very near, going from the lowest 514 l/m^2/s (PT20_5) to the highest 527 l/m^2/s (PT20_8). It is possible to state that the investigated LTP process decreased air permeability of the fabric.

The air permeability is related to the construction characteristics (e.g. structure, thickness and surface) of the yarns and fabrics, and to the air entrapped within their structure. It is known that etching did not alter the fabric structure but rather fibre surface roughness and surface morphology [6, 10, 17]. Besides, the deposition of a thin polymeric film changes surface characteristics. As discussed before, these effects as a whole, closely related to the two-steps plasma process, enhance the inter-spaces between fibres and yarns, induce a certain degree of roughness on the fabric, and, as a consequence, increase the fabric thickness, resulting in changes that acted as a boundary to hinder the air flow through the fabric and consequently reduced the air permeability of the fabrics [6, 17].

Conclusions

In this work several physical, mechanical and surface properties of wool fabrics treated by means of a two-steps RF-plasma process were investigated, applying different plasma conditions to fabrics: varied operating parameters were discharge power (20 W, 40 W e 60 W) and deposition time (from 5 to 8 minutes).

The results clearly show that low stress-mechanical properties were affected significantly, particularly bending and shear. Plasma process induced a general increase in fabric thickness, not only related to the deposition of a thin polymeric film over the substrate, but also to the induced roughness of the fabric, and the differences between treated and untreated samples were more and more evident with the increase of load. This thickening could be one of the reasons for the decrease of air permeability: in fact, after plasma process there was an overall lowering in air permeability of fabrics, independent of process conditions tested. Even if it is difficult to generalize, it seemed that, for the same deposition time, thickness increased with higher discharge power. It is more difficult to state that, for the same power, thickness increased with higher deposition time. No evident influences could be reported as regards surface thickness.

Besides, thanks to bending measurements it could be affirmed that the plasma process caused an important increase in bending length, and consequently in bending rigidity, even if no particular trends related to different operating conditions were observed.

Furthermore, there were no key influences of plasma process as regards fabric warp and weft extensibilities under different

loads. On the contrary, great influence of plasma application was reported as concerns bias extensibility: plasma process induced a drastic decrease in bias extensibility, and consequently a great increase in shear rigidity.
Finally this study highlighted that the investigated plasma process modified air permeability, compression, bending and shear behaviour of fabrics. However it was not possible to point out clear trends on the values of the properties related to the changes in operating conditions, this probably also because of the range of powers and process times taken into consideration.

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