Sustainable finishing of wollen fabrics by means of plasma treatment

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Textile industry is one of the most energy- and chemical- consuming manufacturing sector. Whitin this study the combination of the usage of environmental friendly auxiliaries with plasma pre-treatment has been fully investigated in order to reduce the environmental impact of the dyeing process. The benefits of the implementation of the irradiative technology and the new auxiliaries have been investigated by using an LCA approach.

Textile industry is one of the most important components of the European manufacturing sector. It accounts for more then 250,000 companies (12% of the overall manufacturing companies in the EU-27) and it has a turnover of around 240 M€ in 2007.

Textile production chain is heterogeneous and it consists of many interwoven unit operations, that generally go through repeated wet and dry operations. In order to provide the textile with the desired functionality (both technical and haestatic) a lot of energy, water and chemicals are consumed:

- 6 million tonnes of chemical auxiliaries are consumed) [1].
- at least 40 L of water per kg of fibres must be used, meaning that at least 2,400,000 m^3 of water are consumed [2]
- up to 50-70 MJ of energy (both thermal and electrical) per kg of textile is consumed [3].

Within this study, a different protocol for the dyeing and finishing (they account up to 38% of the overall energy consumption, 80% of the water used and 60% of the chemical consumption) of woollen fabric have been investigated and validated at semi-industrial scale (Fig1).

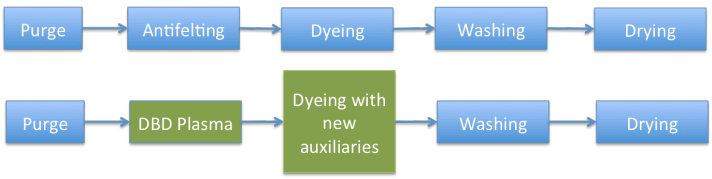

Fig.1 – Workflow for the conventional and environmental friendly deying protocols

In particular the replacememt of the wet conventional anti-felting treatment (i.e. Basolan process) with a continuous DBD Atmospheric plasma and the usage of environmental friendly have been studied in order to significantly reduce the environmental impact of the wool finishing processes.

Plasma Pre-treatment of woollen textiles

Atmospheric Plasma treatment is able to promote the removal of the epicuticle layer (the outer layer of the wool fibres) as demonstrated by the increase in the hydrophilicity of the fibres and by HATR FT-IR analysis. The increase on the amino and sulphur groups available on the fibres surface and the increase on their superficial tension suggested that the fatty layer, responsible for the low water adsorption, is completely removed by the treatment. Moreover, dyeing adsorption tests showed that plasma is enablig to increase the kinetic of the adsorption process. In table 1, the optimal process conditions for DBD plasma treatment have been reported.

Table 1 – Optimal process condition for plasma pre-treatment

Sample ID	Textile speed	Applied Power	Energy	Process Gases
WO_PL	8 m/min	500 W	1.75 J/cm^2	He*: N_2 25:27 NL/m

*He is the carrier gas required to sustain the plasma.

The performances of the plasma treated samples are comparable with the results achieved with the BASOLAN process. In fact, a high dimensional stability has been recorded: the warp and weft dimensions are negligible changing (reduction in the dimension is below 1%) with both processes.

Dyeing of the pre-treated samples with environmental friendly products

The dyeing processes of woollen fabrics is carried out by using acid dyestuffs and some levelling agents (surfactants) enabling to modify the interaction among at the interface among the fibres and the deystuffs. The recipe that has been used for the study of the effectiveness of the plasma-pretreatment and the new auxiliary is reported in table 2.

Table 2 – Recipe used for the dyeing of woolen fabric with new auxiliaries

Chemicals	Amount	Process Conditions
Blue Marino Acid Dyestuff	1% wt. Woollen fabric	Batch ratio 1:20 T = 96 °C*
Acetic Acid	1 ml/100 ml	
New Auxiliary	1.5% wt. Woollen fabric	

* Conventional Dyeing temperature

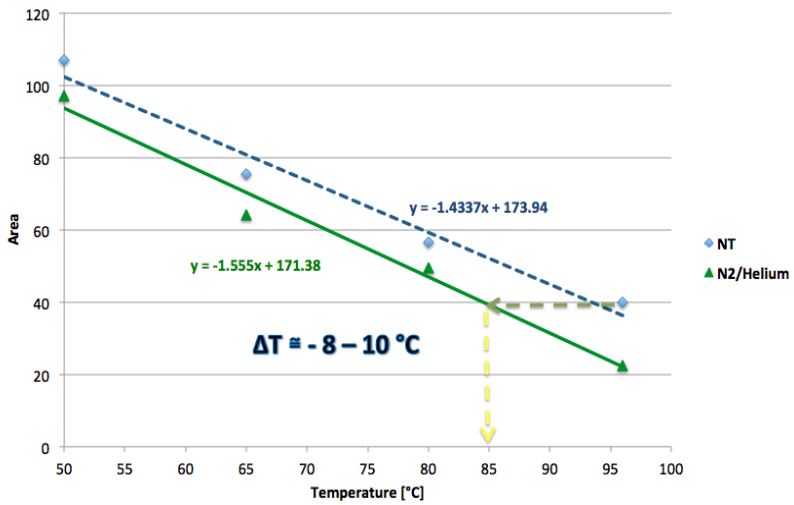

Fig.2 – Adsorption of dyestuff at different temperature for the untreated and plasma treated wool

Etoxylated amine compounds are widely used for this purpose. Within this study a new ethoxylated amine have been synthesised by ACHIMO and its characterisation showed a low environmental impact and a better performance than the conventional product (Oleic Amine has been used as reference): the COD of the new product is 32% less then the conventional one and a proper dyeing of the woollen fabric is achieved by reducing 40% the amount of auxiliary.

The optimisation of the dyeing process by using the plasma pre-treated showed that it is possible to reduce the dyeing temperature up to 12 °C (Fig.2).

In fact the modification of the woollen fibre surface is enabling to increase the kinetic of the dyeing processing enabling to achieve the same dyeing performances with lower energy (up to 31 MJ per dyeing batch can be saved).

The data for the combination for BASOLAN and conventional dyeing processes and for the combination of plasma and new auxiliaries as per the protocol developed with this study have been analysed with SimaPro software and the LCA results showed that a significant decrease on the environmental impact of the new protocol can be arisen.

In fact a reduction of the Ecopoint Score of 72% can be achieved. The main benefits have been achieved in the water deplation and for fossil depletion: a reduction of and 67% respectively has arisen.

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References

[1] W.D Schindler, P.J. Hauser, *Chemical finishing of textiles.* CRC press, 1st edition 2004.
[2] N. M. H. E. Defrawy, *Water management in textile industry;* **Intern. J Env.,** 59, 5 (2002), 573-587
[3] Output of the seminar on Energy Conservation in textile industry, UNIDO, 1992.