

Development of Itch-Free Woollens to Be Worn Next To the Skin by Improvement of Surface Topography of Wool Fibres with the Help of Mechanical/Chemical Processing and Plasma Technology

Jayant Udakhe, Shishir Tyagi, Neeraj Shrivastava, P. R. Kulkarni, Dr. C. W. Acharya & M.
K. Bardhan

Wool Research Association, Thane

Abstract

Itching due to woollen garments worn next to skin can be attributed to prickling due to protruding coarse fibres, and friction with skin due to sharp scales on wool fibre. To reduce the prickling effect different trials were taken to reduce yarn hairiness, knitwear were prepared using these different yarns but it was found that mechanical processing have very little scope of suppressing prickling effect. Wool top was plasma treated to blunt wool fibre surface scales. After plasma treatment wool top was treated with proteolytic enzyme. It was found that plasma and enzyme treatment reduces the critical bucking force of the fibre, as well as the scales on wool fibres are smoothed out. Plasma and enzyme treated wool tops were used for making yarns. Later on these yarns were used to make knitwear. To further coat the scales polymer coating was given on knitwear and softener treatment was also given to improve the handle and feel. Propensity of itching was tested by designing user trial experiments and it was found that these inner garments are completely itch-free and can be worn next to skin, without wearing the intermediate cotton garment.

Keywords: woollen garments, itch-free, plasma, enzyme, polymer and softener

1. Introduction

Even the finest wools like Merino, Pashmina, Cashmere, etc suffer from inadequacies of creating uncomfortable itching sensation to the wearer when worn next to skin. Per se, woollen garments require an intermediate garment made of cotton or other fibres next to the skin to avoid direct contact with the sensitive human skin to avoid itching when worn. This centuries old problem of itching associated with apparel woollen textiles restricted the use of wool in inner or intimate garments, even in extreme cold countries, there by resulting in a loss of an estimated market share of 20% globally by the wool growers /woollen manufacturing industry. Woollen garment worn next to the skin can cause two kinds of problems, one is the prickle and the other is itching. Prickle is the sensation of many gentle

pinpricks, hairiness on the garment prickle to skin. Prickle is solely fibre diameter dependent, and amount of prickle increases drastically with small increase in the fibre diameter. Prickle sensation is due to the level of coarse fibres present in the fabric rather than the average fibre diameter [1]. CSIRO-developed Comfort Meter for measuring prickle sensation [2]. Comparison of different methods like low-pressure compression-testing, laser-counting of protruding fibres, and a modified audio-pick-up method for determining prickling tendency of the garment shown that the modified audio-pick-up method can give better approximation to prickling [3]. Another paper suggests that prickling property of fabric varies from loom state to finished fabric [4]. Itching is cutaneous sensation which provokes the desire to scratch. Itching is the combination of prickliness and friction between human body and fabric. Itching to skin is dependent on the Sex (Male or female), it is well known that female skin is more sensitive and hence more prone to itching due to woollen garments. Itching also depends on the position of nociceptors, which are very close for hairy skin but not in gabrous skin. Hence woollen garments will itch more on the gabrous skin than non hairy skin. Itching is age dependent, as aged person have rough skin hence itching to aged person will be less than that of young child. Environment condition decides the amount of itching, if relative humidity increases the skin becomes soft hence friction of fabric with human body will be more and thus, itching.

Initially many of the peoples were thinking that, the prickle due to woollen garments is due to allergy to wool. First news appeared in **New Scientist Dated 6 August 1987 p. no. 34**, that Itching due to wool is not an allergy and it is solely fibre diameter dependent. Latter on the researchers established the relation between physical stimulus and the neural basis of fabric-evoked prickle. Critical buckling load (P), applied by the single fibre end against human skin can be mathematically expressed as, for mode n where E is the Young's modulus, I is the moment of Inertia ($I = \pi d^4/64$, d is fiber diameter), and L, is the effective length of the fiber specimen. For this study, the lowest mode is significant, that is, n=1, while $L_e = 0.699L$

$$P = n^2 * E * \frac{I}{Le^2}$$

Industrially the comfort factor of the wool is calculated on the basis of how much percentage of fibres are above 30 μ diameter, as it is proved that such fibres prickles much more and garments made of such fibres are not wearable [5,6,7]. OptimTM fine Fiber process is developed by scientist to reduce the average fibre diameter of the fibres [8]. Proteolytic

Enzymes can be used to Reduce Wool-fibre Stiffness and Prickle [9]. In Australia, R&D work has been going on to improve wool genetically on the sheep. This perennial problem of making woollen garments itch free has not been solved yet. On the side-line of IWTO Congress at Beijing held in April 2008, prominent wool growers of Australia posed this long standing problem of itching by woollen textiles when worn next to the skin. They informed that Scientists in Western Australian Department of Food & Agriculture have been working on genetical improvement of sheeps to produce softer wool, but without success so far. As a result, the consumption of wool has not been increasing due to propensity of itching to the human sensation of the skin. They requested that WRA may endeavour to solve this problem by improving the wool fibres by suitable treatment as it would have significant relevance for the Indian woollen processing industry. As India do not produce apparel grade wool and import about 75 million kg of merino wool, the value addition due to non-itchy woollen textiles will boost the Indian woollen brands internationally.

2. Materials & Methods

2.1 Materials

Eight different types of wool samples (medullated and non medullated) having average fibre diameter in the range of (14-48 μm) were used during this work. Australian merino wool fibre having average fibre diameter of 21 μ [IWTO-47] was used in the form of wool top. Linear density of wool top was 6.34 Ktex with moisture content of 9.3% and regain of 10.25% [IWTO-34] was taken after grey combing.

2.2 Wool top scouring

Before plasma treatment lubricants and antistatic were removed by scouring. Wool top was scoured using Sandozol HSI 0.5% on the material weight at 65°C for 15 minute at M: L of 1:10 then dried in radio frequency dryer and conditioned for 24 hr and then used for plasma treatment.

2.3 Plasma treatment

A dielectric barrier discharge (DBD) plasma chamber was employed for plasma treatment of wool fibres at different parameters, eg time, voltage and electrode spacing. Air was used as the non-polymerizing gas for plasma treatment. Wool top was opened in the web form and then plasma treatment was carried out.

2.4 Enzyme treatment

Critical buckling force of wool fibre largely depends on the average fibre diameter and the fibre modulus. Enzyme treatment is well known for its effect on the wool fibre properties, as enzyme treatment can reduce the fibre diameter as well as the tensile properties of the fibre. Hence to study the effect of diameter and modulus variation on critical buckling force of wool fibres, enzyme treatment was carried out on all the samples using 2% and 5% (owf) sebkalkaline protease enzyme (Advance enzyme, India). Enzyme treatment was carried out in the InfraColour machine using material to liquor ratio of 1:20, treatment time of 60 min and pH value 8.5

2.5 Yarn Knitwear manufacturing

As per our initial trails we developed all wool yarn (22 μ , 2/24^S N_m) varying the constructional parameters. The main objective was to reduce yarn hairiness by optimizing the spindle speed and twist of the single and plied yarn. Although we achieved less hairiness in yarn by optimizing the process parameters but still we need to cut down the yarn hairiness index, for this purpose singeing of yarn was done. After optimizing the yarn parameters, we developed some knitted swatches and exact size of vests. The main aim of initial trials was to maintain and satisfy the standards as per the ministry of defence specifications and once the process established we produced the knitted vest in bulk.

2.6 Polymer & softener treatments

These treatments provide on wool outstanding non-felting, wash & wear and crease resist effects fast to washing and dry cleaning. To mask the scales on wool fibre plasma and enzyme treated knitwear were treated with Dicrylan 7702. Dicrylan 7702 is an aqueous solution of modified polyurethane and modified polydimethyl siloxane emulsion. It is anionic in nature and a pH of 2.5-3.5. After polymer treatment solusoft SEN was applied to improve handle of the fabric.

3 Testing Methods

3.1 Scanning electron microscopy (SEM)

Wool fibre samples were coated with gold using JEOL JEC-550 twin coater before scanning electron microscopy. JEOL JSM-5400 scanning electron microscope was used for studying the surface morphology of untreated, plasma and enzyme treated wool fibres.

3.2 Tensile testing

Tensile properties [BS 3411:1971] of untreated and plasma treated wool fibres were tested on SHIMADZU tensile testing machine using traverse rate of 50 mm/min and gauge length of 1 Cm. Modulus of the fibre as taken a 1% elongation. Total 50 readings were taken for each fibre samples. Before testing samples were conditioned at $65\% \pm 2\%$ RH and $27 \pm 2^\circ$ C temperature for 24 hr.

3.3 Thermal properties of knitwear

Fabric samples were tested for their thermal resistance, to study the effect of plasma treatment and enzyme treatment on thermal resistance and thermal conductivity. Thermal resistance and thermal conductivity of the fabric samples were determined as per the standard method for testing of “Thermal resistance of textiles BS 4745:1971”. Thermal resistance (R) of a fabric is the ratio of the temperature difference between the two faces of the fabric to the rate of flow of heat per unit area normal to the faces.

3.4 Itching propensity by user trial

Itching to skin is the subjective phenomenon and as such there are very few instruments available for testing propensity of itching to the skin. For that purpose we have designed an experiment to assess the propensity of itching to skin. In this experiment we have given the manufactured samples for wearing to the selected population and noted their opinions. Coding of the samples was done to hide their identity before giving to the subjective analysis.

4 Results & Discussion

4.1 Surface morphology analysis

SEM images (fig.1) shows that untreated wool fibre is smooth and scales are sharp. After plasma treatment wool fibre surface is etched and scales are slightly blunted. Enzyme treatment with 2% enzyme also shows scale blunting. Plasma treatment if followed by enzyme treatment, then the treatment intensity increases as it can be seen from the photographs below. This indicates that enzyme and plasma treatments can work synergistically.

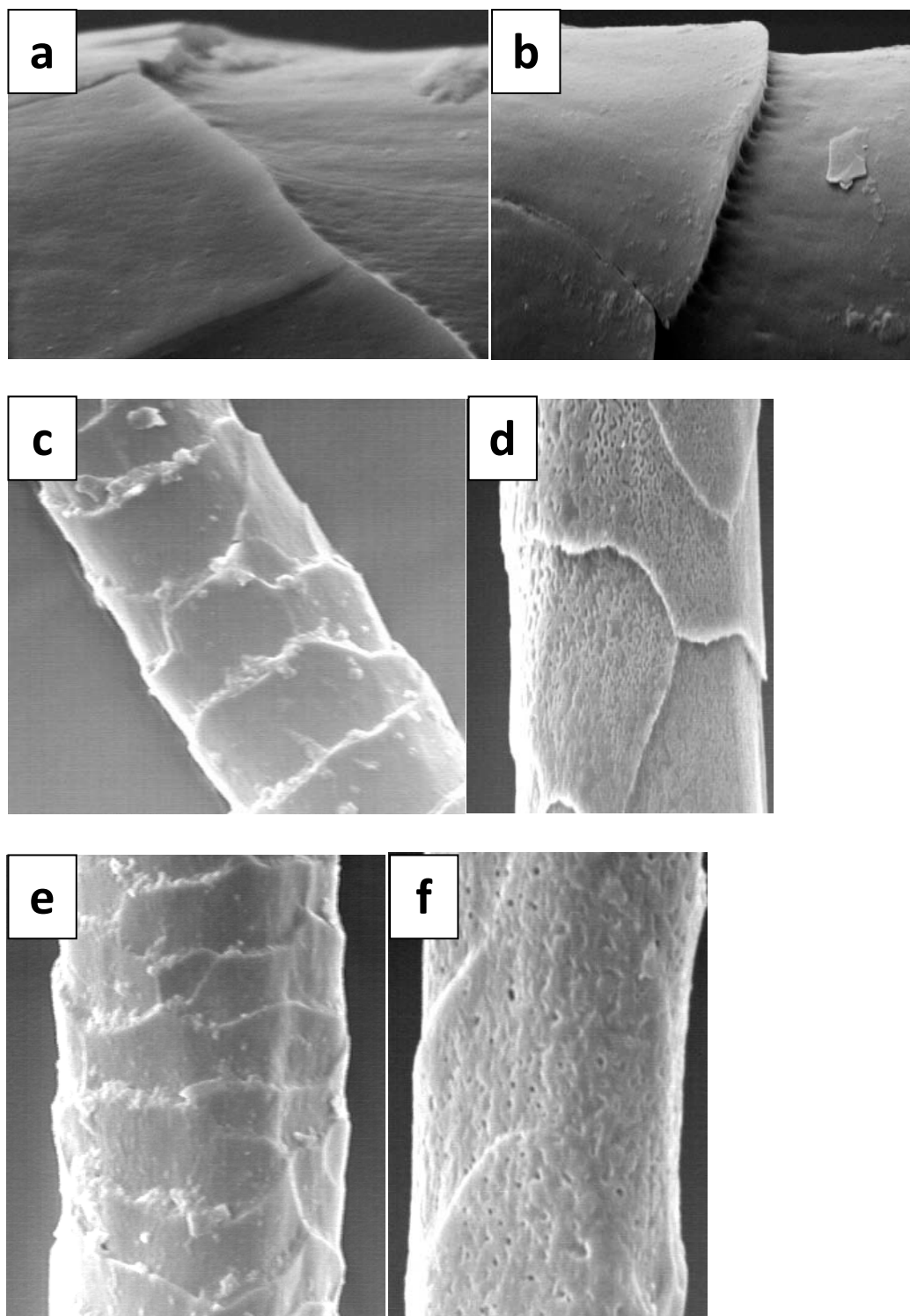


Fig. 1 SEM images of a) untreated wool fibre b) plasma treated wool fibre c) 2% Enzyme treated wool fibre d) Plasma followed by 2% enzyme treatment e) 5% Enzyme treated wool fibre f) Plasma followed by 5% enzyme treatment

4.2 Tensile testing

Critical buckling load (P), applied by the single fibre end against human skin is determined mathematically as,

$$P = n^2 * E * \frac{I}{Le^2}$$

for mode n where E is the Young's modulus, I is the moment of Inertia ($I = \pi d^4/64$, d is fiber diameter), and L, is the effective length of the fiber specimen. For this study, the lowest mode is significant, that is, n=1, while $Le = 0.699L$. Fig. 2 shows the effect of enzyme concentration on the critical buckling force of the fibre. It was found that after enzyme treatment average end diameter of the fibre reduces by 0.3 to 0.5 μm . As it is well known that enzyme treatment reduces the mechanical property of the fibre, modulus of fibre is reduce by the enzyme treatment. Due to the reduce end diameter of the fibre second moment of inertia is reduced. The reduction in critical buckling force of the fibre increases with increase in the enzyme concentration.

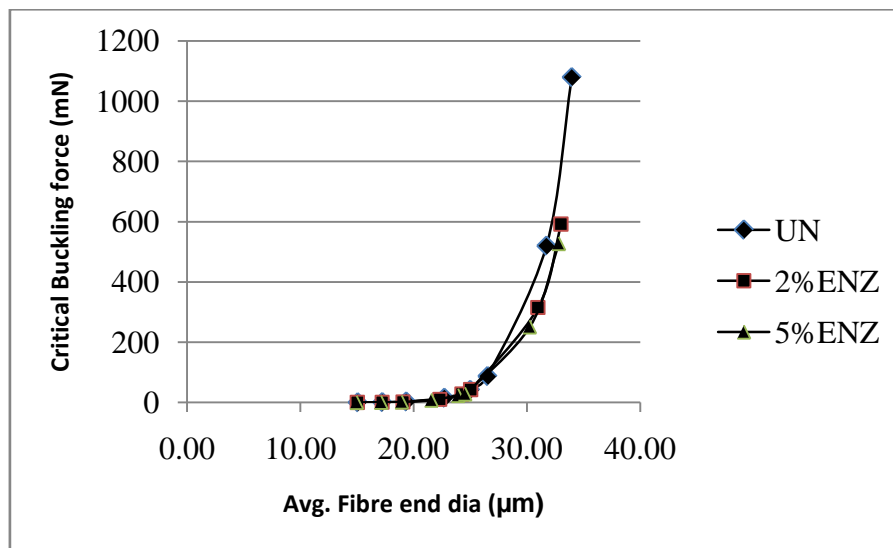


Fig. 2 Effect of enzyme concentration on the critical buckling force

4.3 Thermal properties of knitwear

It was found that the thermal resistance of the knitwear increase after plasma treatment time. Again when plasma treatment is followed by enzyme treatment then thermal resistance increases and the value is more than that of untreated as well as plasma treated samples. To explain the increase in thermal resistance values of the treated garments we propose the following model fig 3. It is reported in many research articles that after plasma treatment,

surface area of the fibre increases by around 50%. As it can be seen from fig. 3 (B) chances of entrapped air will be more and thus the thermal resistance as compared to untreated yarn. After enzyme treatment of plasma treated wool fibre average fibre diameter is reduced by 0.3 to 0.5 μm and surface striations are also seen in SEM image. This shows that the number of fibres in yarn cross section and surface area combinely increases the thermal resistance.

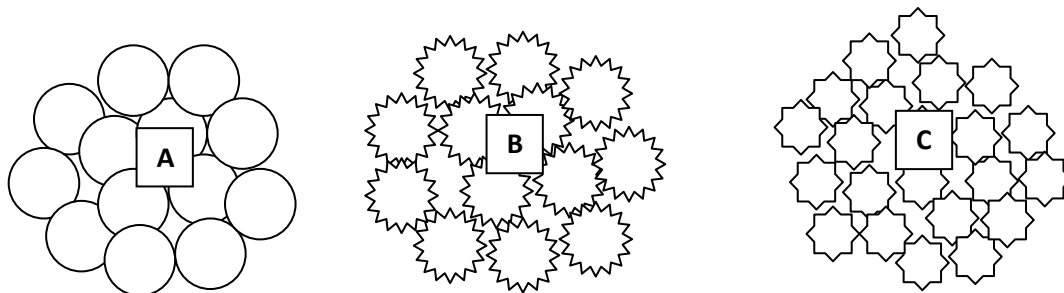


Fig.3 Yarn cross sections of A) untreated yarn B) plasma treated yarn C) plasma followed by enzyme treated yarn

4.4 Itching propensity by user trial

Untreated garments whether they are unsinged or singed causes strong itching to the wearer's skin. Plasma treatment itself on untreated garment is not sufficient to reduce the propensity of itching. After plasma treatment as it is clear from the scanning electron microscopy that surface of fibre has etched, this phenomenon will cause more fibre cohesion in the yarn or fabric stage and hence the feel of the fabric becomes somewhat harsher than non plasma treated fabric. Enzyme treatment has major impact on deciding the itching propensity of the fabric. For example if we consider 2% enzyme treated fabric and 5% enzyme treated fabric peoples said that 5 % enzyme treated fabric itches very less and its feel is also very good as compared to 2% Enzyme treated fabric. Fabric samples treated with plasma+2% enzyme+polymer+softener shows very less skin itching and softer feel. Fabric samples treated with plasma+5% enzyme+polymer+softener, peoples say that all the fabrics are totally itch proof and told that these garments can be readily acceptable as next to skin garments.

5. Conclusion

Effect of yarn hairiness on prickling properties of knitwear was studied and it was found that mechanical processing has very little scope for suppressing the prickling effect. DBD Plasma treatment at lower electrode spacing and higher applied voltage are found to be more effective in terms of wool fibre surface etching. Yarn breakage rates were reduced for plasma treated yarn (1.5 breaks/spindle/shift) compared to untreated yarn (2.104 breaks/spindle/shift). Plasma treated yarn shown 10% increase in yarn strength as well as breaking elongation. Moisture regain of the plasma treated wool top as compared to untreated top was found to increase by 1-1.2%. Thermal resistance of plasma treated fabric was increased compared to untreated fabrics. Plasma treatment assists the enzyme treatment. Plasma+2% enzyme+ polymer+ softener and Plasma+5% enzyme+ polymer+ softener are final samples and are itch-free with 15-20% loss in mechanical properties. These samples pass the commercial area felting shrinkage test with less than 6% shrinkage.

References

1. Dolling, M.; Marland, D. J.; Phillips, D. G.; Naylor, G. R. S.; Singleton, D. J., Proceedings of the Australian Society of Animal Production 1990 Vol. 18 pp. 471
2. D. H. Tester, Animal Production Science 50(12) 1077-1081
3. M. Matsudaira, J. D. Watt & G. A. Carnaby, Journal of the Textile Institute, Volume 81, Issue 3, 1990, Pages 288 – 299
4. M. Matsudaira; J. D. Watt; G. A. Carnaby , Journal of the Textile Institute, 1754-2340, Volume 81, Issue 3, 1990, Pages 300 – 309
5. Science in clothing comfort:- Apurba Das and R. Alagirusamy, page No. 56
6. Li Y. The Science of Clothing Comfort (Textile Progress), ed. Layton j m, The textile institute Manchester Vol. 31, 2001
7. Weiyu He and Xungai Wang, Textile Research Journal, July 2002; vol. 72, 7: pp. 573-578.
8. G.R.S. Naylor, Textile Research Journal April 2010 Vol. 80 No. 6 537-547
9. D. P. Bishop; J. Shen; E. Heine; B. Hollfelder, Journal of the Textile Institute, 1754-2340, Volume 89, Issue 3, 1998, Pages 546 – 553