INTERNATIONAL WOOL TEXTILE ORGANISATION

TECHNOLOGY & STANDARDS COMMITTEE | **NICE MEETING**
Commercial Technology Forum | **November 2001**
Chairman: Allan De Boos (Australia) | **Report No: CTF 01**

The Effect of the Diameter Characteristics of the Fibre Ends on the Skin Comfort and Handle of Knitted Wool Fabrics

By

A.G. De Boos, G.R. Naylor, I.J. Slota and J. Stanton*

CSIRO Textile & Fibre Technology — Belmont, Victoria, Australia
*Western Australia Department of Agriculture — South Perth, Western Australia, Australia

SUMMARY

In recent years considerable interest has been shown by wool producers, particularly those with properties in Mediterranean climates, in the skin comfort or ‘prickle’ associated with wool fabrics and garments, its causes and the impact on this characteristic of changes in shearing times. The time of shearing in such growing areas can affect the fibre profile of the wool produced and offers the prospect of growing ‘low-prickle’ wool. While prickle is a key feature of the handle of wool in next-to-skin applications, it is only one aspect of the overall handle of wool fabrics and garments. This report describes a comparative study of the skin comfort and overall handle of knitted fabrics manufactured from wool grown in a Mediterranean climate and harvested in different seasons so that there is a different relationship between the diameter of the fibre ends and that of the whole fibre.

As expected, there was a good correlation between skin comfort and the mean diameter of the fibre ends. On the contrary, while differences in overall handle (subjectively determined) of the various fabrics were observed, they appeared to be unrelated to the diameter characteristics of the fibre ends. The dominant fibre characteristic determining handle was the mean diameter of the whole fibre.

INTRODUCTION

The ‘prickly’ sensation observed when some wool garments are worn next to the skin is one of the more enduring perceptions associated by consumers with wool products. Extensive research over the past 20 years on the skin comfort of wool-containing garments has identified the cause of the sensation known as ‘prickle’(1-2). This sensation results from the pressure exerted by coarse fibre ends, which protrude from the surface of the fabric and press on the skin hard enough to activate nerve ends. The sensation is not associated with wool specifically but with any fibre that can exert sufficient pressure on the skin. The maximum force the fibre will exert on skin before it buckles depends on its diameter and the free length of the protruding end. It has been shown that both wool and acrylic(3) fibres greater than approximately 30μm in diameter can cause discomfort in knitted goods. The degree of discomfort also depends on the yarn and fabric construction, the techniques used to finish the fabric and the sensitivity of the subject. The wool industry has taken up this concept and model so that ‘comfort factor for apparel wools’ is one of the parameters objectively measured on raw wool.

While skin comfort (prickle) is a key feature of wool in next-to-skin applications, it is only one aspect of the overall handle of wool fabrics. The handle of wool fabrics has been the subject of a very large number of studies for more than 30 years. From the pioneering work of Pierce in the 1930s to more recent techniques(4,5), many studies have sought to relate handle to specific fabric mechanical properties and through them to fibre properties.

Approaches have varied but it is now well accepted that, because of the variety of products made from wool, the term 'handle' encompasses a number of sensations (stiffness, softness, smoothness) and the relative importance of each depends on the application. Each of the various attributes of the handle of wool fabrics depends on the properties of the fibres, the construction of the fabric and the finishing techniques used. Several studies have described the effect of fibre properties(6) but none, to date, have evaluated the role of fibre ends on any handle characteristic other than prickle. The development of a new test procedure(7) to measure the distribution of the diameter of fibre ends has afforded an opportunity to determine the contribution of these ends on the other handle characteristics of knitted fabric.

This report describes a preliminary study of skin comfort and also the softness of smoothness of knitted fabrics manufactured from wool grown in a Mediterranean climate and harvested in different seasons so that there is a different relationship between the diameter of the fibre ends and that of the whole fibre.

EXPERIMENTAL

Fabrics

A series of tops were taken from autumn- and spring-shorn wool from both Fremantle and Sydney. The tops demonstrated the known seasonal variation in the diameter characteristics of the fibre ends. The tops were matched for fibre diameter and other obvious characteristics (Table 1). 'Control' tops ranging in mean fibre diameter from 19.7-23.3μm were also included in the trial. These 'control' tops were taken from commercial production.

Table 1: Characteristics of the wool used

Sample	Top MFD (μm)	Top CVD (%)	Fibre End MFD (μm)	Fibre End CVD (%)	Hauteur (mm)	Curvature* (Deg/mm)
F-Autumn1	21.9	21.9	20.1	21.9	83.4	129
F-Autumn2	22.0	22.3	20.0	22.0	85.0	131
F-Sring1	21.7	21.2	21.7	22.1	73.6	139
F-Spring2	21.8	21.6	22.0	21.8	70.3	134
S-Autumn	21.9	21.0	20.5	21.5	79.1	127
S-Spring	21.7	20.7	21.3	21.6	75.1	129
Control1	19.7	21.8	19.3	22.3	68.0	116
Control2	21.3	21.1	20.3	22.7	70.7	106
Control3	22.0	22.3	21.1	24.2	71.0	98
Control4	23.3	22.7	22.1	24.9	73.0	105

F-Fremantle, S- Sydney
*Curvature measured on the relaxed tops using Laserscan

A comparison of the mean diameter of the fibre ends relative to that of the top is shown graphically in Figure 1. The diameters characteristics of the 'whole fibre' and the fibre ends were measured using IWTO-12 and IWTO-working group draft 'Measurement of the diameter characteristic of Fibre Ends on Wool Slivers'(7), respectively. The observed shift in the mean diameter of the fibre ends as a result of moving shearing from Spring to Autumn for the samples from the Fremantle auction room is similar to a 2 μm change in the mean diameter of a conventionally produced commercial top (ie a mixture of wools shorn at different times with an average CV_D value). Similarly, for the wools from Sydney, the effect of time of shearing is of the order of a 1 μm change in the mean diameter compared to a conventionally produced commercial top.

From each top, 2/25Nm knitting yarn was spun and knitted on a 14 gauge sample knitting machine to a cover factor of $1.4(tex)^{1/2}$/mm. All fabrics were dry finished with a simple steam relaxation.

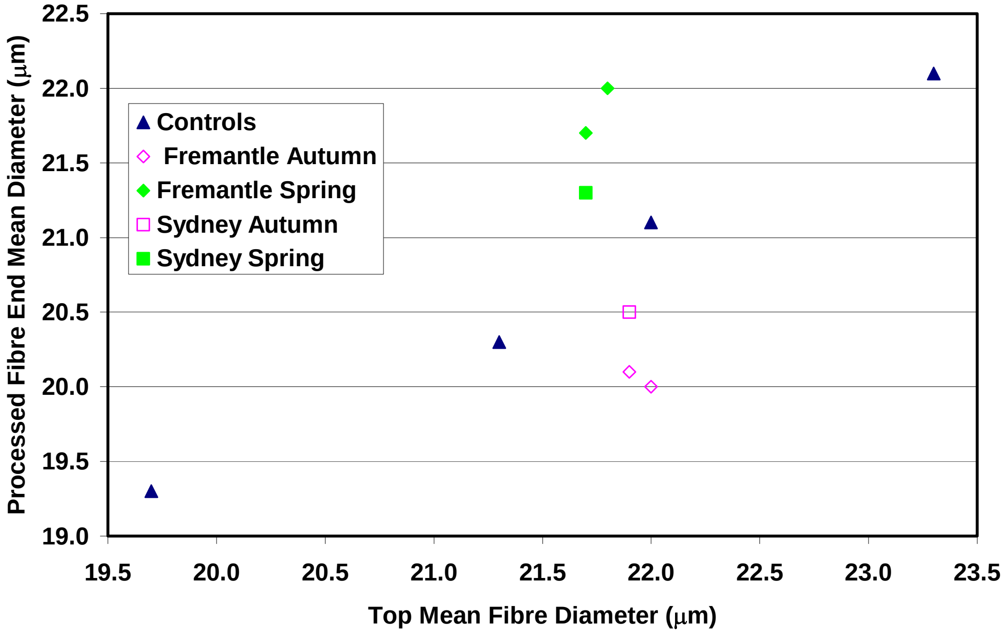

Figure 1: The mean fibre diameter of the processed fibre ends as a function of the top mean fibre diameter.

Evaluation of Skin Comfort

Subjective skin comfort testing was undertaken using the forearm test that has been used routinely at CSIRO(8). This method uses multiple paired comparisons where experienced adult judges are asked to identify the more prickly of each pair. The experimental design used 10 samples in a complete randomised block design with each pair of fabric samples being tested in both of the two possible presentation orders. This gives a total of 90 pairs for each of the seventeen people experienced in judging prickliness. As it has been found previously that approximately 30 paired comparisons is the maximum that can be satisfactorily tested in one sitting, the design used three sittings of 30 fabrics per judge on separate days. The design was randomised between both judges and sittings. Results were analysed using a Friedman analysis as described by Meilgaard et al(9).

Assessment of Overall Handle

Initially, a panel of six 'expert' judges was selected from a group of ten individuals who were asked to rate two sets of the same seven fabrics. The potential judges were asked to rate the fabrics from the 'most luxurious' to the 'least luxurious'. The results were analysed (Spearman test) to obtain a coefficient of rank correlation for each judge to determine a coefficient of concordance between judges. Only those judges who had high rank correlations and ranked the fabrics in the same general order were then selected for the panel of 'expert' judges.

The knitted fabrics were subjectively assessed for two different sensations; softness and smoothness, the trials for which were conducted separately. To assess softness, the judges were asked to pick up and handle samples of single thickness. To assess smoothness, the judges were asked to run their fingers and the palm of their hand on the surface of double thickness samples but were not allowed to pick up the samples. In both trials, the judges were not able to see the fabrics.

Paired comparison tests were used to subjectively evaluate the 10 knitted fabrics. Each experiment used 10 samples in a complete randomised block design. Each sample was compared to every other sample within the set. In the first experiment, the judges were given two samples to handle and asked to select the sample that felt the softest. In the second, the judges were asked to select the smoothest. The pairs were presented to the judges in randomised order, with each pair of fabrics being tested in both of the two possible presentation orders. A Friedman analysis was again used to statistically analyse the result.

.

RESULTS and DISCUSSION

7Table 2 summarises the rank sum value of subjective skin comfort obtained from the paired comparison trials. Statistically the null hypothesis that all samples have similar skin comfort is rejected and the least significant difference ($LSD_{5\%}$) is 27.0. This statistical analysis confirmed that:

- the four controls have significantly different levels of fabric skin comfort,
- the autumn shorn Fremantle samples are more comfortable than the spring shorn Fremantle samples,
- the autumn shorn Sydney sample is more comfortable than the spring shorn Sydney sample, and
- the seasonal effect for the Fremantle samples is approximately twice that of the Sydney samples.

Table 2: Summary of fabric skin comfort results

Sample	Rank Sum Skin Comfort
F-Autumn1	484
F-Autumn2	494
F-Spring1	437
F-Spring2	405
S-Autumn	517
S-Spring	487
Control-1	540
Control-2	466
Control-3	400
Control-4	360

The least significant difference (at the 5% level) is 27.

Figure 2 plots the comfort score against the percentage of fibre ends greater than 32 µm. (Note that the $LSD_{5\%}$ for the skin comfort rankings is approximately equal to the size of the minor tick marks on the vertical axis.) The observed fabric skin comfort is well correlated with the percentage of fibre ends greater than 32 µm, in agreement with our current understanding of fabric skin comfort for this fabric type.

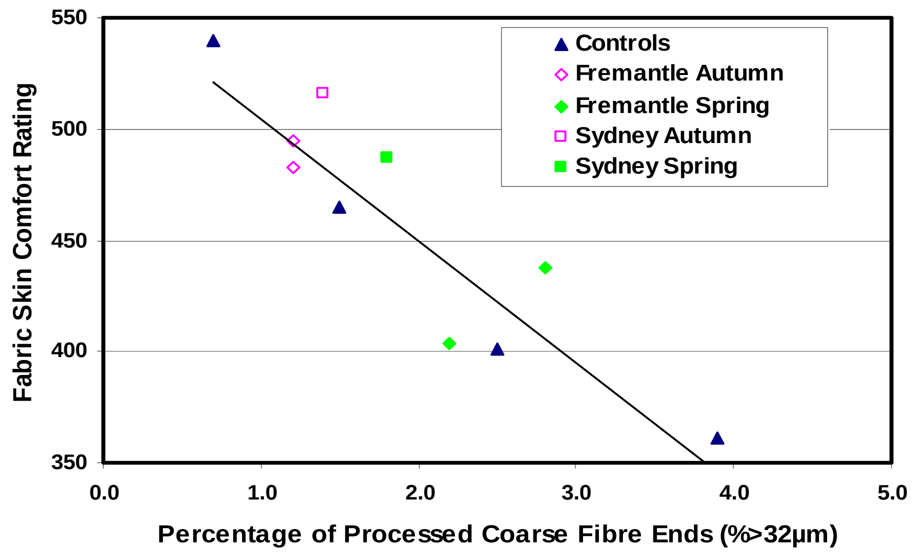

Figure 2: The relationship between the relative skin comfort and the percentage of processed fibre ends greater than 32 µm.

Table 3: Subjective rankings from Handle Trials

Sample	Softness	Smoothness
F-Autumn1	165	188
F-Autumn2	149	145
F-Spring1	160	170
F-Spring2	173	172
S-Autumn	187	185
S-Spring	186	171
Control-1	198	184
Control-2	148	149
Control-3	135	140
Control-4	119	116

The least significant difference (at the 5% level) is 15 for both softness and smoothness.

The rank sum from the subjective evaluations of the handle of the samples is shown in Table 3. All judges were able to successfully rank the fabrics (Coeff. of Consistency = 0.6-0.9). However the coefficient of agreement between judges was not as high (Coeff. of Agreement = 0.33) as had been achieved in earlier work on woven fabrics. Although self-consistent, the judges appeared to be using slightly different criteria in their assessments. This difficulty is often found in studies of handle even where the required component of handle is specified.

When the data from the assessment of the four control samples were analysed separately, the consistency of the judges was much improved. The judges rated fabrics made from the finest wool as the softest and smoothest; (Fig 3 and 7). The handle of the fabric manufactured from the 21.3μm wool was not (statistically) significantly different from that manufactured using 22.0μm wool for either the rankings of softness or smoothness. It appears that the difference in wool quality, that is necessary to be observable (tactile) by the consumer, is well above the minimum significant difference for measurements from Laserscan and OFDA.

Scores of the fabrics manufactured from the Mediterranean wools were poorly differentiated (Fig 3,4) although all these fabrics were rated as softer and smoother than the fabrics manufactured from the control tops at the same mean fibre diameter. There was no obvious effect of the time of shearing. The data was also plotted against effective (rather than mean) diameter(10), and again there was no effect of time of shearing. The effect of the mean fibre diameter of the fibre ends on handle is shown in Figures 4 and 8 and the effect of the number of fibres greater than 30μm is shown in the Figures 5, 6, 9 and 10. Although there appeared to be a weak trend between softness and the number of fibres greater than 30μm, the trend was dominated by the finest and coarsest of the control samples.

Although this is only a preliminary study, it appears that, while real differences in handle characteristics of the fabrics were observed, they were unrelated to the diameter characteristics of the fibre ends.

It is apparent from Figure 3 and 7 that the handle of the fabrics, manufactured from the autumn- and spring-shorn wools, was smoother and softer than fabric from the equivalent control wool. It is well known that the mean diameter of the component fibres is not the only fibre property that can affect handle. Superficial observation of the additional characteristics of the top suggests that the spring- and autumn- shorn wools had lower curvature than those of the control wools. Previous studies on woven fabric have suggested that lower curvature in the component fibres is associated with a softer and silky handle(11) so this may be one cause of the differences in handle observed here.

The weight and thickness of the test fabrics is shown in Figures 11 and 12 respectively. The fabrics manufactured from the control wools were slightly thicker than those manufactured from the autumn- and spring-shorn wools. This difference in thickness between the 'control' fabrics and the others also could explain the difference in the subjective scores given to the fabrics. It has been recorded in previous studies that thickness and weight contribute strongly to subjective evaluations of softness and smoothness of fabric.

CONCLUSION

This work has demonstrated that, although managing the time of shearing of wool grown in a Mediterranean environment can lead to improvements in the next-to-skin comfort of knitted wool fabrics by reducing prickle, it appears to have no significant effect on the subjective softness and smoothness.

The results confirm that skin comfort-prickle is largely determined by the diameter characteristics of the fibre ends. In contrast, softness and smoothness are determined by the mean fibre diameter of the top used to produce the fabric in combination with other factors. The scope of this work was too restricted to identify those other factors.

ACKNOWLEDGEMENTS

Support for the projects within which this work was carried out was provided by Australian wool producers and the Australian government through CSIRO and the Woolmark Company. Part of this study was undertaken as part of the Australian Cooperative Research Centre (CRC) for Premium Quality Wool. The authors would also like to thank Ms J. Marsh for her assistance with the experimental program

REFERENCES

1. Garnsworthy R.K., Gully R.L., Kandiah, R.P., Kenins P., Mayfield R.J. and Westerman, R. A. (1988) *Understanding the causes of prickle and itch from skin contact of fabrics*. Australasian Textiles, 8(4), 26-29.

2. Naylor, G.R.S. and Phillips, D.G. (1995) *Skin Comfort of Wool Fabrics*. Proc. 9th. Int. Wool Textile Research Conf. 3, 203-209.

3. Naylor, G.R.S. (1992) *The Role of Coarse Fibres on Fabric Prickle Using Blended Acrylic Fibres of Different Diameters*. Wool Tech. and Sheep Breeding, 40, 14-18.

4. S. Kawabata, (1980) *The Standardisation and Analysis of Hand Evaluation*. The Standardisation and Analysis of Hand Evaluation, ed. T.H.E.a.S. Committee. Osaka, Japan: The Textile Machinery Society of Japan.

5. H.M. Elder, S. Fisher and K. Amstrong. (1984) *Fabric Softness, Handle and Compression.* Journal Textile Institute, 75, 37.

6. L. Hunter, S. Kawabata, E. Gee and M. Niwa, (1982) *The Effect of Wool Fibre Diameter and Crimp on the Objectively-Measured Handle of Woven Fabrics*, in *Objective Specification of Fabric Quality, Mechanical Properties and Performance*, S.Kawabata, R. Postle and M.Niwa, Editors. Textile Machinery Society of Japan: Osaka. p. 167.

7. G.R. Naylor (2001) *Measurement of the Diameter Characteristics of Fibre ends in Wool Slivers,* IWTO T&S Committee, Shanghai, SG Submission 01.

8. Naylor, G.R.S., Phillips D.G., Veitch C.J., Dolling M., Marland D.J. (1997) *Fabric-Evoked Prickle in Worsted Spun Single Jersey Fabrics. Part 1 : The Role of Fibre End Diameter Characteristics.* Textile Research J., 67, 288-295.

9. Meilgaard, M.D., Guille, G.V. and Carr, B.T. (1987) '*Sensory Evaluation Techniques'*, CRC Press Inc., Boca Raton, Florida.

10. Butler, K.L. and Dolling, M. (1995) *Spinning Fineness for Wool*. Journal Textile Institute, 86(1), 164

11. Stevens, D and Mahar, T. (1995) The beneficial effects of Low Crimp Wool in worsted processing and on fabric properties and fabric handle. Proc. 9th. Int. Wool Textile Research Conf. V, 134.

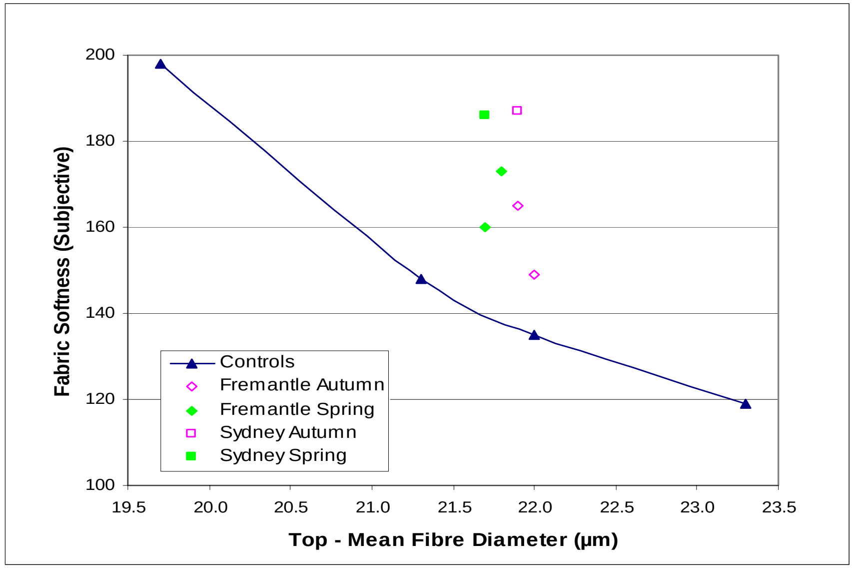

Figure 3: Softness - Effect of mean fibre diameter of top

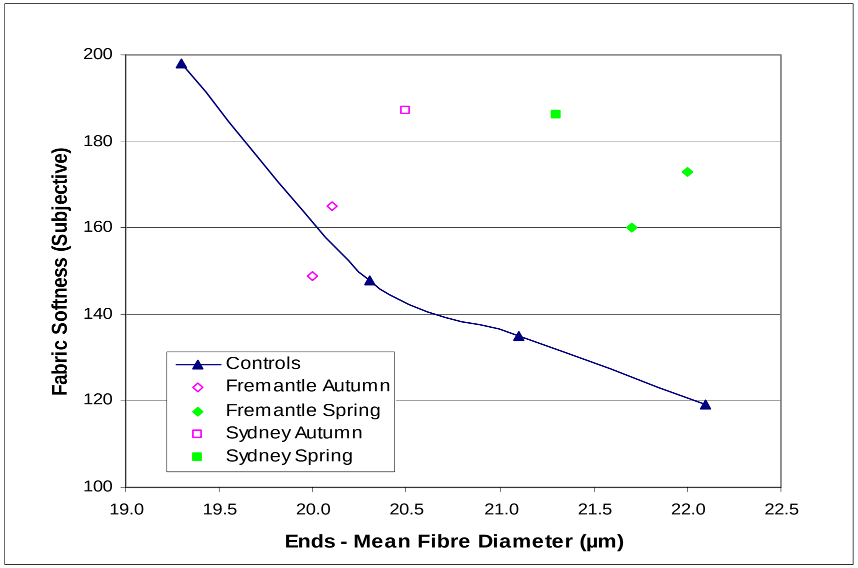

Figure 4: Softness - Effect of mean fibre diameter of fibre ends

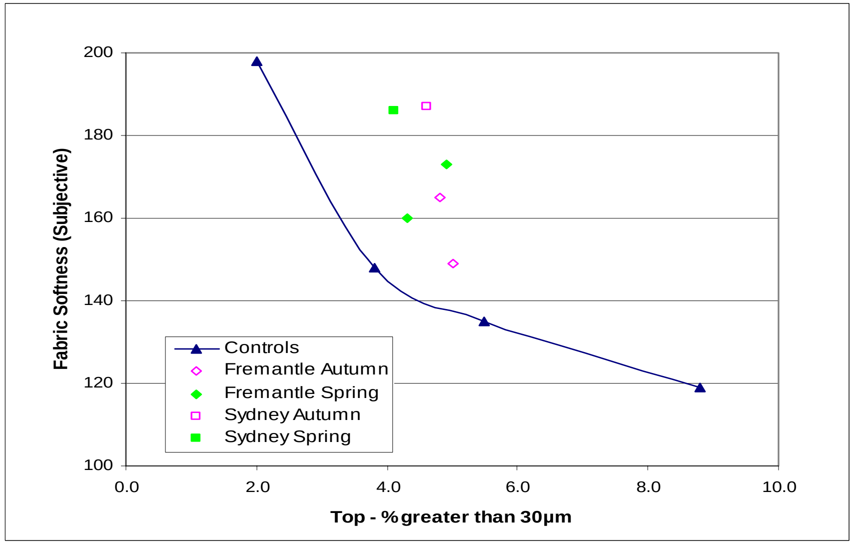

Figure 5: Softness - Effect of fibres > 30µm in top

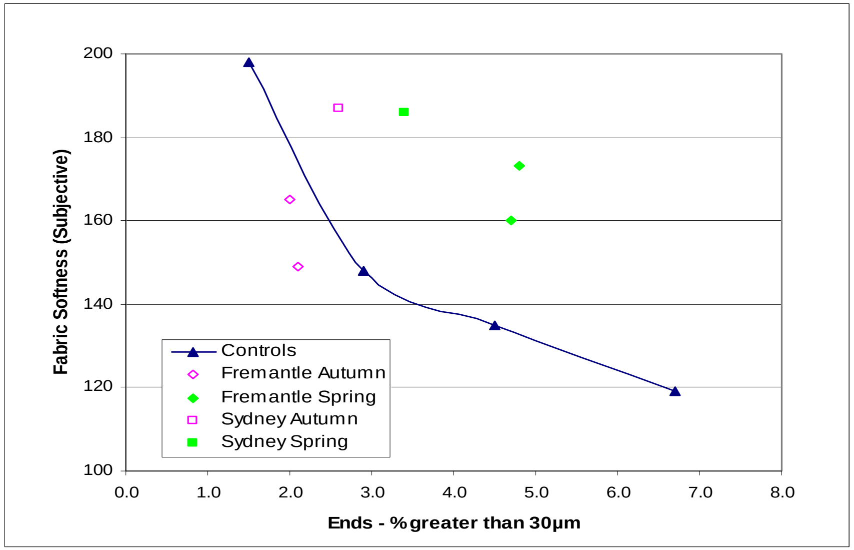

Figure 6: Softness - Effect of fibre ends > 30µm

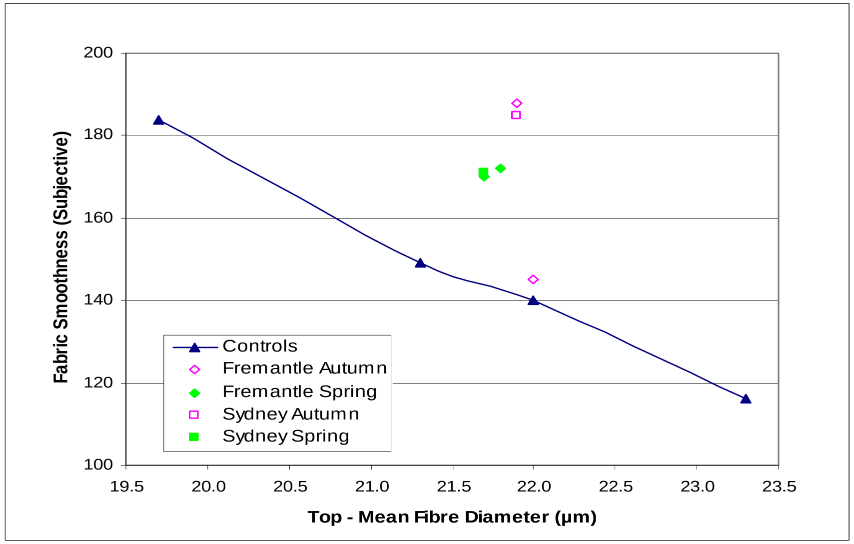

Figure 7: Smoothness - Effect of mean fibre diameter of top

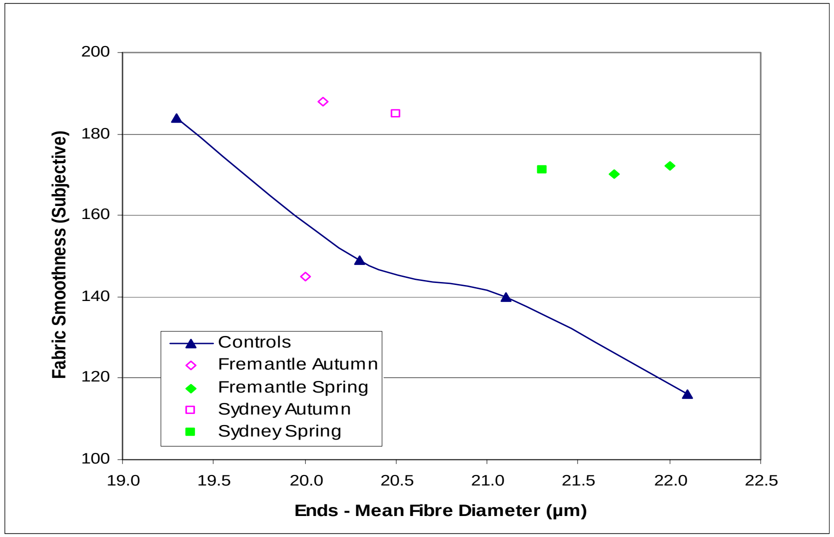

Figure 8: Smoothness - Effect of mean fibre diameter of fibre ends

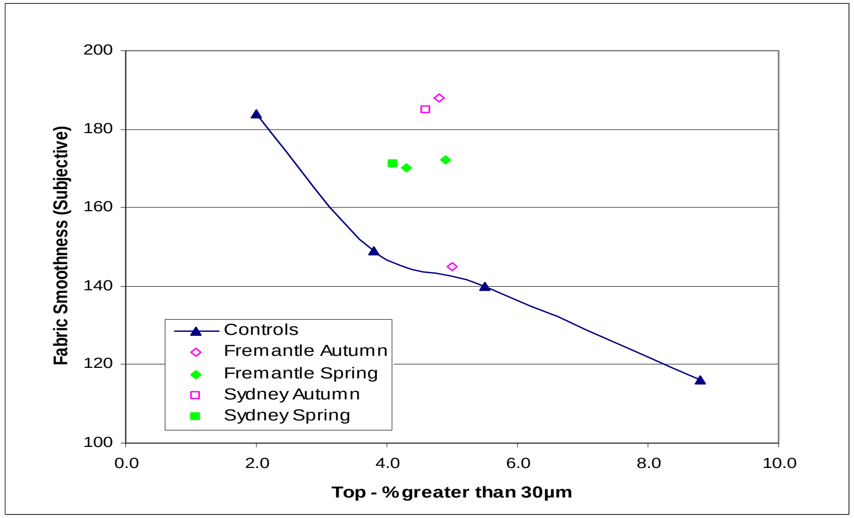

Figure 9: Smoothness - Effect of fibres > 30µm in top

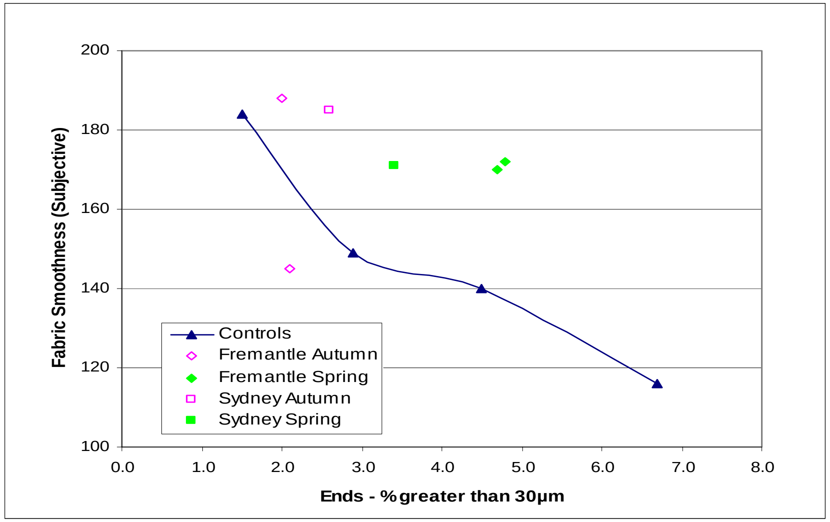

Figure 10: Smoothness - Effect of fibres ends > 30µm

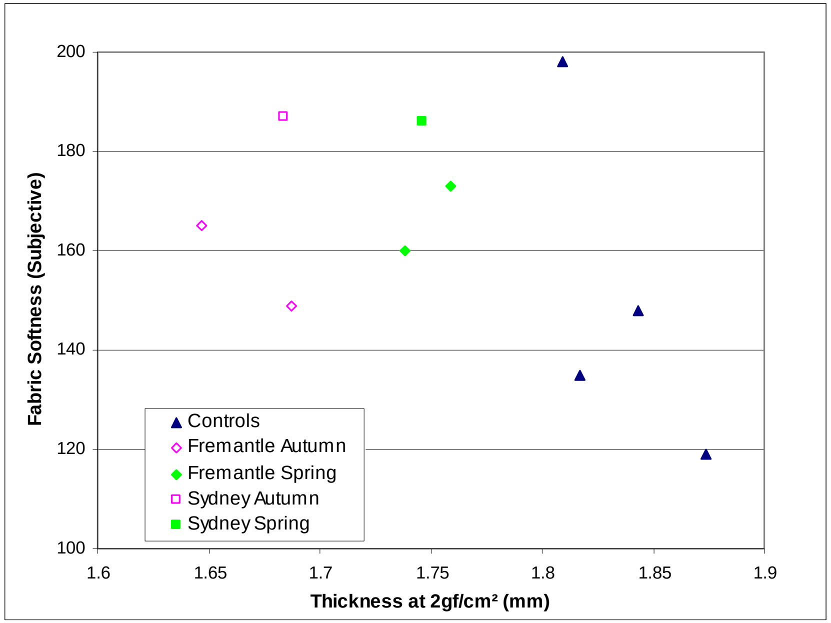

Figure 11: Effect of fabric thickness on Softness

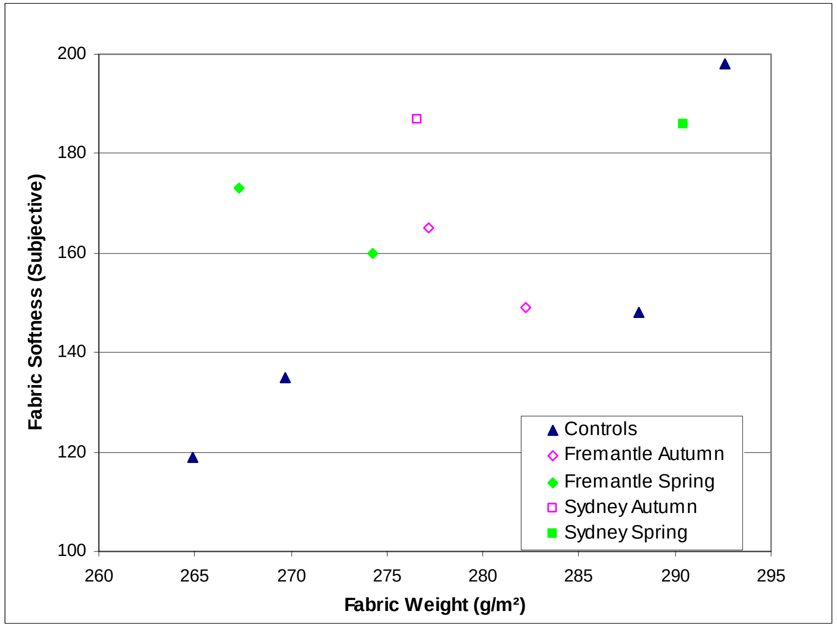

Figure 12: Effect of fabric weight on Softness