

ELASTIC PROPERTIES OF COMPRESSION BANDAGES USED FOR THE TREATMENT OF LOWER LIMB VENUS DISORDERS

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INTRODUCTION

Compression therapy has been used for many years in the treatment of edema and other venous disorders of the lower limb. Wearing compression grants increased healing rates of venous leg ulcers compared with no compression (O'Meara et al, 2008 and Nelson E.A. et al, 2008).

Any effective compression system must be able to generate three distinctive interface pressure levels between the compression material and the leg. These three key pressures are the resting pressure (pressure sustained upon application of compression bandage – also known as supine pressure), the load pressure (pressure during standing) and the working pressure (pressure during walking). To promote pumping of blood upwards these three pressures are in a relationship with low resting pressure, high load pressure and highest working pressure. To achieve these three levels of pressures the compression material must be provided with some characteristics of which elasticity and stiffness are the most important (Partch H., 2005). We can assume that a good bandage must have a low elastic modulus before lock-out but a high modulus after lock-out with a narrow lock-out range.

Presently two types of textile materials, hosiery and bandages are used for compression therapy. Compression bandages appear as simple and the most common compression device which is cheaper in comparison to hosiery. Bandages function as multi-layer systems where compression generating layers are combined with padding. The properties and characteristics of the compression generating layer (elastic bandage layer) are the most important, which determine the interface pressure levels.

Lack of knowledge of the elastic properties of the bandages causes difficulties while application. The interface pressures achieved vary enormously depending on the skill and the experience of the bandager. The present paper studies the elastic properties of some bandages available in the Sri Lankan market with the objective of helping the selection of correct bandage type to achieve a required resting pressure as well as to enable the estimation of working and standing pressures.

METHODOLOGY

Ten (10) different bandages available in the Sri Lankan market were selected for the investigation. All the important fabric structural parameters were first analyzed. Tinus Oleson Tensile Strength Tester available in the research laboratory of the Department of Textile and Apparel Technology was used for testing of the tensile behaviour. The machine was set for a loading rate of 100 mm/min, and the gauge length was 10cm. All the samples were subjected to a tensile load of 10 N per cm width under a preload of 0.1N. The tests were performed under standard atmospheric conditions ($65\pm 2\%$ relative humidity and $27^0\pm 2^0\text{C}$ temperature), and the samples were conditioned for 48 hours before testing. 5 K BS 4952; 2.4. Extension & Recovery [Variable Setting] software was adopted for the evaluation. Ten specimens were tested from each type of bandage.

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RESULTS AND DISCUSSION

Typical Load/Elongation behavior

Figure 1 displays 1.5 cycles of the tensile loading and recovery curve of a bandage. It displays a very low elastic modulus up to an extension of 150mm (Load 3.75 N). The constant modulus in this linear region is about 0.025 N/mm. Thereafter the modulus increases rapidly to reach 3.66 N/mm at an elongation of 185mm. Beyond this elongation any further change of modulus is hardly observed. The recovery of the extension takes a different path (bottom curve). It shows clearly that a bandage which is being stretched produces higher tensions than when it is relaxed from a higher tension. This behaviour of the textile material definitely affects the compression produced by it on the limb when limb dimensions change.

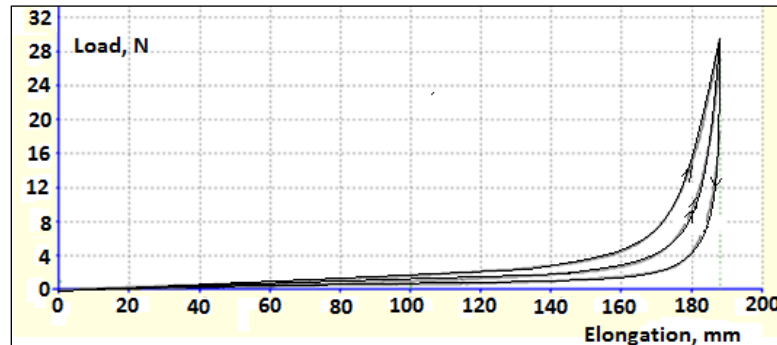


Figure 1. Load / elongation behavior of a bandage with cotton covered spandex and cotton in warp and 100% cotton weft

In the second cycle of loading (Centre curve), the initial modulus is lower than that of the first cycle of loading, and the modulus towards the maximum extension is higher than that of the first cycle of loading. This clearly indicates that when a bandage is subjected to repeated extensions, the tension generated as well as the compression applied on the limb is different. The region in which the modulus varies rapidly is known as lock-out region. The bandage is usually stretched to have an extension in this range during application.

Comparison of different bandages

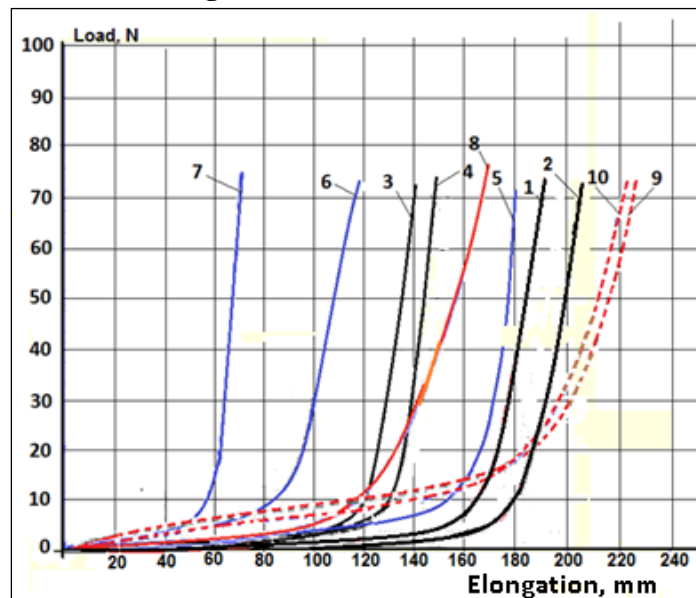


Figure 2. Load Elongation curves of ten different bandages

Figure 2 shows load/elongation curves of 10 bandages, which are designed to use as compression layer of multi-component bandage systems. All the curves have shapes similar to the loading curve illustrated in the Figure 1. The variation of material and the fabric structure

does not have a significant effect on the shape of the curve except in the cases of warp-knitted bandages (9 & 10). However the amount of extensions recorded for application tensions in the range of 8 to 10 N is very much different.

Comparison of bandages 5, 6, and 7 with 100% covered spandex yarns in warp

Table 1 shows important structural features and elastic properties of these bandages. The counts of warp and weft yarns of the bandage fabrics were not determined due to the difficulty of removing of threads from the fabrics without causing permanent stretch and damage.

Bandage 7 has the lowest percentage elongation of 70mm (70%) at a load of 10 N/cm. Its lock-out region is very narrow (From 50mm to 65mm elongation). Bandage six (06) has the second lowest total elongation of 115mm. It has a wider lock-out region than bandage 7 (from 70mm to 100mm elongation). Bandage no. 5 has a very much higher total elongation (about 180 mm) and the width of the lock-out region is about 30% elongation (from 145mm to 175mm), which is similar to bandage 6.

Elastic modulus before and after lock out regions are also different for the three different bandages. Increased amount of spandex in warp must have increased the elastic modulus and decreased the elongation, but it appears that this can be opposed by changing weft density.

Table 1. Important elastic properties of bandages with 100% covered spandex yarns in warp

Bandage No & Weave	Warp Yarn and Warp sett, 1/cm	Weft yarn and weft sett, 1/ cm	Total Elongation at 10 cN/cm, mm or %	Elastic modulus before and (after) lock-out, N/mm
5. Plain weave	Cotton covered spandex, 11	Cotton, 24	180	0.042 , (1.9)
6. Plain weave	Nylon covered spandex, 17	Cotton, 12	115	0.075, (2.68)
7. Plain weave	Cotton covered Spandex, 9	Cotton, 12 double wefts	70	0.097, (8.50)

Comparison of woven bandages with two different types of warp yarns

Table 2. Important elastic properties of bandages with two types of warp yarns

Bandage and Weave	Warp Yarn and Warp sett, 1/cm	Weft yarn and weft sett, 1/ cm	Total Elongation at 10 cN/cm, mm or %	Elastic modulus before and (after) lock-out, N/mm	Crimp of non-elastic warp, %
01. Plain	1. Cotton, 12 2.Cotton covered spandex, 4	Cotton, 24	190	0.018 (5.04)	212
02. Plain	1. Cotton, 8 2.Cotton covered Spandex, 5	Cotton, 25	205	0.021 (4.65)	141
03. Plain	1. Cotton, 11 2. Nylon covered spandex, 4	Cotton, 17	140	0.030 (5.0)	176
04. Plain	1. Cotton, 8 2. Cotton covered spandex, 5	Cotton, 16	150	0.035 (5.5)	169

There are four bandages each with two different types of warp yarns (Table2). The curves 3 and 4 have similar shape. The bandages 3 and 4 have different warp yarns and warp densities but are very much the same in weft yarn type and density. Though the bandages have different elastic warps, they exhibit similar load/elongation behaviour. Both the bandages have approximately equal crimp of the non-stretch warp. The crimp of the non- elastic warp depends on the extent to which the elastic warp is stretched during weaving as well as on the weft density. The similar warp crimp values show that both the bandages had been woven under similar conditions. bandage 3 has a total elongation of 140 mm compared to a total elongation of 150mm of bandage 4 . Total elongation of these bandages lie between the

elongations of bandages with 100% elastic warp (bandages 6 & 7) and bandages with leno and warp knitted structures (8, 9, and 10).

Bandages 1 and 2 have almost the same load/elongation behaviour. These two have almost same weft density but they are different in warp. Bandage 1 has a higher amount of total warp density but a lesser percentage of elastomeric yarns. The total extension of bandage 1 is little smaller (190mm) than that of bandage 2 (205mm). Lesser total warp density (13 against 16 1/cm) allows bandage 2 to elongate easier than bandage 1 and the higher amount of elastic yarn (5 against 4) has no significant effect. The difference in crimp of the non-stretch warp yarns has no significant effect on the total elongation.

Characteristics of bandages with warp knitted structures

Each of the two warp-knitted bandages (9 and 10) has three different warps. The amount of Spandex is less in comparison to low-stretch filament yarns (6 out of 27 and 6 out of 28). These two bandages exhibit the highest total elongation values (bandage 9 -226mm and bandage 10 -222mm). The lesser amount of stretch yarns allow the fabric to stretch easily, and the warp knitted structure applies a lesser resistance against deformation.

Both these bandages also have very large lock-out regions (Bandage 9, 170mm – 225mm and bandage 10, 150mm -210mm). Further, they have higher modulus before lock-out, which allows them to produce higher application tensions.

Leno-woven bandage

Leno-woven bandage has a load-elongation curve similar to those of woven bandages with elastomeric yarns but with a wider lock-out range. The elastic modulus is relatively low after the lock-out region as in the case of warp-knitted structures.

CONCLUSIONS

- Elastic modulus of the fabrics before lock-out increases with increasing amount of elastomeric yarns if there are only elastomeric yarns.
- In fabrics with two types of warp, non-stretch yarns do not significantly affect the load/elongation behavior before lock-out if they have a high percentage crimp.
- Beyond lock-out region the amount of non-stretch yarns as well as the warp and weft densities affects the elastic modulus.
- In fabrics with both stretch and non-stretch yarns, the crimp of non-stretch yarns affects the total elongation, elastic modulus before lock-out and the width of the lock-out region.
- Woven fabrics are the best because they have a low elastic modulus before lock-out and a very high modulus after lock-out with a narrow lock-out range.
- Warp knitted structures are more suitable for achieving high application tensions but difficult to apply due to too wide lock-out region and too high total elongation.
- Leno-woven bandages are suitable for conditions which require average load/elongations between woven and warp knitted structures.

REFERENCES

Nelson EA, Bell-Syer SEM, Cullum NA, (2000), Compression for preventing recurrence of venous ulcers, *Cochrane Database of Systematic Reviews* 2000, Issue 4.

O'Meara S, Cullum NA, Nelson EA, (2008), Compression for venous leg ulcers, *Cochrane Database of Systematic Reviews* 2008, Issue 1.

Partch H, The Static Stiffness Index: A Simple Method to Assess the Elastic Property of Compression Material In Vivo. *Dermatological Surgery* 2005, 31(6).

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