Inverse Relaxation in Yarn and Fabrics

KEYWORDS: Inverse Relaxation, Visco-elastic, Count, Yarn, Fabric, Stress Relaxation, Polymer

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ABSTRACT *All the textile materials are made up of natural and synthetic polymers which are visco-elastic in nature, therefore, exhibit several time dependent properties such as stress relaxation, creep, creep recovery, inverse relaxation, etc. When a fibre is extended stress develops in the fibre due to increasing strain. If this straining is stopped before rupture of fibre and the fibre is constrained at that particular strain, the stress developed in the fibre starts decaying with time. This phenomenon is known is stress relaxation. If a fibre of any polymeric material is strained up to a predetermined level and then allowed to retract partially i.e. the strain is reduced, but not removed completely amounting to some stress being still present in the fibre, then it is observed that the stress in the fibre increases with time. The rate of increase in stress is initially high, but tends to decrease as time. The phenomena of stress build up called as "inverse relaxation". Earlier workers quantified inverse relaxation by a measurement called Inverse Relaxation Index. The transition of inverse relaxation from yarns to fabric has been attempted in the present study. Two yarns, one coarse and other fine were selected for the study and fabrics were woven using these two yarns. After determining constructional parameters of fabric and various properties of yarns, three levels of extension were chosen. In all the cases samples were tested at different levels of retractions. Extension and retraction were kept at the same level for the fabric as that in yarns.*

INTRODUCTION

Mechanical properties of elastic solids like metals and viscous liquids can be explained by hook's law and Newton's law, respectively, for infinitesimal strains. But for finite strains or finite rates of strains, these laws are incapable of explaining the mechanical behaviour of elastic solids or viscous liquids, respectively. Some materials exhibit behaviour which is a combination of elastic solid like and viscous liquid like behaviour, even when strain and rate of strain are infinitesimal. Such a material does not maintain constant deformation under constant stress. Instead, it creeps, i.e. it goes on deforming more and more with time, the rate of deformation decreasing with time. Also, if it is constrained at a constant deformation, the stress required to keep it in the deformed state decreases with time, the rate of change of stress decreasing with time. The first phenomenon is known as creep while the second one is known as stress relaxation. If a fibre of any polymeric material is strained upto some extension level and is then allowed to retract partially, so that there still exists some strain in the fibre, also amounting to some stress present in the fibre, it is observed that the stress in the fibre goes on increasing with time. The rate of increase in stress is high in the beginning but it decreases progressively, so that the stress almost levels off after a long time interval. This particular phenomenon, called as inverse Relaxation, has received very little attention in the field of polymer research. It has been mentioned by Woods[1] though no experimental evidence of the phenomenon is given. Vitkauskas and Matukonis[2-5] reported some work on the phenomenon of inverse relaxation. These authors attempted to explain the phenomenon by assuming a fibre model consisting of a spring in parallel with two Maxwellian elements, one of the elements having period of relaxation many times shorter than the other. They derived a theoretical expression for stress in a fibre to explain the phenomenon and calculated the viscosity and spring constants for the chosen model by using experimental data on rayon and "capron" (nylon) fibres. Though the theory is able to explain the phenomenon qualitatively, it does not seem to stand the test of experiment on a quantitative basis. Inverse relaxation was also observed in the Central Institute for Research on Cotton Technology, independently, and has already been reported by Nachane et al[6-10]. The flow of Inverse Relaxation from yarn to fabric has been studied in the present work.

MATERIALS AND METHODS:

The aim of the present efforts was to study the Inverse Relaxation of cotton yarn and fabrics. In order to achieve it the fabric samples were woven in such a way that warp and weft yarns of the fabrics were derived from the same yarn.

The following sets of yarns and fabric was obtained

Set 1: (a) Yarn of 24s Ne count

(b) Fabric with warp and weft of 24s Ne count yarn

Set 2: (a) Yarn of 60s Ne Count

(b) Fabric with warp and weft of 60s Ne count yarn

The properties of yarns and fabrics are given in Table 1-3. As expected the crimp in weft way is higher than that of warp way. The weft is laid in such a way that it has to move above and below of the warp yarns, therefore, resulting in higher crimp percentage. The results of crimp percentage are very important from the point of view that while testing the fabric samples for inverse relaxation index an extra amount of extension has to be taken into account to the extent of crimp percentage of the particular constituent yarns.

The Inverse Relaxation of yarn and fabric woven from the same yarn was determined at different levels of extension and retractions. The Instron Universal Tester, available at Central Institute for Research on Cotton Technology, Mumbai along with the X9 software, was used to determine Inverse Relaxation Index of yarn and fabric. There was no readymade test method available in the Methods of X9 software. A new test method was created using method editor.

After determining various properties of yarns and constructional parameters of fabric, three levels of extension with the interval of 1.0 mm were selected for both the sets of samples. In each case relaxation of the yarn was studied first then retraction was carried out at 0.3 mm and thereafter at the increments of 0.5 mm. For example yarn was first extended to 8.3 mm and then retracted to 8.0 mm resulted a retraction of 0.3 mm and so on. Similarly in case of fabric samples the same amount of extension was achieved after normalising the crimp percentage. The retraction levels were also kept equal to that of single yarn samples in order to study the flow of inverse relaxation from yarn to fabric. A typical IR curve is shown in the figure 1

Where

F_C = Force at point C
F_B = Force at point B and

F_A = Force at point A

The inverse relaxation index was cal culated using following equation.

INVERSE RELAXATION INDEX OF YARN AND FABRIC:

Inverse Relaxation Index was determined for yarn and fabric samples and an average of 10 readings for each combination of extension and retraction is reported. As discussed above the levels of extension are 6.3 mm, 7.3 mm and 8.3 mm. The amounts of retraction are 0.3, 0.8, 1.3, 1.8, 2.3, 2.8 and 3.3 mm for each level of extension.

The results of both the counts of yarn i.e. 24s and 60s are tabulated in the tables 4 and 5 whereas graphical presentation of the results are given in figures 1a to 1c for 24s count and figures 2a to 2c for 60s count of yarn. As per table 4 and figures 1a to 1c, at 0 mm retraction the value of IR index is negative because at this level of retraction only stress relaxation occurs. At the slightly lower level i.e. at 0.3 mm retraction both yarn and fabric (warp and weft) had shown a negative Inverse Relaxation Index. This may be due to more prominent Stress Relaxation compared to Inverse Relaxation. Inverse Relaxation was not observed at 0 mm, however stress relaxation was observed at this level.

It is observed that with the increased retraction level both stress relaxation and inverse relaxation occur. As the retraction levels are increased further, only inverse relaxation is observed. The highest amount of Inverse Relaxation Index resulted at 2.3 mm, 1.8 mm, and 1.3 mm of retraction for 8.3 mm, 7.3 mm and 6.3 mm level of extension respectively in yarn as well as fabric samples of 24s Ne yarn.

Similarly highest amount of Inverse Relaxation Index resulted at 2.3 mm, 2.3 mm, and 1.3 mm of retraction for 8.3 mm, 7.3 mm and 6.3 mm level of extension respectively in yarn as well as fabric samples of 60s Ne yarn. This infers that occurrence of maximum IR index is dependent of extension level.

The Figures 1 a, b, and c gives a graphical representation of inverse relaxation index vs. retraction levels for a given extension level. As seen from figures it quite evident that I R Index of yarn for a given retraction is higher than that of fabric. The IR Index for fabric is almost similar in warp as well as weft direction. It was found that the phenomenon of inverse relaxation is dependent on the material of the fibre, the extension level upto which it is stretched and the retraction level upto which it is retracted. This is a time-dependent phenomenon much like stress relaxation and creep. At any particular level of extension and retraction, the rate of increase in stress is fast initially, but decreases with time as shown in the Figure 2. the IR Index first increases with the increase in retraction level it reaches maximum at a certain level and then decreases as the retraction level is increased.

Results of Inverse Relaxation Index obtained in case 60s Ne count are tabulated in table 5 and resultant graphs are given Figs. 3a, b and c. Similar to the case of 24s Ne count yarn the Inverse Relaxation Index of yarn was higher compared to that of fabric in both the warp and weft way for a given extension level. In both the cases of 24s Ne count and 60s Ne count yarns the overall graph presented a smooth curve and transition from stress relaxation to inverse relaxation seen to be even.

The Inverse relaxation Index is higher for yarn samples compared to fabric in coarse as well as fine count of yarn. Therefore, it can be concluded that Inverse Relaxation Index for yarn is more than that of fabric for a given extension and retraction levels. This can be attributed to the fact that fabric strip constitutes of the several single strands of yarn which compensate for each other when strain is applied to the fabric strip. Whereas in case of yarn a single strand is subjected to the strain and compensation of this kind is not available thereby higher amount of

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Inverse Relaxation Index is obtained in case of single yarn. Also yarn in fabric is interlaced. Though this wavy structure is somewhat compensated in the experiments, it cannot be completely removed. This factor may also be contributing to the small differences observed in IR Index values of yarns and fabrics.

Also in case of single yarn, the yarn itself was linear; the stress applied was, therefore, always parallel to the yarn axis. However, yarn was having wavy structure in the fabric due to interlacing, therefore, though stress applied to the fabric was in its plane and parallel to the overall yarn structure, at individual places in the yarn it was always at some angle. This may be reason for the difference observed. As seen from the results, the IR Index for fabric is almost equal in warp as well as weft direction, since the fabric was woven in such way the both the constituent yarns i.e. warp and weft were from the same yarn.

CONCLUSIONS:

Mathematical treatments of phenomena like stress relaxation, creep, creep recovery, etc. have already been reported in the literature but these are based on relaxation and retardation spectra. These treatments have been applied to a large number of polymeric materials and have been found to be quite satisfactory. However, the data on the Inverse Relaxation of visco-elastic material is very scarce. This work was, therefore, aimed to study the transmission of inverse relaxation from yarn to fabric.

Study revealed that the Inverse Relaxation Index is higher in case of yarn compared to corresponding fabric samples for a given extension and retraction level. Further it has been observed that there is not much difference in Inverse Relaxation Index of Warp and Weft Way of the fabric for a given extension and retraction level. It may due to the same material used in both ways of the fabric.

Table1. Different parameters of Yarn Samples:

Sr. No.	Nominal Count (Ne)	Actual Count (Ne)	Breaking Strength (gms.)/ Tenacity (g/tex)	Breaking extension %
1.	24	24.1	414.3/16.9	6.7
2.	60	59.8	173.1/17.5	5.0

Table 2. Different Properties of Fabric Samples:

Sr. No.	Parameter	Woven with 24s count yarn	Woven with 60s count yarn
1.	Ends/Picks per 25.4 mm	60/56	160/110
2.	GSM (gms.)	128	107
3.	Br. St. (kg.) (Warp)	27.9	28.7
	Br. St. (kg.) (Weft)	24.2	19.6
4.	Extension (%) (Warp)	10.9	11.1
	Extension (%) (Weft)	11.9	10.1

Table 3. Crimp Percentage:

Sr. No.	Fabric		Crimp %
1.	Woven with 24s count yarn	Warp Way	3.8
		Weft Way	4.3
2.	Woven with 60s count yarn	Warp Way	4.4
		Weft Way	5.9

Table 4. Inverse Relaxation of 24s Ne Count Yarn and Fabric Woven with it

Sr. No.	Extension Levels in mm	Difference between Extension and Retraction mm	IR index of yarn	IR index of fabric Warp	IR index of fabric Weft
1.	8.3	0	-8.2	-10.4	-7.6
		0.3	-0.5	-6.2	-4.1
		0.8	0.4	-1.1	0.1
		1.3	5.3	0.2	3.2
		1.8	7.7	5.0	5.4
		2.3	8.8	5.5	6.5
		2.8	8.4	6.8	6.4
		3.3	6.7	6.5	5.5
2.	7.3	0	-14.8	-12.9	-13.5
		0.3	-7.5	-6.4	-7.3
		0.8	0.1	0.2	-0.3
		1.3	5.8	3.4	4.1
		1.8	7.7	5.9	6.0
		2.3	6.5	5.7	5.3
		2.8	2.2	2.1	2.1
3.	6.3	0	-3.5	-12.2	-11.7
		0.3	-0.5	-7.8	-8.7
		0.8	2.4	1.3	1.3
		1.3	4.3	2.9	2.9
		1.8	2.9	1.9	1.8

Table 5: Inverse Relaxation of 60s Ne Count Yarn and Fabric Woven with it

Sr. No.	Extension Levels in mm	Difference between Extension and Retraction mm	IR index of yarn	IR index of fabric Warp	IR index of fabric Weft
1.	8.3	0	-9.3	-8.6	-7.0
		0.3	-1.7	-1.7	-1.2
		0.8	0.0	-0.5	0.1
		1.3	4.0	0.1	3.1
		1.8	8.1	5.3	6.7
		2.3	8.2	5.7	6.0
		2.8	7.8	6.4	6.1
		3.3	7.1	5.9	5.7
2.	7.3	0	-9.6	-6.7	-5.9
		0.3	-3.4	-3.0	-2.8
		0.8	1.1	0.8	1.0
		1.3	5.1	4.6	4.1
		1.8	6.4	5.5	5.2
		2.3	6.7	5.1	6.5
		2.8	1.8	1.2	2.0
3.	6.3	0	-3.9	-5.0	-4.9
		0.3	-0.6	-1.3	-1.2
		0.8	1.7	2.0	1.9
		1.3	4.0	2.7	3.3
		1.8	2.8	1.9	1.9

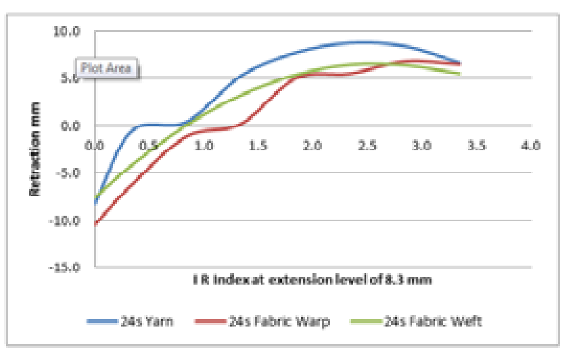

Figure 1a Transfer of Inverse Relaxation from 24s Ne Yarn to Fabric (Extn. Level 8.3 mm)

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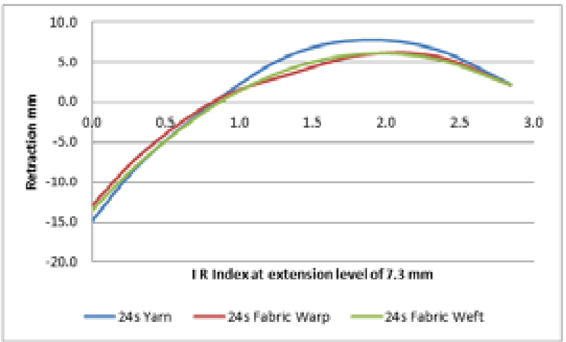

Figure 1b Transfer of Inverse Relaxation from 24s Ne Yarn to Fabric (Extn. Level 7.3 mm)

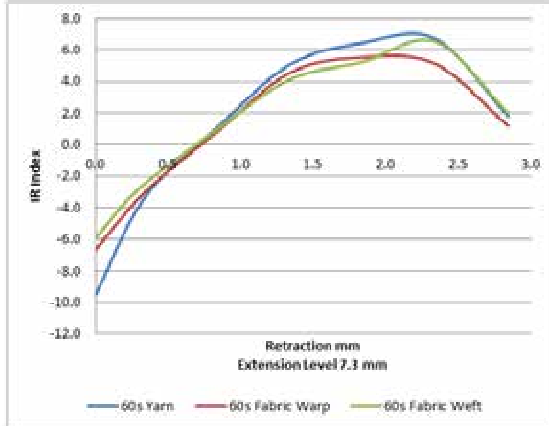

Figure 3b Transfer of Inverse Relaxation from 60s Ne Yarn to Fabric (Extn. Level 7.3 mm)

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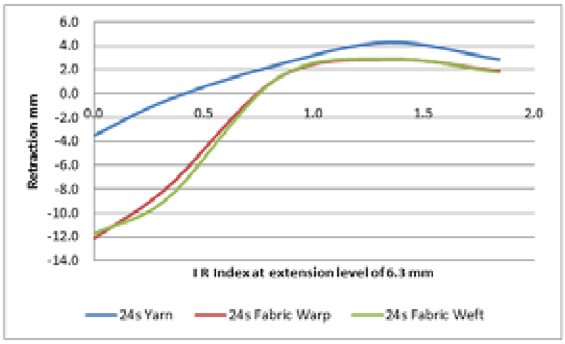


Figure 1c Transfer of Inverse Relaxation from 24s Ne Yarn to Fabric (Extn. Level 6.3 mm)

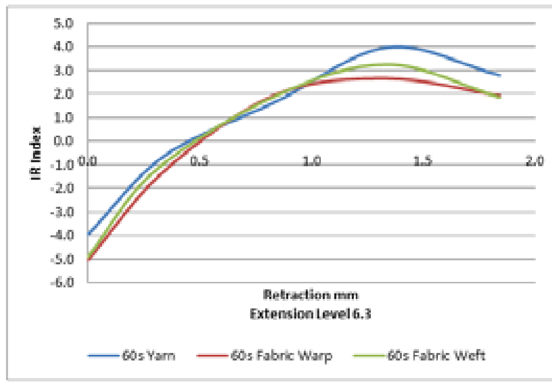
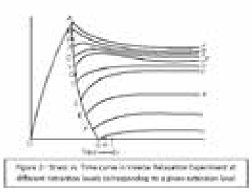
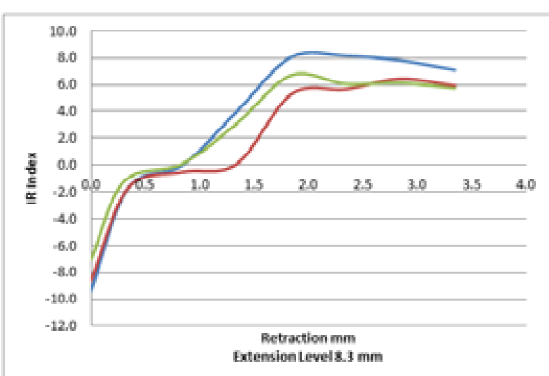


Figure 3c Transfer of Inverse Relaxation from 60s Ne Yarn to Fabric (Extn. Level 6.3 mm)





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