Study of Inverse Creep In Textile Yarns

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ABSTRACT

Creep has been known and studied for textile materials for decades. In comparison, a newly observed phenomenon of inverse creep seems not to have received much attention. A new instrument has been fabricated to measure creep and inverse creep in textile materials particularly yarns. Creep and Inverse creep measurements of nylon multifilament yarn, polyester multifilament yarn, cotton and wool yarn at different levels of stress have been studied using the new instrument and results are reported in the present paper.

INTRODUCTION

Almost all textile materials are made up of polymers and are viscoelastic in nature and exhibit creep, stress relaxation, inverse relaxation and inverse creep. A material under constant stress shows continuous increase in strain with time, a phenomena known as creep. On the other hand if the material is strained and kept at constant strain, stress decreases continuously with time. This phenomenon is known as stress relaxation. The phenomena in which applied strain in viscoelastic material is partially reduced, giving rise to increase in stress with time is known as inverse relaxation. This phenomenon has been studied for some textile materials. (1-8). Inverse creep is a phenomenon, which is found to occur in viscoelastic materials when the applied stress is partially reduced. At this reduced stress, the strain in the material reduces continuously with time, though it is still under stress.

Inverse creep values depend on the material and also on its stress history. During weaving of a fabric, weft threads are inserted in between the warp threads, which are along the direction of the fabric production. A weft thread undergoes variation in stress during weaving. It is at high stress when it is being laid down in the fabric. But the stress may not reduce to zero once the thread is laid down; thus giving rise to the phenomenon of inverse creep. Variations in inverse creep behaviour for the same higher and lower stress levels in a given yarn can lead to fabric defect. Any phenomenon in a polymeric substance where applied stress is partially reduced will give rise to inverse creep.

Creep of textile materials has been measured by a number of researchers. Inverse creep can be measured by the method demonstrated by Nachane (9, 10, 11). However this method is cumbersome and tedious. Also, the level of accuracy in measurements is low as it depends on subjective observation.

The objective of the present work was to design an instrument, which can measure the instantaneous extension or contraction of yarn. Inverse creep as well as creep behaviour of different materials by varying initial and final stress values. Automation in storing the data is achieved. Stored data can then be easily analyzed. Creep and inverse creep of four textile yarn types at various levels of stress have been studied by using this device. The results are presented in this paper.

MATERIALS AND METHODS

Materials

Four different samples of nylon, four of polyester, two of wool and one sample of cotton were tested. Two nylon, one polyester, one wool and one cotton are discussed here. Nylon and polyester yarns were obtained from a reputed manufacturer of Vapi, District Thane. Cotton and wool samples were obtained from Raymond's Mill, Thane.
The following were used for the observations:

1. Nylon yarn of 111 denier and 24 multi-filaments and Nylon yarn of 70 denier and 24 multi-filaments
2. Polyester yarn of 111 denier and 24 multi-filaments
3. Cotton yarn of 30s count
4. Wool yarn of 15s count

Nylon multifilament yarns of 111 denier, 24 filaments and 70 denier, 24 filaments

Gauge length was kept at one meter (1 m). Yarn was loaded by a pan with a clamping arrangement. The pan weighed 28.36 gm.

To start, a weight of 120 gm was added to the pan, developing tension of 148.36 gm in the yarn. After every 5 minutes loads of 25 gm, 25 gm, 25gm, 25 gm, and 20 gm were sequentially removed from the pan. The weight was added and removed gently to avoid any pan swinging or agitation. The loads on the pan with respect to time (for both the yarn samples) are shown in *Table I.*

TABLE I Loads on pan per time

Obser. No.	Time Duration (min)	Load (gm)
1.	0 min – 5 min	148.36
2.	5 min – 10 min	123.36
3.	10 min – 15 min	98.36
4.	15 min – 20 min	73.36
5.	20 min – 25 min	48.36
6.	25 min - 30 min	28.36

Polyester multifilament yarn of 111 denier

To start, a weight of 241 gm was added to the pan developing tension of 269.36 gm in the yarn. As shown in *Table II*, after every 5 minutes loads of 50 gm, 50 gm, 50 gm, 50 gm and 41 gm were removed from the pan sequentially. This procedure was repeated five times, the average calculated, and the observations recorded.

TABLE- II

Obs. No.	Time Duration (min)	Load (gm) (Weight in the pan + 28gm)
1.	0 min – 5 min	241 + 28.36 = 269.36
2.	5 min – 10 min	191 + 28.36 = 219.36
3.	10 min – 15 min	141 + 28.36 = 169.36
4.	15 min – 20 min	91 + 28.36 = 119.36
5.	20 min – 25 min	41 + 28.36 = 69.36
6	25 min - 30 min	28.36

Cotton yarn of 30s count

A weight of 91 gm was added to the developing tension of 119.36 gm in the yarn. As shown in *Table III*, after every 5 minutes, loads of 50 gm and 41 gm were removed from the pan sequentially. This procedure was repeated five times, the average calculated, and the observations recorded.

TABLE-III

Obser. No.	Time Duration (min)	Load (gm) (Weight in the pan+ 28.36g)
1.	0 min – 05 min	91 + 28.36 = 119.36
2.	5 min – 10 min	41 + 28.36 = 78.36
3.	10 min – 15 min	28.36

Wool yarn of 15s count

A weight of 241 gm was added to the pan developing tension of 269.36 gm in the yarn. As shown in *Table IV*, after every 5 minutes, loads of 50 gm, 50 gm, 50 gm, 50 gm and 41 gm were removed from the pan sequentially. This procedure was repeated five times, the average calculated and the observations recorded.

Before testing, all samples were kept for conditioning for 24 hours. While testing, the room temperature was 27°C and humidity was 65%. The tensile properties of the yarns are given in *Table V*.

TABLE IV Wool yarn of 15s count

Ob. No.	Time Duration (min)	Load(gm) (Weight in the pan+ 28gm)
1.	0 min – 05 min	175 + 28.36 = 203.36
2.	5 min – 10 min	75 + 28.36 = 103.36
3.	10 min – 15 min	25 + 28.36 = 53.36
4.	15 min – 20 min	28.36

TABLE V The tensile properties yarns

Type of Yarn	Tex	Breaking Strength (g)	Tenacity =g/tex	Breaking Extension(%)
Nylon – PR06	12.4	607	48.9	19.5
Polyester-PR08	13.2	420	31.8	24.8
Cotton-PR13	20.7	171	8.3	5.8
Wool-PR14	40.8	272	6.7	17.9

Details of the test instrument are as follows

1. Ultrasonic Trans-receiver: Trans-receiver (Operating Frequency: 40 KHz): It is a pair of pezo-electric transducers.

2. Oscillator: It consists of Schmitt-Trigger NAND gate (IC 4031) and R-C network, which produces 40 KHz frequency signal. The output of the Oscillator is given to one terminal of the Transmitter and the same out put of the Oscillator is inverted and is fed to the second terminal of the transmitter.

3. Amplifier: It is a combination of an inverting and non-inverting amplifiers designed by Operational Amplifiers (IC 741). The appropriate gain is adjusted.

4. Buffer: This is a tri – state buffer generally known as a line driver. IC 74LS244 is specifically used for this purpose

5. Level shifter: Basically it converts an anolog signal (± 2.5V) to a digital signal (0V-5V) and consists of a common emitter amplifier. PNP transistor (SL – 100) is used.

6. Embedded System Unit: An Embedded system with a Micro-Controller 89V51RD2 was used which had serial and parallel ports. IC 89V51RD2 (Philip Make) was used and run by Assembly Language Program.

The Assembly Language Program is a source program, which waits for the transmitted pulse and on receiving the latter, it starts the internal time and immediately stops the Oscillator, which disables the transmitter. In short, the receiver receives the first transmitted pulse. The moment the transmitted pulse is received by the receiver it sends the pulse to the microcontroller. On getting this pulse the timer stops and the time difference is loaded on the ports. A pulse is sent to the PC, indicating that data is available on the port. Computer receives the data and sends a pulse to the microcontroller, indicating it to have the next pulse from the transmitter. The cycle repeats again.

7. Personal Computer: Intel branded motherboard with Flash Magic Software and a Turbo-C editor is used. Flash Magic Software is used to load the Assembly Language Program in Micro Controller IC-89C51RD2 through the serial port. The C- language program is used to load the data (time difference) in the PC. The program stores up to1000 data units in the file. And after that it opens another text file to store next 1000 data items. The data port of the Printer Port is used to transfer data items from Micro Controller Port to the PC. For Hand Shaking (acknowledgement) between Micro Controller and PC, one terminal of both Control port and Status Port is used. Microsoft Excel can be used to see the results graphically.

Incidentally a Patent application for the instrument has been filed with the Controller General of Patents, Mumbai Office, India (850 / MUM / 2007).The patent was published on 30th May 2008.

METHODS

Operating Procedures

Yarn segment is caught at both the ends by clamps. One end is hooked at the top of the 3m stand. At the other end the weighing pan is attached on which the load can be added at a particular time instant.

When the load is put in the pan, the first pulse from transmitter is transmitted and instantaneously the Timer is started in the Micro-Controller. When the receiver receives the same pulse, the Timer is stopped. The Timer of the Micro-Controller computes the time duration and it puts the byte on its port. Thus time taken by the ultrasonic pulse to travel from transmitter to receiver is measured. This time is usually in microsecond. When the pulse is sensed by the receiver circuit, it sends a signal to the transmitter circuit to stop the transmission. Once the data are processed and stored in the data file by the computer, computer sends a signal to the transmitter to start transmitting again. The time duration in the successive measurements is approximately one second. This can be reduced to a few microseconds with the same Instrument.

The time lag between the transmission of the pulse by the transmitter to the receiver is converted into change in distance between the two transducers which is the displacement. Thus with the passage of time measured by the timer of the computer, displacement of the receiver and therefore, the extension in the yarn is measured to a fraction of a mm.

The extension / reduction in length of the yarn are stored in the data file of the P.C. This text file then can be opened in MS-Excel. From the data and the corresponding graph, the creep and inverse creep behaviour can be observed.

RESULTS AND DISCUSSIONS

A typical inverse creep graphical presentation is shown in Figure 1. Point O corresponds to the start of the experiment. At O, certain load (that is stress S_1) is applied to the yarn. As a result there is immediate extension OA in the yarn followed by extension corresponding to the curve AB over a period zero to t_1.At the time t_1, the stress S_1 is reduced partially to S_2 by removing a part of the load. Corresponding to this reduction in stress from S_1 to S_2, we get immediate reduction BC in the extension of the yarn, followed by the reduction in extension corresponding to the curve CD over the period from t_1 to t_2. In the present experiments, zero to t_1 and t_1 to t_2 were both 300 sec. It may be seen from figure that extension A'B' corresponds to creep in the specimen over the period zero to t_1 under stress S_1.The reduction in extension C'D' corresponds to inverse creep in the specimen at reduced stress level S_2 over the period t_1 to t_2.These creep and the inverse creep values have been reported in tables.

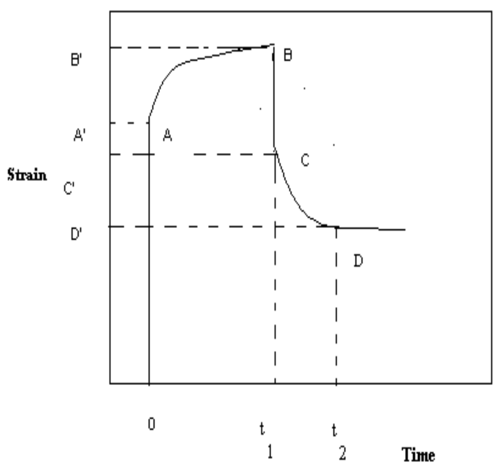

FIGURE 1 Graphical Presentation of Typical Inverse Creep

Nylon Multifilament Yarn

Nylon yarn of 70 denier and 24 multi-filaments and Nylon yarn of 111 denier and 24 multi -filaments: *Table VI* and *Table VII*, give inverse creep data for the two yarn samples A and B respectively, studied with initial stress S_1 corresponding to 120 gm load. This load was reduced by 25 gm after every 300 sec and 20 gm at the last time, giving reduced stresses in the yarn. The stress values are expressed in mN / dtex while the extension values are expressed in percentage of initial length of the yarn. The length of the yarn was maintained at 1m.

For the 70 denier yarn, of length 1m, it may be seen from *Figure 2* that at stress level S_1 both the samples show creep as expected. For reduced stress levels S_2, S3, S_4, S_5, S_6 all the samples show inverse creep. When 148.36 gm load is reduced to 123.36 gm, it can be seen that the ratio of inverse creep at stress S_2 to creep at S_1 is comparatively small. When the load is reduced by 25 gm four times, the inverse creeps at reduced stresses S_2, S_3, S_4, S_5, are 13.55%, 15.25%, 22.03%, and 34.74%, with respect to the creep at S_1 respectively. When the fifth time load of 20 gm was removed and inverse creep was noted, the ratio was recorded as 32.20%.

As can be seen in *Figure 3*, for the 111 denier yarn, when the load is reduced by 25gm four times,and 20 gm the last time. The inverse creep at reduced stress S_2, S3, S_4, S_5, S_6 is 14.29%, 19.06%, 26.20%, 38.12%, and 38.12% of the creep at S_1 respectively.

TABLE VI: Nylon Multifilament Nylon Yarn of 70 Denier and 24 Filaments.

Obser. No.	Time (sec)	Stress (mN / dtex)	Extension (%)	Inverse Creep (%)
01.	0	3.57	0	0
02.	0.8	18.69	150.22	0
03.	300 S_1	18.69	165.79	-1.56*
04.	300.8	15.54	161.04	-
05.	600 S_2	15.54	158.93	0.21
06.	600.8	12.39	153.25	-
07.	900 S_3	12.39	150.88	0.23
08.	900.8	9.24	140.18	-
09.	1200 S_4	9.24	136.75	0.34
10.	1200.8	6.09	122.23	-
11.	1500 S_5	6.09	116.82	0.54
12.	1500.8	3.57	104.41	-
13.	1800 S_6	3.57	099.40	0.56

TABLE VII: Nylon Multifilament Nylon Yarn of 111 Denier and 24 Filaments.

Obser. No.	Time (sec)	Stress (mN / dtex)	Extension (%)	Inverse Creep (%)
01.	0	2.25	0	0
02.	0.8	11.78	86.20	0
03.	300 S_1	11.77	97.41	-1.11*
04.	300.8	9.79	93.06	-
05.	600 S_2	9.80	91.48	0.16
06.	600.8	7.81	85.40	-
07.	900 S_3	7.81	83.29	0.21
08.	900.8	5.82	74.32	-
09.	1200 S_4	5.82	71.41	0.29
10.	1200.8	3.84	59.66	-
11.	1500 S_5	3.84	55.44	0.42
12.	1500.8	2.25	43.43	-
13.	1800 S_6	2.25	39.20	0.42

(*Negative sign indicates the Creep in the yarn)

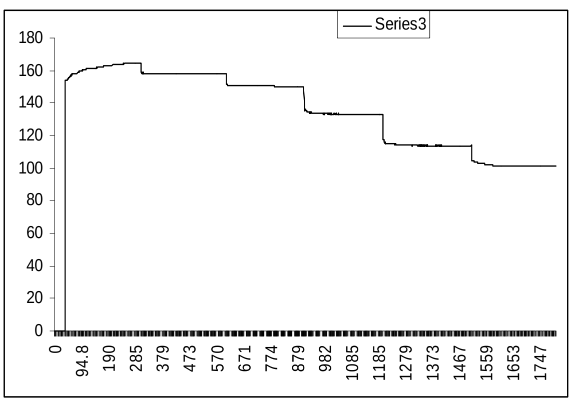

FIGURE 2: Extension (mm) verses Time (s) for 70 Denier Nylon Yarn

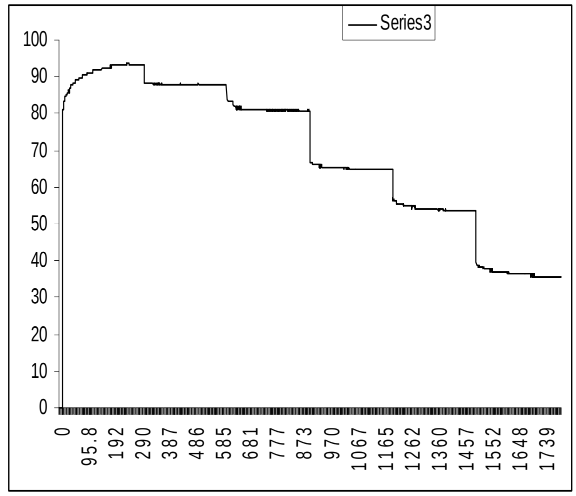

FIGURE 3. Extension (mm) verses Time (s) for 111 Denier Nylon Yarn

Polyester Multifilament Yarn

For Polyester Multifilament Yarn of 111 Denier and 24 Filaments, the loading sequence is shown in *Table VIII.*

TABLE VIII: Loading Sequence for Polyester Multifilament Yarn of 111 Denier and 24 Filaments

Ob No .	Time (sec)	Load (gm)	Stress (mN / dtex)	Ext/C ont (mm)	Inverse Creep (%)
1	0	28	2.3	0	-
2	0.8	269.4	21.4	172.5	--
3	300	269.4	21.4	190.2	-1.77*
4	300. 8	219.4	17.4	187.6	-
5	600	219.4	17.2	186.3	0.13
6	600. 8	169.4	13.5	183.3	-
7	900	169.4	13.5	181.5	0.18
8	900. 8	119.4	9.5	173.6	-
9	1200	119.4	9.5	169.5	0.41
10	1200 .8	69.4	5.5	162.9	-
11	1500	69.4	5.5	157.1	0.58
12	1500 .8	28.4	2.3	149.2	-
13	1800	28.4	2.3	140.4	0.87

(*Negative sign indicates the Creep in the Yarn)

TABLE IX

Obs No.	Point on Curve	Time (sec)	Load (gm)	Stress (mN / dtex)	Ext/ Cont (mm)	Inverse Creep (%)
1	O	0	28.4	3.6	0	--
2	A	0.8	119.4	15.0	48.4	-
3	B	300	119.4	15.0	53.9	-0.55*
4	C	300.8	69.4	8.7	50.7	-
5	D	600	69.4	8.7	48.7	0.20
6	E	600.8	28.4	3.6	45.5	-
7	F	900	28.4	3.6	43.7	0.18

For a few conclusions the pan was hung without any load in it. A load of 241gm was added to the pan for 300sec., yielding a load of 269.4gm or stress of 21.4 mN/dtex. The increase in load elongates the yarn. There are two parts to the extension; immediate extension and delayed extension. The immediate extension is 172.5mm and the delayed extension is 17.7mm. Hence the total extension is 190.2mm. As the contraction is considered as positive, the extension is referred as negative.

The delayed extension of 17.7mm or 1.77% is Creep. After 300.8sec, 50gm were removed from the pan. So the load was 191.4gm which was 17.4 mN/dtex. Partial removal of the stress gave rise to the sudden contraction and the delayed contraction. The delayed contraction of 1.3mm or 0.13% is Inverse creep Further 25 gm of load was removed for 3 more times and finally 41 gm of load was removed. This partial reduction yielded rises in inverse creep of 0.13%, 0.18%, 0.41%, 0.58% and 0.87%. It can be seen from *Table VIII* and *Figure 4* that;

1. Gradual reduction of the stress produces increase in the inverse creep values.

2. The addition of the inverse creep values is (2.17%) greater than creep value (1.77%).

3. There is variation in inverse creep values.

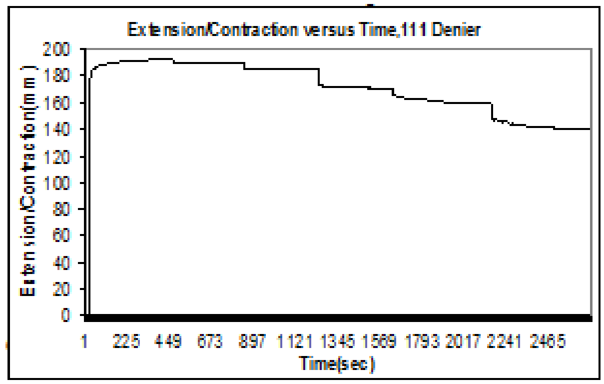

FIGURE 4. Extension(mm) verses Time(s) for 111 Denier Polyester Yarn

Cotton Yarn

The loading sequence for cotton yarn is shown in *Table IX*. The initial load is 119.4gm. 50gm were taken out after 300 sec and more after 600 sec. Next 41 gm were taken out leaving only the weight of the pan (28gm) in action.

The immediate extension was 48.4mm and the delayed extension was 5.5mm. Hence the total extension was 53.9mm. As the contraction is considered as positive, the extension is referred as negative. The delayed extension or creep was 5.5mm, or 0.55%.

After 300.8sec, a 50gm load was removed from the pan, yielding a load of 69gm or 8.7 mN/dtex. Partial removal of the stress gave rise to the sudden contraction and the delayed contraction or inverse creep of 2.0mm, or 0.22%. With the last 41 gms of added load removed, the applied load was 28.4gms and the stress 3.6mN/dtex. This partial reduction gave rise to inverse creep of 0.18%.

It can be seen from *Table IX* and *Figure 5* that:

1. Gradual reduction of the stress produces increase in the inverse creep values.
2. The addition of the inverse creep values is (0.38%) less than creep value (0.55%).
3. There is variation in inverse creep value.

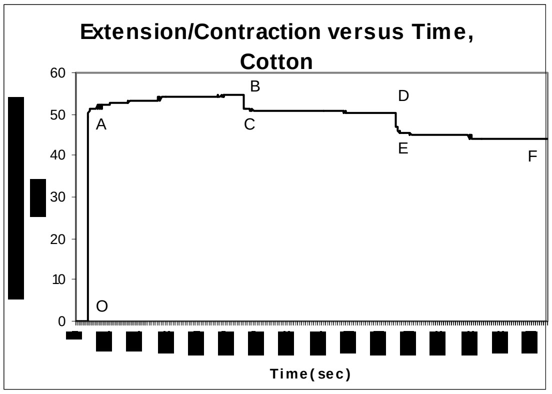

FIGURE 5. Extension (mm) verses Time (s) for Cotton Yarn

Point "O", on the curve is the initial reference point, where the only load on the yarn is the weight of the pan. Point "O" to point "A", is the sudden extension in the yarn. Point "A" to "B", is delayed extension in the yarn. This is Creep. Hence in front of point "B", creep value is written 2.55%, in the table. From point "B" to "C" is a sudden contraction and from point "C" to "D" is a delayed contraction. This is termed as an Inverse creep. Further from point "E" to point "F" all are delayed contractions, which are termed as "Delayed Recoveries". These delayed recoveries are inverse creep values for different partial reductions in stresses

Wool Yarn

The loading sequence for cotton yarn is shown in *Table X*. The initial load was 169.4gm, 50gm were taken out after 300 sec. and again after 600 sec. With the last 41 gms of added load removed, keeping the applied load of 28.4 gms and the stress 4.2mN/dtex. This partial reduction gave rise to inverse creep of 0.80%.

TABLE X Loading Sequence for Wool Yarn

Obs. No.	Time (sec)	Load (gm)	Stress (mN / dtex)	Ext/Cont (mm)	Inverse Creep (%)
1	0	28	4.2	0	--
2	0.8	169.4	25.0	128.2	--
3	300	169.4	25.0	150.0	-2.20
4	300.8	119.4	16.8	145.4	-
5	600	119.4	16.8	143.9	0.15
6	600.8	69.4	10.2	138.1	-
8	900	69.4	10.2	134.5	0.36
9	900.8	28.4	4.2	127.3	-
10	1200	28.4	4.2	119.2	0.80

(*Negative sign indicates the Creep in the Yarn)

CONCLUSIONS

For few moments the pan was hanged without any load in it. A load of 141.28gms was added to the pan for 300sec. (a total load of 169.4gm and stress of 25.0mN/dtex). The increase in load elongates the yarn. There are two parts to the extension. One is immediate extension and the other is delayed extension. The immediate extension is 128.2mm and the delayed extension is 21.8mm. Hence the total extension is 150.4mm. As the contraction is considered as positive, the extension is referred as negative.

The delayed extension or Creep is 21.8mm or 2.18% after 300.8sec., 50gm were removed from the pan yielding a load of 119.4gms or 16.8mN/dtex. Partial removal of the stress gave rise to the sudden contraction and the delayed contraction. The delayed contraction is called as Inverse creep and it is 1.5mm, which is 0.15%. 50gms of load was removed for one more time and at last 17 gm of load was removed. This partial reduction gave rise to inverse creep of 0.36% and 0.80%.

It can be seen from *Table X* and *Figure 6* that:

1. Gradual reduction of the stress produces increase in the inverse creep values.

2. The addition of the inverse creep values is (1.30%) less than creep value (2.20%).

3. There is variation in inverse creep values.

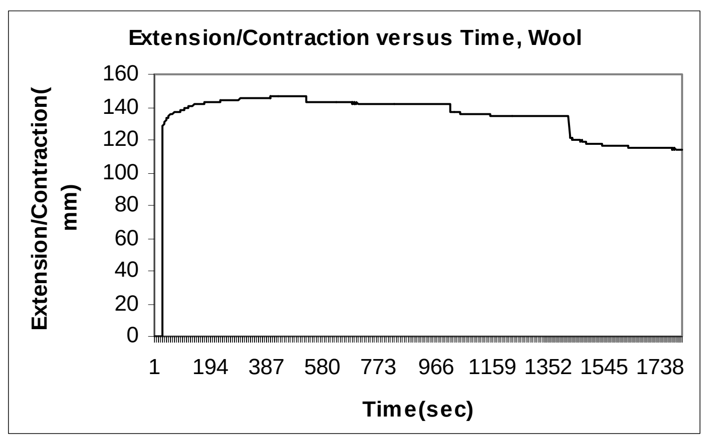

FIGURE 6. Extension (mm) verses Time(s) for Wool Yarn

From the above observations it is seen that the percentage inverse creep increases when the reduced stress decreases in case of all the yarns. It is evident from the results that viscoelastic materials do exhibits inverse creep and the extent of inverse creep increases as the stress is decreased. Inverse creep value is dependent on its stress history. The phenomenon of inverse creep is relatively new and has not been much studied. The author's present work is the just the beginning of this complex study. A lot more research obviously is needed to fully explore the phenomenon for different types of textile materials.

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REFERENCE/ BIBLIOGRAPHY

[1] Vitkauskas A. and Matukonis A., Tech. of Textile Industry U.S.S.R. 1968, No.4 (19 – 21)

[2] Vitkauskas A. and Matukonis A., Tech. of Textile Industry, U.S.S.R, 1969, No.3, (23 – 26).

[3] Vitkauskas. A. and Matukonis A., Tech. of Textile Industry, U.S.S.R. 1970, No. 2, (14 – 17)

[4] Nachane R.P. and Hussain G.F.S. and Krishna Iyer K. R., Textile Research Journal 1982, (483 – 484)

[5] Nachane R.P. and Hussain G.F.S. and Krishna Iyer K. R., Journal of Applied Polymer Science, 1986, Volume 31 (1101 – 1110).

[6] Nachane R.P. and Hussain G.F.S. Patel G. S. and Krishna Iyer, Journal of Applied Polymer Science, 1986 Volume 38, (21-28)

[7] Manich A.M. and De Castellar M.D. 1992, Textile Research Journal 62 (196 – 199).

[8] Vengheluwe Lieven, 1993, Textile Research Journal, 63 (552 – 556).

[9] Nachane R.P., Applied Polymer Science, 1994, Volume 53, (1123 – 1124).

[10] Nachane R. P. and Sundaram V.,Journal Textile Institute,1995, 86 Number 1,(10 - 19).

[11] Nachane R. P. and V. Sundaram, Journal Textile Institute, 1995,86 Number 1, (20 - 32)

[12] Nachane R.P, Hussain G.F.S, Indian Journal of Fiber and Textile Research, Volume 23, June 1998, (81 -84).

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