Studies on Cyclic Loading of Mulberry Silk Warp Yarns

Subrata Das

Abstract:: ***Mulberry silk warp yarns were subjected to cyclic loading on tensile testing instrument by simulating the conditions of weaving. Minimum and maximum load for these cyclic loadings were selected based on the theoretical base tension on the warp yarns and maximum tension at beat-up process. The speed of cyclic loading was adjusted to match with the speed of the conventional power loom. The stress-strain curves of the yarns were investigated and the deformation behaviour was analysed with respect to yield point, maximum load, elongation and energy. The behaviour of silk warp yarn to fatigue developed during weaving due to its tensile deformation was studied at the fabric formation stage. All the three warp yarns showed significant deformation during weaving***

Keywords: Cyclic loading, elongation, load extension curves, strain hardening, tenacity, warp tension, yield point.

I. INTRODUCTION

The propensity to failure slowly reduces in engineering materials when exposed to recurring loading and unloading under low stress. Man-made textile fibres/yarns and cotton yarns have shown such phenomenon under different conditions of cyclic loading [1-6]. Repeated cyclic extension at low stress below the breaking point results in failure of warp yarns on the loom. This is attributed to cumulative damage and is called as fatigue[6]. Mechanical pre-loading and unloading transforms the deformation behaviour of yarns. These changes in yarn properties play a major role in forecasting the failure of warp yarn for a given warp quality and fabric construction, in achieving the desired efficiency during the production process as also predicting the properties of the fabrics produced from the yarns. Certain magnitude of warp tension is necessary to form a distinct warp shed for even passage of weft insertion elements. This helps the fell of the cloth to remain in the same position during beat-up operation. The tension of the warp is referred to as ‘Base tension’. During opening of the shed, the warp yarn is stretched and thus the Tension increases; during closing of the shed it recovers the original length and the tension decreases. This happens each time a weft yarn is inserted. A tension pulse is arising from the beat-up and superimposed upon this. This pulse is small for a light open fabric and can be very large with a heavy dense fabric. In order to withstand damage, the warp yarn must absorb and release energy without the incidence of failure.The study is undertaken to investigate changes that occur in the tensile behaviour of silk warp yarns as they endure repeated stress and strains below the yield region during weaving

II. MATERIALS AND METHODS

A. Materials

The studies were performed on 22/24 dtex raw silk (RS), 22/24 x 2 dtex undegummed organzine yarn (UO) and 22/24 x 2 dtex degummed organzine yarn (DO), the commonly used warp yarns for the manufacture of the popular varieties of silk fabrics. The yarns were prepared in Central Silk Board, Bangalore.

B. Speed of cyclic loading

The experiment was designed to simulate weaving conditions on conventional silk power looms. The speed of the loom commonly used in practice i.e. 120 pick per minute (ppm) was considered. Hence, the speed of cyclic loading [7] and unloading was adjusted to 120 cycles per minute.

C. Minimum and maximum limits for cyclic loading

The minimum load corresponding to the base tension on the warp was taken as 20 g for raw silk and 40 g for the organzine yarns, both raw and degummed. At the beat-up, the typical warp tension ranges from 40 to 60 g for light, open fabrics to heavy and dense fabrics [8]. As raw silk is usually used for light, open fabrics and the organzine yarns for heavier fabrics, the maximum load on the warp yarns at the time of beat-up was taken as 40 g for raw silk and 60 g for organzine.

D. Determination of numbers of cycles

The warp is held between the lease rods and the fell of the cloth and it is between these two points the tension on the warp yarn is applied during the weaving cycle. A point on the warp yarn while traversing from the lease rod to fell of the cloth would experience a number of stress cycles depending on the speed of the loom and the distance between these two points. The normal distance between the lease rod and the fell of the cloth on a silk loom is around 150 cm [9]. For a loom speed of 120 ppm and a pick density of 31.5 picks per cm, the traverse speed of warp would be 120/31.5 = 3.8 cm per minute. Any point on the warp would reside in the length between lease rod and the fell of the cloth, for a period of 150 cm + 3.8 cm/min = 39.47 or about 40 minutes. Thus the number of stress cycles any point on the warp between lease rod and the fell of the cloth undergoes during the weaving process is 40 min x 120 cycles per minute = 4800. So, 5000 stress cycles of loading

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and unloading was chosen as one of the factors of the experiment.

In order to assess the tensile deformation at an earlier stage i.e., before completion of 5000 cycles, 1000 cycles of loading and unloading was chosen as another factor of the experiment and 0 cycle was considered as the control.

E. Method

The experiments were done on Instron tensile tester. A gauge length of 100 mm was selected. The samples were conditioned and tested in the standard atmospheric conditions i.e. 65±2% R.H. and 27±2^{0}C temperature. In all the cases, 30 readings were recorded. For each type of warp yarns, the number of cycles for pre-loading was 0 cycle (control). 1000 cycles and 5000 cycles. In each cycle, the yarn was loaded from the base tension load to the maximum beat-up load and returned to the base tension load, completing around 120 cycles per minute. A time interval of 60 seconds was allowed for the yarn to relax and then the tensile test was conducted till rupture with a rate of traverse of 150 mm/min.

III. RESULTS AND DISCUSSION

The load extension curves (Fig.1) for RS, UO and DO show the extent of deformation in their tensile characteristics after cyclic loading. The average values were considered while plotting those graphs.

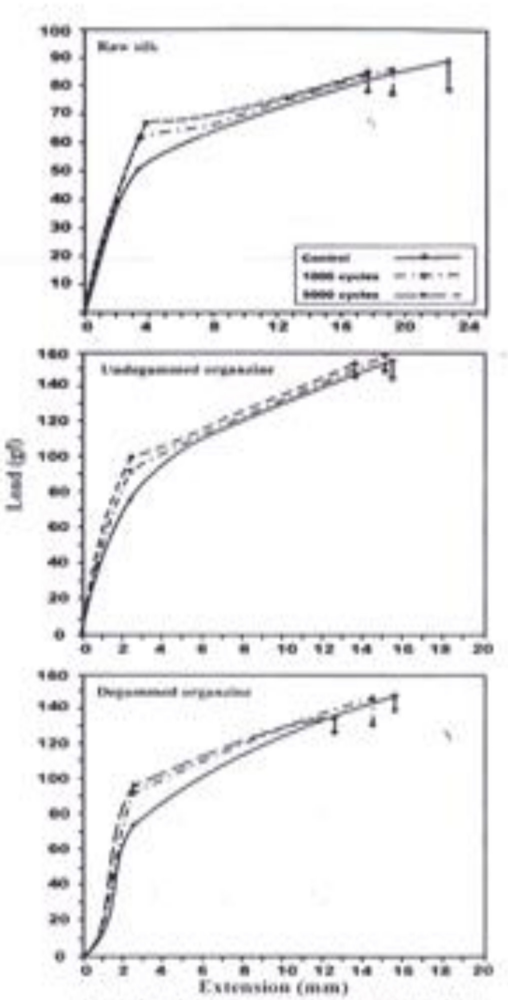

Fig. 1: Load extension curve for the three warp types for control, 1000 cycles and 5000 cycles

Test		Raw Silk			Undegummed organzine			Degummed organzine		
		Control	1000 cycles	5000 cycles	Control	1000 cycles	5000 cycles	Control	1000 cycles	5000 cycles
Breaking load (cN0	Mean	86.8	84.45	82.49	151.3	155.9	151.3	145.5	144.7	132.2
	CV%	5	7.3	6.3	4.7	4.9	9.8	4.2	5.1	4.5
Tenacity at yield point (cN/tex)	Mean	20.2	25.1	26.6	15.3	18.3	20.1	17.5	21.7	23.0
	CV%	3.5	3.5	4.3	2.9	3.4	3.9	3.5	2.8	3.1
Elongation at yield point (%)	Mean	3.3	3.4	3.9	2.41	2.38	2.54	2.54	2.49	2.65
	CV%	13.6	17.4	25.6	8.7	6.7	13.4	7.1	9.6	17
Maximum Elongation (%)	Mean	22.6	19.1	17.8	15.7	15.1	13.8	15.8	14.6	12.7
	CV%	11.5	15.3	15.1	12.4	9.1	21.9	9.4	10.1	10.6
Tenacity cN/tex)	Mean	38.7	37.2	36.8	31.0	31.9	31.0	35.4	35.2	32.2
	CV%	5.0	7.3	6.2	4.6	5.0	9.7	4.2	5.0	4.4
Energy (gm.cm)	Mean	100.6	82.1	75.4	121.8	120.4	108.5	117.8	108.3	85.9
	CV%	15.3	21.9	19.6	16.4	12.5	25.9	13.1	14.1	13.9

Table 2 - Change in tensile characters between control and treated warp

Warp type	No of cycles	Breaking load	Tenacity yield point	Elongation yield point	Maximum elongation	Maximum tenacity	Energy at maximum load
Raw silk	1000	-3.5*	24.4*	1.8	-14.9*	-3.4*	-17.5*
	5000	-4.6*	31.9*^	18.2*^	-20.7*	-4.6*	-24.2*
Undegummed	1000	3.0	20.2*	-1.2	-3.9	3.1	-1.2
organzine	5000	-5.2	31.8*^	5.8*^	-16.9*^	-5.1	-16.7*^
Degummed	1000	2.8	24.2*	-2.0	-7.5*	2.8	-4.6
organzine	5000	-6.0*^	31.8*^	4.3	-19.7*^	-5.9*^	-24.3*^

Multivariate analysis showed that there is significant difference between the control and corresponding warp yarns after 1000 cycles and also after 5000 cycles. Later, univariate analysis and post hoc analyses were carried out in order to assess the significance of the levels of treatment in all the three warp types separately. The percentage decrease and their significance are given in Table 2.

*indicates the change between control and treatment is significant at 1%

^indicates that the change between 1000 cycles and 5000 cycles is significant at 1%

The energy [10] at yield point (Fig.2) was calculated using the average graphs by finding the area under the curve and the Initial Young's Modulus (Fig.3) was measured in all the three warp types.

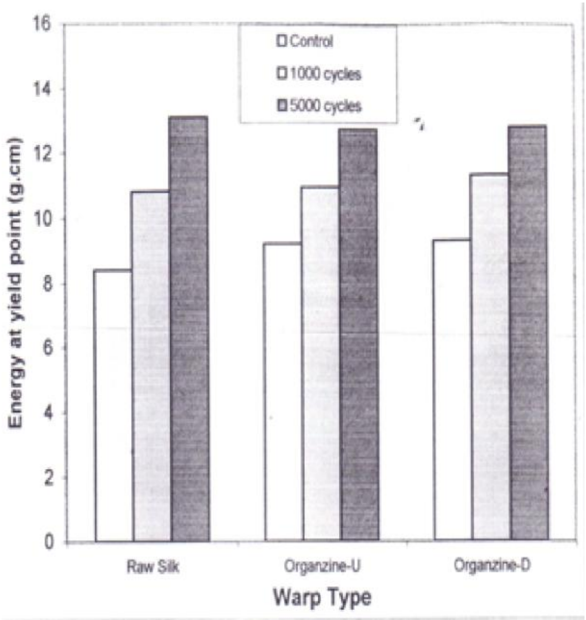

Fig 2 Comparison Of Energy At Yield Point For The ThreeWarp Types

A.Change in tensile properties observed in case of RS

Cyclic loading reduces the breaking load of the yarn. Tenacity at yield point increases with cyclic loading, .5000 cycles recording higher increase than 1000 cycles. Elongation at yield point after 5000 cycles increases but is unaffected after 1000 cycles. Maximum elongation, tenacity and thus the energy decrease significantly after cyclic loading.

B. Change in tensile properties observed in case of UO

There is no significant difference in the breaking load and tenacity even after 5000 cycles. Tenacity at yield point increases with cyclic loading. Higher values are obtained after 5000 cycles than 1000 cycles. This trend is similar to raw silk. Elongation at yield point after 5000 cycles but is unaffected after 1000 cycles. there is no significant difference after 1000 cycles.

C.Change in tensile properties observed in case of DO

There is significant reduction in the breaking load and tenacity after 5000 cycles but such a trend is not observed after 1000 cycles. The tenacity at yield point has increased significantly with cyclic loading and the trend is similar as in RS and UO. There is no significant difference in elongation at yield point after cyclic loading, while there is significant difference in the case of UO ad RS. Maximum elongation and energy decrease significantly after cyclic loading.

D.Change in tensile properties at the hookean region

Tenacity at yield point has increased by about 23% after 1000 cycles and about 31% after 5000 cycles in all the three warp types. It has been observed that the shift is higher for 5000 cycles when compared to 1000 cycles in all the three varieties of warp yarns. This indicates that structural modification takes place and the yield point is shifted to a higher level making a difference in the hookean region. The elongation at yield point has increased only in the case of RS and UO by 18% and 6%, respectively, but not in the case of DO. Energy increases with the increase in number of cycles which indicates that energy is absorbed at the yield region. The initial young's modulus increases i.e. the yarn becomes less easily extensible with cyclic loading in all three types of warp. This implies strain hardening.

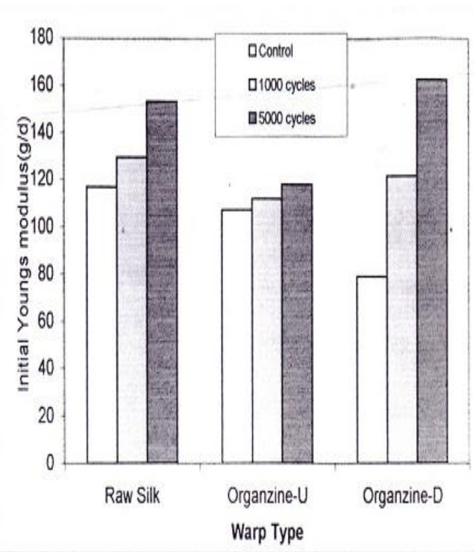

Fig 3 Comparison Of Initial Young's Modulus For The Three Warp Types

E.Change in tensile properties in the post yield region

In the case of raw silk, tenacity has decreased significantly by 3.5% after 1000 cycles and by 4.6% after 5000 cycles. After 5000 cycles of stress cycles, maximum elongation has decreased by about 17% to 21% in all the three warp types. In the case of RS and DO, the decrease in maximum elongation is significant even after 1000 cycles and the same has decreased by about 15% in the case of RS and about 8% in the case of DO. Energy also decreases after 5000 cycles in all the three warp types by about 17% to 24%. In other words, energy is dissipated. In case of RS, the energy has reduced after 1000 cycles by about 17%.

IV. CONCLUSIONS

i) RS has been affected the most after cyclic loading. In comparison to plied and due to cyclic loading than UO. The presence of sericin in the organzine yarn helps the yarn to withstand the stresses and strains during weaving to a greater degree. Degummed yarn is easily extensible and more ductile as indicated by a higher initial modulus and thus suffers higher deformation. While comparing the single and plied yarns, it is obvious that the single yarn suffers more deformation. This is because even though the base tension can be reduced proportionately to denier, the tension at beat-up cannot be reduced proportionately.

ii) The silk warp yarns absorb energy in the yield region (Fig.2) and dissipate energy as the breaking point approaches with increase in the number of cycles. As energy is a measure of toughness, this indicates that the yarns have become less resistant to break.

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iii) It can be observed from the values of young's modulus that the DO which is the most easily extensible of the three warp types has become the lease easily extensible after 5000 cycles loading (Fig.3). This implies that cyclic loading has caused noticeable changes in the three types of yarns to various extents.

iv) Cyclic loading and unloading modifies the tensile deformation characteristics of the yarns and the deformations in the hookean region suggest that strain hardening has occurred.

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