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A Study of Collapsed Balloon Spinning and Its Effect on Cotton Yarn Properties

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Abstract: *Yarn tension during spinning affects the production rate as well as the quality of the yarn produced. Several efforts have been taken to reduce yarn tension for increasing the production rate. In modern spinning system, the main parameters that are giving tension to the yarn such as balloon formation and traveller has been totally eliminated. The 'collapsed balloon technique' is one, which is previously used only in woolen spinning to reduce yarn tension. In this study the collapsed balloon introduced in cotton spinning system also by changing some process parameters. And the quality of yarn produced in such a collapsed condition was compared with yarn produced in un-collapsed condition. The balloon characteristics such as balloon diameter, rotational speed, tension and collapse time were analyzed in both the collapsed and un-collapsed conditions. In collapsed balloon condition, the balloon diameter is greatly reduced which in turn reduces the yarn tension. The yarn hairiness shows lower value in the yarn produced at collapsed condition. However, the yarn unevenness value is higher and no significant difference in strength and elongation.*

Keywords: *balloon height, balloon diameter, collapsed balloon, spindle speed, traveller weight, yarn tension, yarn quality*

I. Introduction

During spinning, yarn is rotated around the spindle axis to give tensile strength by inserting twist. The rotation of the yarn forms an imaginary surface around the spindle is called as balloon. Understanding the balloon dimensions and the tensions created in the yarn by the rotation of balloon is extremely important for the design and efficient operation of ring spinning frames because which directly affects both quality and productivity. Yarn tension during spinning must not exceed the strength of the yarn at any instant otherwise the yarn would break. In contrast, yarn tension is necessary to spin at a high enough tension to prevent larger balloon diameter formation, or else the yarn will abrade on balloon control ring and lappet guide causes more amount of hairiness, moreover the balloon will collapse on the rotating cop causes to yarn break [1,2]. The yarn tension also affects the structural parameters like fibre migration and packing density of the yarn, which in turn affects the tensile properties of the yarn. As the yarn tension increases the fibre migration decreases and packing density increases [3]. Many research works [4-7] have been carried out on the parameters that affecting the balloon dimension and the yarn tension and stated that spindle speed, traveller weight, ring and traveller friction, ring to cop diameter ratio and height of the cop as important parameters. Also a number [8] of efforts have been taken to reduce balloon tension by reducing the frictional force between ring and traveller, changing spinning angle and reducing the height of the balloon. In new spinning system such as rotor, air-jet and friction etc the balloon formation and employing ring and traveller have been fully eliminated [9].

In woollen spinning industry, to reduce tension in the yarn 'collapsed balloon technique' is being utilized. The instability of the spinning balloon resulting in the formation of a 'neck' in the balloon that engages onto the rotating cop is referred to as 'collapsed balloon'. The collapsed balloon reduces the balloon diameter and hence the yarn tension, which in woolen spinning permits to achieve higher production rate, to reduce spindle-to-spindle distance, to use lengthy package with bigger diameter. The balloon collapse will occur only if any parameter such as the spindle speed, the balloon height or yarn linear density is higher or the traveller weight is lower [1].

In cotton spinning systems, normally very finer count is being spun when compared to woolen spinning, so the chance of forming collapsed balloon is very less. In this work, collapsed balloon is intentionally introduced in the cotton spinning system to reduce the yarn tension and to analyze the yarn properties produced in such a collapsed balloon condition. The balloon characteristics such as the balloon diameter, tension and rotational speed and their effect on the yarn quality were compared at collapsed and un-collapsed conditions.

II. Materials And Methods

The balloon diameter, rotational speed, tension and collapse time measurements were carried out throughout the cop build up on the machine not fitted with balloon control ring and separator. The presence of balloon control ring causes two balloons i.e. one above and another below the control ring. And the balloon separator will also act as a balloon controller when the balloon strikes. Hence, to measure the actual balloon diameter, it was decided to conduct without fitting balloon control ring and separator.

2.1 Materials Preparation

The ring frame LRG5/1 was set for producing 50s cotton combed yarn with 26.57 TPI from the roving of 1.25Ne. The distance between the thread guide and ring rail was kept to 28.4cm before the start of the machine. The yarn samples were produced for three different spindle speeds (10000, 14000 and 17500 rpm) and three different traveller weights (16/O, 12/O and 8/O) with and without using balloon control ring and separator.

2.2 Measurement of Balloon Diameter and its Speed

For easy visibility a white paper scale fixed on a blackboard was kept behind the rotating balloon. Light rays coming from the stroboscope were sent over the rotating balloon and light-emitting speed was tuned equal to balloon rotational speed to stop optically the movement of the balloon [10]. At this condition, the maximum diameter of the balloon was noted from the paper scale and the light emitting speed displayed in the stroboscope was taken as balloon rotational speed.

2.3 Measurement of Effectiveness of Balloon Collapse

The effectiveness of balloon collapse is the time for which the balloon remains collapsed on the cop expressed as percentage of the ring rail traverse time. The balloon collapse time was noted using a digital stop clock for 10 traverses of the ring rail and the average value (t_a) was calculated. Also the time taken for one traverse of the ring rail (t) was noted using digital stop clock. The effectiveness of balloon collapse is expressed as follows

$$\text{Effectiveness of balloon collapse} = \frac{t_a}{t} X 100$$

2.4 Measurement of Yarn Tension

Measuring yarn tension for staple fibre spinning is very difficult because when the tension-measuring device is kept between the lappet and front roller, the twist flow towards front roller is restricted due to the friction developed between the yarn and device, which causes the yarn to break. To overcome this problem, pre-twisted (16 TPI) yarn of same variety produced at low spindle speed (7000rpm) was fed directly at the backside of the front roller and twisted again so as to obtain the same yarn twist (26.75 TPI) in the resulting yarn [11]. While twisting the pre-twisted yarn, the tension in the yarn was measured between lappet guide and front roller by using the paramount digital yarn tension meter.

2.5 Yarn Testing

The every permutation of spindle speed and traveller weight, 10 cops were spun and the collapsed balloon occurred portion of the cop was noted, which is usually bottom of the cop**.** The yarn hairiness and U% were determined using a PREMIER evenness tester at top portion (un collapsed) and then in bottom portion (collapsed balloon) of the cop. Two tests at top portion and two tests at bottom portion for each cop was carried out and the average values (of the 20 tests) were tabulated (Table 3). The yarn tensile strength and elongation% were determined using PREMIER TENSOMAX and two hundred and fifty tests per sample were done.

III. Results And Discussions

3.1 Effectiveness of Balloon Collapse

The collapsed balloon formation was observed to occur only in the case lower traveller weights (18/O and 12/O). In the case of heavier traveller (8/0), the balloon remained stable (normal) throughout the cop build up for the given three different spindle speeds. The Table 1 indicates the effectiveness of balloon collapse at different balloon heights for different spindle speeds and traveller weights. It is observed that for a given spindle speed and traveller weight, the effectiveness of collapse first increases to a small amount and then decreases as the balloon height decreases. This is because the yarn is initially wound on bare bobbin where the yarn tension is higher which will restrict the balloon to collapse and as the cop builds up the yarn is wound on larger diameter where the yarn tension decreases that causes a slight increase in effectiveness of collapse and hence collapse time increases. After that the decrease in balloon height causes to decrease the balloon diameter and hence, the effectiveness of balloon collapse decreases gradually and finally vanishes. From the Table 1 it is also obvious that the increased spindle speed and reduced traveller weight enhances the effectiveness of balloon collapse.

Increase in spindle speed and decrease in traveller weight increases the diameter of the balloon and also rotational speed of the balloon. At higher balloon diameter and speed the air-drag force acting against to the balloon rotation movement increases that cause to increase the effectiveness of balloon collapse. There fore, balloon collapse time increases.

Table 1. Effectiveness of Balloon Collapse at Different Balloon Heights for Various Spindle Speed and Traveller Weight

Spindle Speed (rpm)	Balloon Height (mm)	Traveller weight 18/O	Traveller weight 12/O
10000	28.4 (bare bobbin)	78.76	70.37
	27.4	79.23	70.89
	26.4	64.69	57.80
	25.4	54.95	39.57
	24.4	44.34	21.78
	23.4	22.13	Nil
	22.4	Nil	Nil
14000	28.4 (bare bobbin)	83.46	78.44
	27.4	85.32	79.54
	26.4	77.47	69.58
	25.4	64.75	55.42
	24.4	50.54	40.23
	23.4	37.94	18.33
	22.4	29.76	Nil
17500	28.4 (bare bobbin)	87.52	84.46
	27.4	89.02	86.32
	26.4	80.20	76.79
	25.4	69.76	62.35
	24.4	54.67	48.73
	23.4	38.39	22.13
	22.4	26.73	Nil

3.2 Balloon Diameter

The diameter of the balloon measured at four different balloon heights while winding yarn at full package diameter and empty package diameter (i.e bare bobbin) for different spindle speed and traveller weight are given in Table 2 and analyzed by considering the balloon collapse time as a fraction of the ring rail cycle time (Table 1 and section 3.1). As the ring rail traverses upwards, the diameter of the winding point of the package decreases and the tension in the yarn increases. So the balloon diameter is expected to decrease[1]. But in this study (Table 2) it is observed that at cop bottom portion due to balloon collapse there is a lower balloon diameter while winding yarn onto greater package diameter. As the balloon height decreases, the following trend was observed that the diameter increases while winding yarn at full package and the diameter decreases while winding yarn at bare package due to decrease in balloon collapse time, the diameter of the balloon decreases with increase in traveller weight, and increases with increase in spindle speed. As the traveller weight increases the centrifugal force acting on the thread at ring portion increases, to balance this centrifugal force, inward force on the balloon increases. So the diameter decreases. When the spindle speed increases, the centrifugal force acting on the thread increases that causes to increase the diameter of the balloon.

Table 2. Effect of balloon height, spindle speed and traveller weight on balloon diameter, traveller speed and yarn tension (Without balloon control ring)

Balloon height at BT in mm	Position of cop	18/O BD	18/O TS	18/O YT	12/O BD	12/O TS	12/O YT	8/O BD	8/O TS	8/O YT
Spindle speed = 10000 rpm										
285	BT	65	9883	3.0	68	9849	3.3	71	9813	4.9
	TT	68.5	9848	4.3	67	9803	4.5	64	9776	7.2
255	BT	63	9946	4.5	68	9894	5.7	69	9866	7.4
	TT	69	9879	6.3	62	9851	7.2	58	9823	8.0
215	BT	62	9952	5.2	59	9913	5.6	56	9892	6.3
	TT	50	9904	5.5	46	9882	5.9	42	9857	7.0
175	BT	62	9978	4.9	50	9940	5.3	47	9926	6.0
	TT	48	9926	5.1	41	9903	5.4	38	9886	6.5
Spindle speed = 14000 rpm										
285	BT	67	13862	3.5	71	13810	5.6	72	13740	9.8
	TT	65	13836	5.0	65	13771	8.1	68	13692	16.4
255	BT	62	13884	6.5	64	13839	7.6	74	13765	9.1
	TT	64.5	13832	10.2	66	13784	13.9	67.5	13712	14.7
215	BT	69.5	13896	9.6	68	13842	13.1	66	13803	15.2

	TT	54	13841	7.1	52	13779	10.4	46.5	13741	12.7
175	BT	66	13907	8.0	64	13859	10.5	58	13817	12.6
	TT	49	13861	6.3	45	13787	8.6	40	13752	12.8
Spindle speed = 17500 rpm										
285	BT	67	17282	3.1	69.5	17196	6.3	76	17107	15.0
	TT	69.5	17205	6.6	68	17122	16.1	64	17044	19.5
255	BT	72	17340	7.6	70	17239	13.2	74	17153	15.4
	TT	74	17262	11.2	60	17148	14.6	58	17100	17.0
215	BT	70	17303	6.3	66	17243	12.5	64	17197	14.9
	TT	58	17228	8.4	54	17160	11.8	48	17117	15.2
175	BT	67	17343	6.0	64	17274	9.4	54	17236	10.2
	TT	53	17276	8.1	45	17210	10.3	43	17167	12.7

(BT – Bottom of the ring rail traverse; TT – Top of the ring rail traverse; BD – Balloon diameter in mm; TS – Traveller speed in rpm; YT – Yarn tension in g)

3.3 Yarn Tension

The Table 2 indicates that the yarn tension measured between the thread guide and the front roller is drastically reduced in the case of collapsed balloon condition. This is due to the reduction in centrifugal force on the thread, which causes to decrease the downward pulling force through the lappet guide, the decrease in frictional force between the traveller and ring. The engagement of the collapsed yarn in the reverse direction with the rotating cop obtains an extra energy for the rotation of traveller that causes to reduce the frictional force between the ring and travellers. From the Table 2 it is also observed that the increase in spindle speed and traveller weight increase the yarn tension. For a given spindle speed, as the balloon height decreases the effectiveness of balloon collapse also decreases which leads to increase the diameter of the balloon and the yarn tension (In the case of 12/O and 18/O). This trend remains till the middle of the package buildup after which the decrease in balloon diameter reduces the yarn tension.

3.4 Yarn Uneveness

From analysis of the data given in Table 3 it is inferred that the yarn unevenness increases with the increase in spindle speed, which is statistically significant in the case of yarn samples produced without balloon control rings, but not significant in the case of yarn produced with balloon control ring. The use of balloon control ring controls the diameter of the balloon, which reduces the tension variation in the balloon. There fore, the unevenness decreases. From the Table 3 it is also observed that the yarn unevenness decreases with increasing traveller weight in the case of without balloon controlled samples where as increases in the case of with balloon controlled samples. The unevenness measured at collapsed balloon potion (bottom portion) shows higher value than at un-collapsed portion (top portion) in both with and without control ring. At bottom portion, while winding at full package diameter the balloon collapses that causes to decrease the balloon diameter, as the diameter of the winding package decreases the balloon collapse is released suddenly which causes to sudden change in yarn tension and hence the unevenness increases.

3.5 Yarn Hairiness

In the yarn samples spun with balloon control ring there is a trend of decreasing hairiness with increase in traveller weight. This trend is reversed in the case of yarn spun without balloon control ring i.e. the yarn hairiness increases with increase in traveller weight. From the Table 3 it is observed that as the spindle speed increases the hairiness value increases in both yarn samples produced with and without control rings. As the spindle speed increases, the tension in the yarn increases dramatically, which increases the frictional force between the yarn and the traveller, and between the yarn and the lappet guide leading to increased yarn hairiness. The other factor that affects yarn hairiness is the increase in air-drag force while increasing spindle speed that acts against to the thread movement and untwists the loosely twisted fibres on the yarn surface [12].

The yarn hairiness value is higher in the samples produced with balloon control ring compared to without balloon control ring at both collapsed and un-collapsed portion. As the balloon diameter increases, the abrasion of the yarns on the balloon control rings increases that leads to more hairiness. No such abrasion takes place in the case of yarn samples spun without control rings, but the yarn will abrade over the cop surface only when the balloon collapses. However, this abrasion of the yarn over the cop surface is proportional to the delivery rate only where as the abrasion of the yarn over the control ring is proportional to the yarn rotating speed. The absence of balloon control ring and separator increases the effectiveness of balloon collapse due to more air resistance. At collapsed state the yarn tension is very low which results in lower frictional forces between yarn and traveller that leads to less hairiness.

3.6 Yarn Strength and Breaking Elongation

The tensile data given in Table 3 shows clear trend that the breaking elongation decreases with increase in spindle speed and also that the observed variations in yarn strength with the changing of the spindle speed, (both with and without control rings) was not statistically significant. The increase in traveller weight does not shows any significant difference in yarn strength and its breaking elongation, in the samples produced without balloon control ring but the strength and its elongation decreases significantly with increase in traveller weight in the yarn samples produced with balloon control rings. The overall observation of strength and elongation at collapsed condition shows poor value than at un-collapsed condition. This is due to higher unevenness of the yarn at collapsed condition.

Table 3. Effect of spindle speed and traveller weight on yarn quality produced at with and without yarn collapse

Yarn quality parameters	Without balloon control ring						With balloon control ring					
	18/O		12/O		8/O		18/O		12/O		8/O	
	CC	UCC	CC	UCC	CC	UCC	CC	UCC	CC	UCC	CC	UCC
Spindle speed = 10000rpm												
U%	13.34	11.86	11.59	11.37	11.43	11.30	10.87	10.14	11.32	10.27	11.06	10.67
Hairiness index	3.5	3.62	3.9	3.73	3.94	3.86	3.94	4.16	3.74	3.81	3.87	3.83
Breaking force in gm	251.66	258.75	249.96	251.84	256.4	252.06	259.34	268.07	259.33	263.49	251.02	259.13
Breaking elongation %	5.22	5.27	5.24	5.21	5.24	5.18	5.62	5.73	5.34	5.65	5.05	5.37
Spindle speed = 14000rpm												
U%	13.67	12.33	11.88	11.49	11.85	11.67	10.53	10.22	10.51	10.4	10.60	10.31
Hairiness index	3.77	3.89	3.82	3.84	3.98	3.87	4.59	4.53	4.32	4.12	4.03	3.96
Breaking force in gm	240.34	246.07	255.8	259.03	234.7	261.09	270.33	288.34	264.40	273.46	274.63	262.71
Breaking elongation %	4.89	4.92	4.93	5.01	5.14	5.23	5.55	5.69	5.08	5.61	4.97	5.46
Spindle speed = 17500rpm												
U%	14.04	12.32	12.31	11.74	12.21	11.95	10.69	10.64	10.28	10.35	10.53	10.47
Hairiness index	3.96	4.13	4.02	3.95	4.21	4.08	4.46	4.11	4.41	4.27	4.16	4.24
Breaking force in gm	224.54	241.02	251.46	249.06	253.86	233.64	267.10	286.53	251.70	274.98	229.50	241.14
Breaking elongation %	4.11	4.27	4.22	4.38	4.27	4.59	5.50	5.54	5.22	5.37	4.74	5.19

CC – Collapsed condition UCC – Un-collapsed condition

IV. Conclusion

The yarn manufacturers are constantly concentrating to increase the production rate without affecting the quality of the yarn. The yarn tension and traveller speed are most important parameters that limits the production rate. Several efforts have been taken towards to reduce the yarn tension. In modern spinning system the problematic balloon formation and traveller have been eliminated to reduce yarn tension. Conventional spinning system is not possible to remove balloon and traveller, but possibility lies to reduce yarn tension by collapsing the balloon. Balloon collapse is more likely to occur during winding on larger package diameters at higher balloon heights. Increase in spindle speed as well as reduction of traveller weight increases the possibility of balloon collapse. Balloon collapse reduces the balloon diameter that leads to less yarn tension. Hairiness values of yarns produced from a collapsed state shows improved results over yarns produced in the un-collapsed state due to less yarn tension. However, the yarn unevenness increases at collapsed state, strength and elongation does not show any significant difference. In the absence of control rings, the hairiness increases with increasing traveller weight and spindle speed. When balloon control rings are used, the hairiness decreases while increasing the traveller weight due to reduction of yarn abrasion with control ring.

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