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Abrasion Resistance of Polyester Air – Jet Yarns

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Air- jet spinning system, with its higher productivity for manufacturing medium and fine yarns, is growing popular in India. However, the yarns produced by the system have quality attributes quite different from that of the ring spun yarns. Most of the information available on air-jet spinning is related to the influence of fiber properties and process parameters on yarn structure and ultimate properties. Information on abrasion property of air-jet yarns and factors influencing the same ids less extensive. Yarn abrasion determines the fabric abrasion, surface characteristics and the durability of fabrics to a great extent.

Fibers that are likely to form better wrappers impart higher abrasion resistance to yarns and thereby fabrics. The present study is towards improving the abrasion resistance of air-jet yarns by process optimization. The work is aimed to evaluate the effect of process variables like delivery speed, main drat ratio, first nozzle pressure (N_1), second nozzle pressure (N_2), first nozzle to front roll distance (N_1 – front roll distance) and the feed ratio on abrasion resistance of air-jet spun from 100% polyester fibers.

Three yarn liner densities of 19.68, 14.76 and 9.84 tex were spun using air-jet spinning system by appropriately altering the process variables. A total number of 81 samples were produced consisting of 27 yarns of each liner density.

A total of 27 were produced by maintaining the delivery speed at three different levels and the main draft ratio at three different levels and by producing three liner densities of yarn. Similarly another batch of 27 samples were spun by maintaining first nozzle pressure, second nozzle pressure and yarn linear density each at three different levels. Third batch of 27 samples were spun by maintaining N_1 – front roll distance, feed ratio and yarn linear densities each at three different levels.

In all, 81 yarn samples were spun and they were tested for abrasion resistance (number of abrasion strokes to break the specimen) using Zweigle yarn Abrasion Tester Model G551. polyester fibers of 40mm length and 0.111 tex were used for the present study. A 20 readings/sample were taken for assessing the abrasion resistance of yarns. Yarn diameter measurements were made using projection microscope for yarn linear density of 9.84 tex.

Results and discussion:

The abrasion resistance values (for 40 mm length and 0.111 tex fineness) was taken as abstract from the earlier published report of Basu & Chellamani. It is clear from that air-jet yarn has lower abrasion resistance compared to that of ring spun yarns. Nikolic stated that air-jet yarns have better abrasion than ring spun yarns, due to the transverse strips of wrap fibers in the structure of air-jet spun yarn resist axial disposition with friction and stress. This imparts higher resistance to abrasion for air-jet yarns when compared to ring spun yarns.

However, these findings are contradictory to what has been reported by Basu & Cheelamani. This anamoly may be due to difference in process variables employed by the two group of researchers. To verify this, air-jet yarns of 19.68, 14.76 and 9.84 tex were spun under different process conditions.

Table 1 : Abrasion Resistance of Air –Jet Yarns

Sl. No.	Process Variables						Abrasion Resistance (No. of strokes to break the specimen) Yarn Linear Densities (tex)		
	Delivery speed (mpm)	Main Draft (kg/Cm^2)	N1 pressure (kg/Cm^2)	N2 pressure (kg/Cm^2)	N1 Front roll Dist. (mm)	Feed ratio	19.68	14.76	9.84
1	140	26.8	2.5	3.5	39.0	0.98	200	167	97
2	180	26.8	2.5	3.5	39.0	0.98	344	208	62
3	220	26.8	2.5	3.5	39.0	0.98	192	133	55
4	140	35.7	2.5	3.5	39.0	0.98	262	177	109
5	180	35.7	2.5	3.5	39.0	0.98	363	240	80
6	220	35.7	2.5	3.5	39.0	0.98	230	142	67
7	140	45.0	2.5	3.5	39.0	0.98	311	193	128
8	180	45.0	2.5	3.5	39.0	0.98	435	262	97
9	220	45.0	2.5	3.5	39.0	0.98	272	153	79
10	180	45.0	2.0	3.5	39.0	0.98	254	153	67
11	180	45.0	2.5	3.5	39.0	0.98	430	264	82
12	180	45.0	3.0	3.5	39.0	0.98	359	188	89
13	180	45.0	2.0	4.0	39.0	0.98	225	166	78
14	180	45.0	2.5	4.0	39.0	0.98	274	274	94
15	180	45.0	3.0	4.0	39.0	0.98	328	283	110
16	180	45.0	2.0	4.5	39.0	0.98	217	183	93
17	180	45.0	2.5	4.5	39.0	0.98	223	282	106
18	180	45.0	3.0	4.5	39.0	0.98	316	286	113
19	180	45.0	2.5	3.5	39.0	0.96	312	161	102
20	180	45.0	2.5	3.5	40.5	0.96	336	227	104
21	180	45.0	2.5	3.5	42.0	0.96	345	250	107
22	180	45.0	2.5	3.5	39.0	0.97	339	182	105
23	180	45.0	2.5	3.5	40.5	0.97	343	237	112
24	180	45.0	2.5	3.5	42.0	0.97	356	257	119
25	180	45.0	2.5	3.5	39.0	0.98	431	265	111
26	180	45.0	2.5	3.5	40.5	0.98	361	267	113
27	180	45.0	2.5	3.5	42.0	0.98	370	285	123

The effect of delivery speed, main draft ratio, N1pressure, N2 pressure, N1 – front roll on abrasion resistance of air-jet yarns are given in Table 1. the influence of six process variables, along with yarn linear density, on the abrasion resistance was evaluated with the help of the ANOVA analysis shown in Table 2.

It is clear from table 2 that the delivery speed, main draft ratio and yarn linear density significantly influences on air-jet yarn abrasion resistance. Among the interactive influences, delivery speed with yarn linear density and main draft ratio with yarn linear density were found significant. Abrasion resistance increases with an increase in yarn linear density and increase in the main draft ratio.

In 19.68 tex yarn & 14.76 tex yarns, abrasion resistance increases with an increases in delivery speed from 140 to 180 mpm. With further increase in delivery speed, abrasion resistance comes down. However, in 9.84 tex yarn, abrasion resistance continues to decrease with increase in delivery speed from 140 mpm onwards. Higher abrasion with coarser yarns is due to the greater number of fibers per cross-section and the consequent better uniformity.

As far as delivery speed is concerned, there seems to be an optimum value around 180 mpm. Lower and higher values of delivery speed result in reduced abrasion resistance in19.68 and 14.76 tex yarns. Indra doraisamy and Chellamani observed that the tenacity of polyester/cotton yarn increases

Table 2 : ANOVA Test Results

Process Variables	**Abrasion Resistance**
D	S
M	S
N_1	S
N_2	S
G	S
F	S
Y	S
D*M	S
D*Y	NS
M*Y	S
N_1*N_2	S
N_1*Y	S
N_2*Y	S
G*F	S
F*Y	NS
D*M*Y	NS
N_1*N_2*Y	S
G*F*Y	S

D-Delivery speed; M-Main draft ratio; N- first nozzle pressure; N-second nozzle pressure; G-first nozzle to front roll distance; F-feed ratio and Y- Yam linear density
S – Significant at 95% confidence level
NS- Non –significant at 95% confidence level

With an increase in delivery speed up to 180mpm, and afterwards tenacity starts deteriorating with further increase in speed. This is due to the high surface speed of the front roller. The airflow caused by the rotating rollers plays an importance role.

Upstream of the nip between the two rollers, there is a strong air flow along this nip and away from the axis of the fibre material. Downstream of the nip, the air flows back towards the axis of the fibre material. These airflows, which are perpendicular to the fibre strand, disturb the fibre flow considerably. In particular, the fibres on the surface of the fibre ribbon in the drafting unit risk separation from the rest of the fibres, and those fibres go at least partly out of control.

Table 3 : Average diameter at different delivery speeds

Sl. No.	Delivery Speed (mpm)	Average Yarn Dia. (mm)
1	140	0.149
2	180	0.154
3	220	0.158

Studies by Punj and Debanth have shown that air-jet yarn tenacity improves upto 190mpm, beyond which it tends to fall down. Since abrasion resistance is very much related to tensile strength it follows a similar trend as yarn tenacity in regard to the spinning speed.

However, I n fine count (9.84tex), 140 mpm seems to be the optimum level and increase beyond 140 mpm continue to bring down abrasion values. With a view to understanding the reason for this phenomenon, the change in average yarn diameter for 9.84 tex yarn spun at different delivery speeds was found out and given in table 3.

With increase in delivery speed, the yarns become less compact, which in turn could be expected to reduce the inter-fibre friction. The decrease in inter-fibre friction (higher values of inter-fibre friction resist the pulling out of fibres during abrasion) is logically the reason behind the reduction in abrasion with increase in delivery speed.

The wrapper fibres, which effectively bind and shield the core, increases with increase in main draft, resulting in higher abrasion resistance. Continual increase in abrasion due to increase in the main draft ratio was noticed in all the three yarn linear densities. From this it may be inferred that the critical value of the main draft (from the point of view of core-sheath ratio) lies at a level higher than the range of main draft ratios covered in this investigation. Tyagi and others reported that the increase in the main draft ratio increases abrasion resistance due to the higher incidence of wrapper fibres.

The ANOVA results (table2) show that N_1 pressure, N_2 pressure and yarn linear density have individual as well as interactive significant influence on abrasion resistance. It could

Be seen from the table 1 that an increase in N_1 pressure increases the abrasion resistance of air-jet yarns, whereas an increase for 14.76&9.84 Tex yarns and decreases for 19.68 Tex yarns.

N_1 pressure is a major factor in producing free fibres, which will later become wrappers. With increase in N_1 pressure, abrasion resistance increases. This could be attributed to the higher incidence of wrapper fibres. However, the extent of improvement in abrasion with N_1 pressure varies between yarns of different linear densities. The improvement in 19.68, 14.76 and 9.84 Tex yarn is 46%, 70% and 41% respectively.

The second jet inserts the false twist to the fibre bundle coming out of the front roller as the N_2 pressure is comparatively higher than the N_1 pressure and the twisting process goes beyond the first nozzle right up to the nip of the front roller. As a result, the percentage of tight wrappers, both short and long, and the wrapper fibre extent increase in N_2 pressure. This could be the factor behind the increase in abrasion with an increase in N_2 pressure in finer yarns. However, in 19.68 tex yarn, an exactly opposite trend is noticed.

From the ANOVA results (Table 4), N_1- front roll distance, feed ratio and yarn linear density significance influences abrasion resistance individually. Among the interactive influences, N_1 – front roll distance with feed ratio, N_1 – front roll distance with yarn linear density and N_1 - front roll distance, feed ratio along with yarn linear density found significant.

It could be seen from the figures 5 and 6 that abrasion resistance increases with in yarn linear density, N_1 – front roll distance and feed ratio.

Wang and Jordan have shown that increase in the gap between the N_1 – front roll distance tends to increase yarn stiffness due to increase in the incidence of wrapper fibres, and this could be the reason for the observed behaviour of yarn abrasion with N_1 – front roll distance. This phenomenon is in accord with the findings of Tyagi and Jindal. In the present study, maximum improvement in yarn abrasion is noticed for 14.76 Tex yarn (41% increases when N_1 – front roll distance is changed from 39.0 to 42.0) with finer and coarser yarns exhibiting lower improvement. With higher values of feed ratio, flexural rigidity tends to go up due to which higher yarn abrasion could be anticipated.

The abrasion resistance of air-jet yarns is highly dependent on process parameters, the major contributing factors being delivery speed and main draft ratio. Depending on the level at which these two parameters are employed, air-jet abrasion resistance can either be lower or higher than that of ring spun yarns.

With increase in delivery speed and main draft ratio, there is an increase in wrapped-in-length along with the number of wrapper fibres, which effectively shield the core, thereby leading to higher abrasion resistance. Coarser yarns have shown higher abrasion values in both the systems of spinning, which is expected, since for coarser yarns, a greater number of fibres will be available to bear the abrasion load.

Coarser yarns show higher abrasion resistance in air-jet as well as ring system of spinning. Depending on the process variables employed in air-jet spinning, the abrasion values can either be lower or higher than that of spun yarns. There seems to be an optimum value of delivery speed in air-jet spinning at which yarn abrasion is maximum and this is influenced by the yarn linear density. The value lies around 180mpm for 19.68 and 14.76 Tex yarns and 140 mpm for 9.84 Tex yarns.

An increasing trend in abrasion resistance is observed with main draft ratio, N_1 pressure, N_1 – front roll distance and feed ratio. The effect of N_2 pressure on abrasion resistance is found to depend on the yarn linear density. Abrasion improves with N_2 pressure in medium and fine yarns and deteriorates in coarse yarns.