Performance of Indian crossbred wool on khadi spinning system

H C Meena[1], D B Shakyawar[2,a], R K Varshney[3] & Ajay Kumar[2]

[1]IKG Punjab Technical University, Jalandhar 144 603 India

[2]ICAR-Central Sheep & Wool Research Institute, Avikangar 304 501 India

[3]Giani Zail Singh, Engineering College, Bathinda 151 001 India

HP Crossbred, JK Crossbred and JK Merino yarns have been spun on the New Model Charkha (NMC) spinning system to find out the suitability of Indian crossbred wool in Khadi sector. These crossbred wools produced in the north temperature region of India have been spun into medium quality yarn linear density of 42 tex. The pure crossbred wool yarns have higher U%, imperfections and hairiness index; and lower tenacity, elongation-at-break and coefficient of friction. The mixing of Australian merino wool with JK crossbred wool significantly improves yarn performance in terms of fineness (31 tex), evenness (U%), imperfections and hairiness index. The tenacity, elongation-at-break and coefficient of friction of mixed yarns increase significantly by mixing of Australian merino wool with JK crossbred wool. These findings will help in increasing the utilization of crossbred wool and reducing the costing of end products.

Keywords: Indian crossbred wool, Khadi sector, NMC charkha, Yarn properties, Wool

Khadi refers to hand spun and handloom textile production. It plays an important role in generating employment opportunities in the unorganized rural non-farm sector, which contributes significantly in rural economy of the country. Khadi sector predominantly uses cotton and wool fibre for yarn production on different Charkha systems[1]. The cotton Khadi sector is well established, however woolen Khadi sector struggles due to fibre shredding, harsh and prickling yarn. The products made from pure indigenous wool are inferior in quality in terms of higher harshness and fibre shredding, resulting in poor acceptance among consumers. There is a scope to improve wool khadi yarn quality through proper fibre mix selection and spinning interventions.

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[a]Corresponding author.
E-mail: dbshakya_67@yahoo.co.in

Wool produced in India has diverse quality attributes due to different climatic conditions across the country. The majority of wool produced is medium-coarse (25-40 µm) and thus not suitable for production of quality fabrics, viz. suiting, knitwears, etc. The Indian crossbred wool produced in J & K, Himachal Pradesh and Uttarakhand has fineness about 22-25µm which is not suitable for high end suiting fabric. However, such wool are suitable for Khadi sector[2]. Due to lack of information, Khadi sector is not using these crossbred wools, rather, it consumes about 1 Mkg of Australian merino wool annually[3]. Australian merino wool is costlier and suitable for production of high value products like suiting, etc. State khadi boards are using Australian merino wool for manufacturing of coarser and heavy weight khadi products. The utilization of Australian merino wool in khadi sector is not only under utilized but uneconomical too. Moreover, this practice also discourages Indian farmers to produce crossbred wool in the country. Thus, the objective of the present study is to encourage utilization of Indian crossbred wool in the khadi sector by mixing it with Australian merino wool and also to improve the spinnability and quality of Indian woolen products manufactured from yarn produced on NMC charkha.

NMC charkha is a modified version of Amber charkha used in the khadi system for woollen spinning[4]. Khadi spinning system is divided in two sections, viz. roving making and NMC charkha spinning. NMC charkha requires roving (pooni) as feeding material for making yarn. Kumar[5] reported spinning performance of Bharat merino wool, Indian farm wool and Chokla wool on NMC charkha. He found that the properties of yarn produced from Bharat merino wool are close to the yarn made from Australian merino wool. Sharma *et al.*[6] successfully blended crossbred wool with cotton using NMC charkha to develop khadi yarn and hand knitted fabric. Sharma and Pant[7] used khadi spinning system to prepare different blended yarns of camel hair with merino wool. Sharma and Pant[8] also conducted trials on the blending of camel hair and Chokla wool on the khadi spinning system. They found that blending of Chokla wool with camel hair improves the strength of the blended yarn and performance of knitted khadi

fabrics in terms of strength, abrasion resistance and warmth.

In the present study, to find out the suitability of Indian crossbred wool in Khadi sector, the yarn is spun on the New Model Charkha (NMC) spinning system using HP crossbred (HPC), JK crossbred (JKC) and JK merino (JKM) wool. JK crossbred wool is also mixed with Australian merino wool to improve yarn fineness. The yarn quality performance has been studied in terms of yarn evenness, imperfection, tensile and frictional properties.

Experimental

H P crossbred (HPC) wool was collected from Himachal Pradesh. JK Crossbred (JKC) and JK merino (JKM) wool were sourced from SKUAST-K Srinagar. The Australian merino wool top was procured from M/s Mahadev Woolen Mills, Sunder Nagar (HP). Pure wools and JKC wools were mix separately with Australian merino (AM) wool in the proportions of 25:75, 50:50 and 75:25 for yarn manufacturing.

The wool fibres were processed on modified card and combing was done in combing machine at M/s Mahadev Woollen Mills Sunder Nagar, Himachal Pradesh, India. The combed sliver was given three passages of gill for improving uniformity, and top of 4.6 ktex linear density was prepared. The prepared tops were further drawn on the roving frame for making of roving of desired linear density, viz. 500 tex and 250 tex. The yarns were spun on NMC charkha spinning system in khdai sector at CSWRI Avikanagar. NMC charkha is a modified version of Amber charkha used in khadi system for woolen spinning[7]. The schematic working principle of NMC charkha is shown in Fig. 1. Front roller to middle roller and middle roller to back roller gauge was kept 70 mm and 65 mm respectively. Total gauge length of Amber Charkha was 135 mm and spindle gauge length was 70 mm. NMC charkha was operated manually with the single operator for preparation of all yarn samples. The medium fine count yarn of 41.6 tex (denoted as A) was produced by using 500 tex roving of HPC, JKM & JKC wool. The finer yarn of 31.2 tex (denoted as B) was spun from mixed wool (JK crossbred wool and AM wool) by using 250 tex roving.

The fibre diameter and medullation (%) were evaluated on a computerized projection microscope[9]. The fibre length and crimp (%) were measured with the help of Oiled-plate method as per ASTM

D1575standards. The tensile properties of wool fibres were evaluated on Universal testing strength machine (Instron -5965) as per ASTM D3822 standard. The yarn linear density or count in tex was measured with the help of the warp reel as per ASTM D 2260 method. Yarn twist was measured with the help of Innolab Twist Tester as per ASTM D1482 standards using twist de-twists principle with a gauge length of 500 mm. The yarn tensile properties, viz.. yarn tenacity, elongation and initial modulus, were measured on Universal testing strength machine (Instron -5965). The gauge length was fixed at 250 mm and crosshead speed was kept 300 mm/min. The yarn hairiness index was evaluated by Zweigle hairiness tester (G-565), keeping specimen length of 100 using the standard test method ASTM 5647. The metal to yarn friction was evaluated on Lawson Hemphil yarn friction meter, keeping yarn speed at 70 m/min and using standared test method ASTM D 3108. The yarn diameter was measured using image processing technique[9]. The yarn packing density (μ) was determined using following formula[10]:

$$\mu = \frac{962.1 \times tex}{D^2} \qquad \qquad \dots (1)$$

where tex is the yarn count in the direct system; and *D,* the yarn diameter (μm).

The statistical analysis of variance (two-way ANOVA test) was carried out using Microsoft excel software to detect the significant difference between the means of the properties of yarns spun using three different wool, three different blends of AM and JK crossbred wool for two different counts.
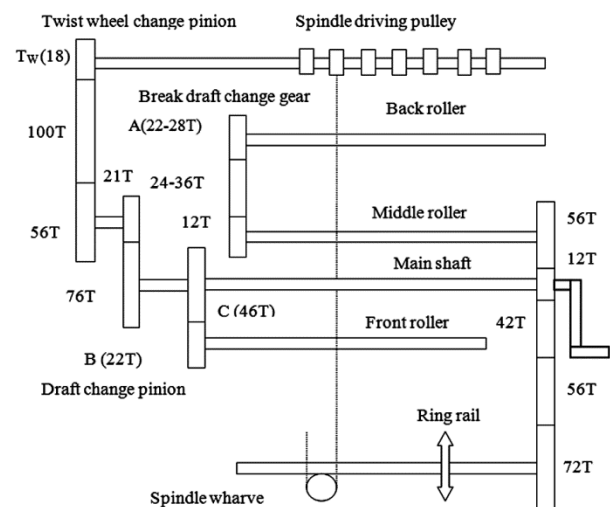

Fig. 1 — Plain view diagram of NMC Charkha

Results and Discussion

Properties of Wool Fibres

The physical properties of crossbred wool and mixes of JKC+AM wool are presented in Table 1. The Australian merino wool has lowest fibre diameter (19.17 µm) followed by JK Merino, HP crossbred and JK crossbred wool and mixes of AM+JK crossbred wool. The fibre diameter shows decreasing trend with increase in proportion of AM wool in the fibre mixes. Indian wool possesses higher medullation (%) than Australian merino wool. JK crossbred wool shows highest value of medullation (8.66%) followed by HP crossbred and JK Merino wools. The proportion of medullated fibres is reduced in the fibre mix after mixing of AM wool with JK crossbred wool. The results are in conformity with the finding of Ramarao & Chopra[11] and Gupta *et. al.*[12]. They observed that medullated wool fibres have the higher diameter than non medullated wool fibres. These facts are attributed to decrease the average fibre diameter of wool mix with the increasing component of AM wool. Australian merino wool has the higher fibre length than other indigenous wools. Mixing of Australian merino wool with JK crossbred wool significantly improves fibre length of mixed yarns. The wool crimp of AM wool is also found higher followed by other indigenous wools, viz. JKM, HPC and JKC.

The tensile properties, such as tenacity, elongation-at-break (%) and modulus of Indian crossbred wools and Australian merino wool are presented in Table 1. It shows that HPC wool fibre has higher tenacity than AM, JKM and JKC wool fibres. It may be due to the higher percentage of crystalline region and the para

cortex structure of HP crossbred wool[13]. Among Indian wool, the presence of medullated fibres significantly reduces the tenacity of wool fibres. Gupta *et. al.*[14] reported that the tenacity (g/tex) is higher in non-medullated fibres than in medullated fibres. Australian merino wool shows higher elongation (36.38%) than other wool fibres, however JK crossbred shows lowest elongation (21.46%). Initial modulus is higher for Indian crossbred wool, such as HPC, JKC and JKM than Australian Merino wool; it may be due to the higher fibre diameter and medullation. HP Crossbred wool has the highest modulus followed by JKM, JKC and AM wool; this is attributed to the higher proportion of para-cortex in crossbred wool than in A M wool[12].

Yarn tex, Uniformity, Imperfections and Hairiness Index

The yarn linear density (tex) of pure and mixed wool yarns are shown in Table 2. The HPC, JKC and JKM wool could be spun into 41.6 tex yarns successfully. The wool mix having 75% of JKC wool with AM wool could be spun into yarn of 35.6 tex, while AM:JKC wool mixes of 50:50 and 75:25 are able to spin in yarn of 29.41 tex. The twist range is found in the range of 400- 538 twist per meter.

The yarn uniformity and imperfections as well as hairiness index of wool and wool mixed yarns are shown in Table 2. The U% and imperfections (thin & thick places and neps) are found lowest in JK Merino yarn followed by HP and JK crossbred wool yarns, mainly because of the lower fibre diameter and higher fibre length and crimp in the JK merino wool as compared to HP and JK crossbred wool. The blending of AM wool with JK crossbred wool significantly

Table 1 — Characteristics of wool fibres

Fibre	Diameter, µm	Medullation, %	Length, mm	Crimps /cm	Tenacity, cN/ tex	Elongation-at-break, %	Modulus M.cN/cm^2
HP crossbred	25.6 (31.4)	1.99	65.9	3.3 (18.5)	17.5 (50.3)	26.3 (34.9)	5.3 (49.6)
JK merino	23.4 (35.8)	5.85	65.4	4.2 (21.2)	12.5 (28.2)	27.5 (25.3)	4.4 (32.4)
JK crossbred	26.1 (30.1)	8.66	56.6	1.6 (29.7)	12.548 (35.1)	21.5 (43.0)	4.3 (34.9)
Australian merino	19.2 (15.4)	0.33	97.5	6.5 (19.2)	12.7 (25.5)	36.4 (40.4)	4.1 (34.5)
AM:JKC (75:25)	19.9 (24.5)	0.66	82.7	-	-	-	-
AM:JKC (50:50)	21.6 (29.7)	0.66	82.1	-	-	-	-
AM:JKC (25:75)	22.2 (28.1)	3.66	82.9	-	-	-	-

Values in parentheses are CV %.

improves the uniformity of yarn and reduces the yarn imperfections. It is observed that the U%, imperfections values of AMJKC50/A and AMJKC75/A yarns are reduced significantly with the increase in the proportion of Australian merino wool in the mixed yarn. It may be due to higher length and lower fibre diameter as well as medullation content of Australian merino fibre than JK wool. It is further observed that finer yarns show the slightly higher U% and imperfections than coarser yarns, but lower than pure wool yarns.

The hairiness index of wool and wool mixed yarn is shown in Table 2. The HP crossbred yarn shows lower hairiness index than JK Merino and JK crossbred wool. This may be due to higher fibre length and lower

medullation percentage. The mixing of AM wool with JK crossbred wool significantly reduces hairiness index, which is attributed to the higher fibre length of AM wool. Liu[15] reported that hairiness occurs because of the fibre length. It also revealed that the finer yarn has the higher hairiness index than the coarser yarn of respective wool mixed yarn.

Tensile Properties of Yarn

The tensile properties of yarns are shown in Table 3. It is observed that among crossbred wool yarns, the tenacity and elongation of JK merino yarn are higher followed by HPC & JKC yarns mainly due to more even yarn and lesser proportion of medullated fibre. The tenacity of HPC and JKC yarn is

Table 2 — Properties of woolen khadi yarns

Yarn	Yarn count tex	Yarn twist TPM	Unevenness (U%)	Imperfections			Hairiness /index /100 m
				Thin places -50% / km	Thick places +50% / km	Neps +200% / km	
HPC100/A	38.8	435.0 (0.8)	23.3	845	255	245	3,440
JKM100/A	38.9	503.1 (5.1)	22.1	865	420	635	4,290
JKC100/A	41.6	497.2 (0.6)	29.3	1095	870	1105	3,980
AMJKC25/A	45.1	476.4 (16.1)	18.3	525	230	390	3,640
AMJKC50/A	41.4	446.1 (11.3)	19.8	590	218	248	2,710
AMJKC75/A	39.1	515.7 (8.0)	16.3	197	410	460	2,583
AMJKC25/B	35.6	531.5 (8.5)	26.6	2705	720	905	4,180
AMJKC50/B	29.8	538.9 (11.4)	20.2	1233	437	347	4,140
AMJKC75/B	29.7	440.5 (3.7)	17.6	397	650	653	3,634

Values in parenthesses are CV%.

Table 3 — Tensile, friction and packing density of woolen Khadi yarns

Yarns	Yarn tenacity cN/tex	Yarn extension, %	Yarn modulus cN/cm²	Yarn diameter μm	Yarns packing density, ρ	Metal to yarn friction, μ
HPC100/A	5.5 (26.3)	9.9 (1.9)	42.1 (145.3)	335.7 (15.4)	0.331	0.242 (2.24)
JKM100/A	8.5 (18.9)	9.5 (22.2)	31.8 (142.9)	360.3 (16.0)	0.288	0.237 (1.77)
JKC100/A	5.5 (31.4)	7.1 (25.4)	52.1 (120)	288.4 (20.6)	0.481	0.246 (2.72)
AMJKC25/A	8.4 (18.3)	7.2 (25.9)	20.5 (86.4)	324.1 (18.2)	0.413	0.248 (1.02)
AMJKC50/A	7.7 (26.1)	8.3 (23.0)	38.4 (59.3)	304.5 (15.9)	0.429	0.254 (1.24)
AMJKC75/A	9.9 (14.0)	7.7 (16.9)	21.2 (62.1)	343.7 (13.8)	0.318	0.247 (1.39)
AMJKC25/B	4.6 (34.2)	6.3 (63.7)	55.5 (93.1)	271.4 (17.2)	0.465	0.230 (1.89)
AMJKC50/B	5.9 (24.6)	7.2 (28.7)	45.8 (119.6)	295.7 (17.1)	0.327	0.254 (1.40)
AMJKC75/B	6.6 (23.)	10.5 (44.1)	54.6 (85.0)	282.1 (16.8)	0.359	0.232 (1.12)

Values in parentheses are CV%.

comparable, however the elongation-at-break is higher in HPC yarn as compared to JKC yarn due to higher crimps in HPC wool. Among yarns produced from mix wool of AM & JKC, the yarn tenacity of AMJKC50/A is observed lower followed by AMJKC25/A & AMJKC75/A yarns. This is attributed to the poor coherence of wool mixes at equal proportion. The yarn tenacity of AM-JKC wool mixed yarns is found significantly higher than pure JKC yarn (p<0.001). Among wool mixed finer yarns of 31.2tex, AMJKC75/B yarn has higher tenacity and elongation-at-break followed by AMJKC50 and AMJKC25 yarns. The difference in tenacity and elongation of AM-JKC mixed yarns is highly significant (p<0.001). The yarn tenacity and elongation-at-break (%) increases with the increase in the proportion of AM wool in the mixed yarns. It is attributed to higher crimp in AM wool which improves fibre cohesion in the yarn strand. The yarn modulus of wool and wool mixed yarns are shown in Table 3. The JKM yarn has found lowest yarn modulus followed by HPC & JKC yarns, mainly due to finer fibre and higher crimp of JKM wool. The yarn modulus is reduced in mixed yarn of AM & JKC wool. The differences in modulus of different wool and mixed yarns are non-significant.

Yarn diameter, Packing Density and Coefficient of Friction

The results of yarn diameter and its packing density are shown in Table 3. It is observed that the yarn produced from JK Merino wool shows higher yarn diameter followed by HPC and JKC yarns. It is mainly due to higher crimp/cm which results in the lowest packing density of JK Merino yarn. The difference in yarn diameter of JKM, JKC and HPC is found highly significant at 99.9 % confidence level. Mixing of AM wool with JK crossbred wool significantly increases the yarn diameter (p< 0.001) and decreases the packing density of yarn mainly due to higher crimps of the AM wool. Among finer yarn, the AMJKC25/B yarn has the lower yarn diameter (271.2 μm) as compared to other two wool mixed yarns which results in highest packing density.

The coefficient of friction (metal to yarn) of pure wool and mixed yarns is shown in Table 3. JK crossbred yarn shows higher coefficient of friction values (0.246) than HP crossbred and JK Merino yarns. The AM -JKC mixed wool yarns have the higher coefficient of friction than pure wool yarn; it may be due to more scales per unit length and crimp in AM wool, which results in higher contact point. The finer yarn has lower coefficient of friction than

coarser yarn, mainly due to the lower yarn diameter, which results in lower surface contact area of finer yarn[16]. The difference in coefficient of friction among different wool mixed yarns of 41.6 tex and 31.2 tex is found highly significant (p<0.001) at the 99.9% confidence level.

The HPC, JKC and JKM wool in pure form could be spun in 41.6tex yarns successfully. The Indian JKC wool mixed with AM wool in the proportion 50:50 and 75:25 could spin into yarn of 31.2 tex successfully. However, AM: JKC (25:75) can be spin into 35.6 tex. Pure Indian woolen yarns have higher unevenness CV%, imperfections and hairiness, which significantly reduce in mixed woolen yarn of AM:JKC wool for same yarn linear density. The tenacity of AM-JKC mix yarn is higher than pure Indian wool yarns, however, elongation-at-break is significantly lower. The yarn produced from J K merino wool has the lowest modulus than other wool yarns, which reduces with mixing of AM wool in the JK crossbred wool yarn. The yarn made from J K crossbred wool has significantly higher coefficient of friction than yarns of other wool. However, mixed yarns of AM-JK crossbred wool possess higher coefficient of friction than pure wool yarns.

Acknowledgement

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