Reyhaneh Torfeh Esfahani,
Mohsen Shanbeh

Effect of Navel and Rotor Type on Physical and Mechanical Properties of Viscose Rotor Spun Yarns

Department of Textile Engineering,
Isfahan University of Technology,
Isfahan 84156-83111, Iran
Email: mshanbeh@cc.iut.ac.ir

Abstract
This work investigates the influence of the navel and rotor type on the tenacity (cN/tex), elongation at break (%), mass irregularity (CVm), total number of imperfections (IPI), hairiness (H-value), and twist difference values (ΔT%) of viscose rotor spun yarns. Twelve samples using six different navels and two kinds of rotor with a different structure of rotor grooves were produced. The nominal count was 20tex and the nominal twist value 800 twists per meter. Statistical assessment based on one-way analysis of variance (ANOVA) and the TukeyHSD test was performed at a 95% confidence level to study the effect of independent parameters and their interaction.

Key words: *viscose yarns, rotor spinning, physical properties, navel type, rotor type, statistical evaluation.*

Introduction

Viscose staple fibre is one of the most popular fibres for rotor spun yarns and is used very often in the clothing industry. This study aims to present some information about physical and mechanical properties such as the breaking strength, elongation at break, mass irregularity, hairiness, total number of imperfections, and twist efficiency of viscose rotor spun yarns based on the navel and rotor type as two main parameters of rotor spinning. Statistical evaluation based on analysis of variance at a 95% confidence level was performed to estimate the difference between the rotor spun yarns.

The most special feature of the open end rotor spinning process is changing disordered fibres into the separate ones, then collecting them together and connecting them to the yarn end with the twisting mechanism. In this system, twisting and wrapping are done with two different operations [1]. In the rotor spinning process, three parameters have an important effect on yarn properties: the opening roller, rotor and navel [5].

The nominal amount of twist inserted into the yarn is equal to the ratio of the spinning chamber speed and to the yarn withdrawal speed. However, it is to be expected that because of the torsional rigidity of the fibres in the untwisted ribbon, there will be a reaction to the turning moment, and therefore the process will not be 100% efficient [2]. One of the most important rotor spun yarn properties are wrapper fibres on the sheath of the yarn; nevertheless ring yarn is without it. Wrapper fibres cause yarn contraction. The rotor diameter, rotor speed, fibre length etc, are some parameters that have an influence on the formation of wrapper fibres [3]. Wrapper fibre is one of the main characteristics of rotor spun yarns which does not make twist measurement precise. Wrapper fibre does not allow the yarn to be untwisted to zero [4].

The material and surface form of the navel, of which there are various types, affect the quality properties of yarns. There is some information about choosing the navel type in literature, especially concerning the advice of machine and spare part manufacturers; but this information is general [6 - 9].

The navel is like a guidance device for yarn. Navels with a rough surface resist inserting twist in the rotor groove, thus the spinning process deteriorates. There is a high friction force between the yarn and navel, which causes a lot of effects on the yarn properties. In the yarn's way (detour) from the navel towards the rotor wall, the false twist level continuously becomes higher. This situation improves the performance of the spinning action [4]. Compared to steel, navels made of ceramics are brittle hard. However, they have the ability to exhibit equivalent favorable tribological behaviour towards yarn as steel navels, given the right material structure and surface [10].

Erbil et.al [5] did a study about the influence of the navel type on the yarn hairiness of polyester/cotton and polyester/viscose blend rotor spun yarns. They concluded that the number and form of notches on the navel have an influence on hairiness. The Multi Criteria Decision Making (MCDM) technique was used to evaluate the effect of ten kinds

*Table 1. Spinning parameters. *Bronozied and diamond coated.*

Opening roller type	B174DN
Opening roller speed, r.p.m	9500
Rotor type	T933BD*, G933BD*
Rotor speed, r.p.m	115000
Nominal twist, t.p.m	800

of navel on the properties of cotton rotor spun yarns used for denim weaving [11]. Kaplan and Goktepe studied the effect of different navels on the physical and mechanical properties of cotton waste rotor spun yarns [12].

The twist property of rotor yarns has been the subject matter of several studies concerning the effects of process parameters and the measurement method on the twist value of rotor spun yarns. The effect of four process parameters (opening roller type, material type, opening roller speed and yarn linear density) on the twist of 100% polyester rotor spun yarns measured was studied by Palamutcu and Kadoglu [4] and they concluded that the twist insertion efficiency of rotor yarn is affected by fibre linear density. Increasing the fibre stiffness of thicker fibres helps decrease the formation of wrapper fibres, causing higher twist insertion in the rotor spun yarn.

Audivert [13] found that the difference between the measured and nominal twist depends on the value of machine twist and yarn linear density. Gong and Kumar [14] found that the fibre type, twist factor and rotor speed are the most important parameters affecting the twisting efficiency of cotton and cotton/polyester blended rotor spun yarns. The influence of the yam extractive nozzle on the apparent loss of twist was studied for rotor open-end acrylic staple spun yarns by Manich et.al [15].

Material and methods

To produce rotor spun yarns, viscose fibre from Lenzing (Austria) with a 38 mm mean length and 1.33 dtex fineness was used. A Savio FRS3000 (Italy) rotor spinning machine was used and all samples were produced in the same spinning position. Details of the constant spinning parameters are shown in ***Table 1***. Air temperature and humidity during the spinning process were 25 ± 2 ºC and 55 ± 2%, respectively. As shown in ***Table 2***, six types of ceramic commercial navel (Suessen Co., Germany) were employed during the trials. The difference between navels comes from their surface form and radius curvature. KS and ProfilS navels have a spiral shape but the pitch of loops in a KS navel is higher than in a ProFilS. The difference between KN4 and Mima2 is in their radius curvature and length of the groove. All navels have no fluted insert. We used two types of rotor (Suessen Co., Germany) with a 33 mm diameter and different groove structure, namely G-Type and T-Type (As can be seen in ***Figure 1***). The T-Type rotor groove has a larger radius and angle collecting the rotor groove than the G-Type. Twelve different samples with a 20 tex nominal count and 800 t.p.m nominal twists, based on the parameters mentioned, were produced.

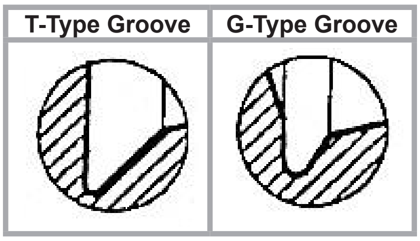
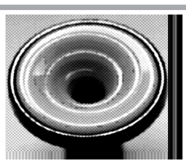
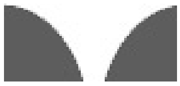
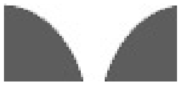
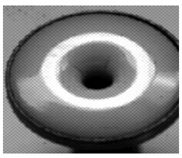
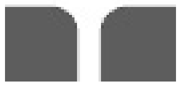
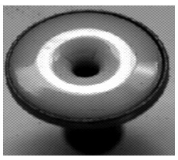
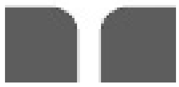
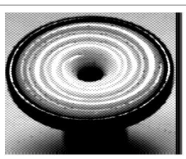
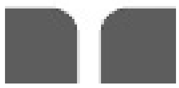
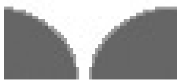


***Figure 1**. Two types of rotor groove [6].*

Table 2. Different kinds of navels.

Navel design	Navel type	Navel shape	Groove length	Schematic shape of radius curvature
	ProFilS	Spiral	-	
	KS	Spiral		
	KN4	4 notch	long	
	Mima2	4 notch		
	KSK6	Spiral + 6 notch	short	
	KSK4	Spiral + 4 notch		

Mass irregularity, imperfections, and hairiness characteristics were measured by the use of an Uster Evenness Tester5_S 800 (Switzerland). Each sample was tested five times and 1000 m of samples were tested each time. Tensile properties were measured by a Zwick Tensile Tester (Germany), which works based on the constant rate of elongation (CRE) method according to the ASTM-D2256 [16] method. Each sample was tested 15 times. The twist level of the samples was measured 5 times with as Uster Zweigle Twist Tester 5 (Switzerland) according to the triple untwist_retwist method. According to this method, the length of testing was 500 mm and the pretension was set to 1 cN/tex [17]. The purpose of this method is not to determine the real twist level of the samples but to establish a comparable twist value. This is because of the irregular twist structure and wrapping fibres of rotor spun yarns.

All measurements were performed under a standard atmosphere of 20 ± 2 ºC and 65 ± 2% RH. Deussen [16] defines the twist difference as follow *(**Equation 1**)*:

$$\%\Delta T = (T_a - T_m)/T_m \times 100 \qquad (1)$$

where:
$\%\Delta T$ - twist difference,
T_a - nominal twist,
T_m - measured twist.

The twist difference value suggested for cotton rotor yarn is between 0 to -20 and for cotton-polyester blend yarn between -10 to -45 [18].

Mean values of test results were used in one-way analysis of variance using SPSS 17.0 software at a 95% significant level. Besides the analysis of variance, Tukey HSD was performed.

***Table 3**. Physical and mechanical properties of viscose rotor spun yarns.*

Sample No.	Navel type	Rotor type	ΔT, %	Tenacity, cN/tex	Elongation, %	CV_m, %	H	IPI
1	KSK 6	T 933BD	30.8	11.2	13.5	14.2	4.2	51.0
2	KSK 4		31.1	11.0	11.6	13.9	3.8	41.5
3	Mima2		37.4	11.7	12.4	14.2	3.9	42.0
4	ProFilS		19.4	11.6	13.3	13.9	3.8	36.0
5	KS		17.3	11.3	12.5	14.0	4.0	49.5
6	KN4		62.0	11	10.7	14.6	3.8	94.0
7	KSK 6	G 933BD	27.1	10.9	11.3	14.7	4.3	106.0
8	KSK 4		23.2	10.4	11.4	14.7	4.0	82.5
9	Mima2		25.3	10.0	11.0	14.9	4.1	96.0
10	ProFilS		16.1	10.8	12.0	14.5	3.9	71.0
11	KS		16.1	9.7	11.7	14.6	4.0	80.0
12	KN 4		45.3	10.6	11.4	15.2	4.2	150.5

Results and discussion

In ***Figures 2.a - 2.f***, the effect of the navel type and rotor groove on hairiness (H-value), tensile properties (tenacity in cN/tex, elongation at break in %), the total number of imperfections (IPI), mass irregularity in CV_m, and twist difference value (ΔT%) of viscose rotor spun yarns are illustrated. In ***Table 3*** the experimental results of viscose rotor spun yarns are presented.

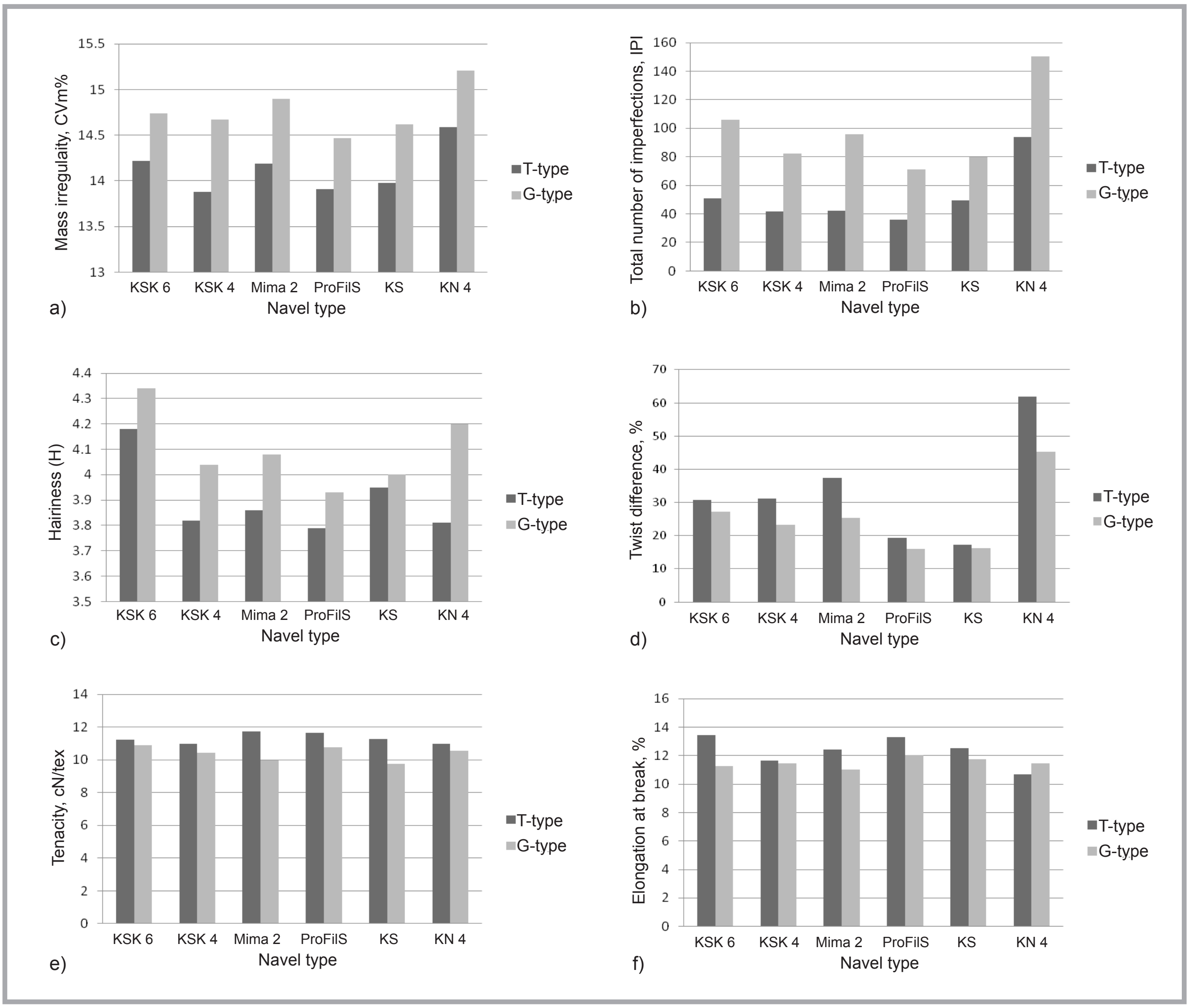


***Figure 2**. Experimental results of rotor spun samples - a) Mass irregulaity, b) Total number of imperfections, c) Hairiness, d) Twist difference, e) Tenacity, f) Elongation at break.*

***Table 4**. Analysis variance results of experiments; * - the mean difference is significant at a 95% confidence level.*

	Imperfection (IPI)		Hairiness (H)		CVm, %		Stress, cN/tex		Elongation, %		Twist Difference , %	
	Sig.	F-Value	Sig.	F-Value	Sig.	F-Value	Sig.	F-Value	Sig.	F-Value	Sig.	F-Value
Navel Type	0.000*	22.664	0.047*	2.530	0.000*	21.602	0.574	0.769	0.116	1.814	0.000*	58.080
Rotor Type	0.000*	115.781	0.221	1.666	0.000*	199.804	0.000*	14.507	0.020*	5.600	0.000*	26.584
Navel*Rotor	0.366	1.200	0.864	0.363	0.552*	0.830	0.360	1.109	0.230	1.400	0.116	1.877

Results of the analysis of variance at a 95% significant level are presented in ***Table 4***. When the significant values in the table are smaller than 0.05, it means that there are significant differences between the target parameter of samples [19].

As can be seen in ***Figure 2.a*** and ***Table 2***, rotor spun yarns produced by a T-type rotor groove, which has a larger collecting groove angle and radius, have the better mass irregularity (CV_m) in all types of navels used, which could be because of better doubling action of fibre in the rotor groove, which is one of the main characteristics of rotor spinning, causing regular and normal distribution of fibre in the yarn cross section. Samples produced by KSK4 (CV_m = 13.88%) and ProFilS (CV_m = 13.91%) showed the best mass irregularity and KN4, yielding 14.59%, was the worst. The TukeyHSD test revealed that there is no significant difference between these two samples. It could be said that these navels yield less deformation and twist variation in the yarn during the false twist creation process [12]. The increase in the number of notches from four to six (KSK4 to KSK6 navel) causes an increase in mass irregularity; the TukeyHSD test shows that their difference is significant at a 95% confidence level. Experimental results confirm the effectiveness of the spiral form of the navel surface on mass irregularity.

The analysis of variance at a 95% significant level (as can been seen in ***Table 4***) shows that the effect of the navel and rotor groove type is statistically significant. The interaction between these two parameters does not show a significant effect on the CV_m of viscose rotor spun yarns. By considering the F-value in ***Table 4***, it is clear that the rotor groove shows more influence on CV_m than the navel type.

According to ***Figure 2.b*** and ***Table 2***, samples produced by a T-type rotor groove show a lower value of IPI than a G-type rotor groove. Again a rotor groove with a larger groove angle and radius, which may improve the doubling action and disposition of fibre in the yarn structure, could be a reason for lower values of IPI than for the G-Type rotor. As with the results obtained for mass irregularity, samples produced by ProFilS and KSK4 show the lowest and KN4 the highest value of IPI, respectively. The minimum and maximum number of IPI was 36 and 94 per kilometer when using a T-Type rotor. Statistical evaluation at a 95% confidence level shows that the rotor type and navel type has a significant effect on IPI values. Interaction between these two parameters does not show a significant effect on the IPI. According to ***Table 4*** and the F-value, the effectiveness of the rotor groove was more than the navel type. TukeyHSD reveals that there is significant difference between the IPI of KSK4 and ProFilS navels at a 95% confidence level. The spiral shape of the navel surface, which causes more friction between the navel and yarn, could be a reason for lower values of IPI compared with another surface. If we explore the properties of rotor spun yarns produced by KSK4 and KSK6 navels, it seems that by increasing the number of notches from four to six, the IPI values deteriorated and the positive effect of the spiral shape of the navel is neutralised by the number of notches.

Based on ***Figure 2.c***, according to the mass irregularity and total number of imperfections, the T933BD rotor shows a lower value of hairiness (H-value), whereas ProFilS and KSK4 were the best choice between navels. Analysis of variance shows that the effect of navel type is significant at a 95% confidence level; however, rotor type and interaction between these two parameters does not show a significant effect on hairiness (H-value). The TukeyHSD test shows that the difference between these two navels i.e. KSK4 and ProFilS is not statistically significant.

Based on ***Figure 2.d***, in all samples when we use a G-type rotor with a smaller collecting groove angle and groove radius, higher values of twist were measured. On the other hand, samples produced by KS and ProFils show the lowest values of twist difference, i.e. 16.08% and 16.13%, respectively. It seems that a rotor groove with a larger collecting radius and angle may cause lower penetration of twist, which could be because of more friction of the yarn body against the wall of the G-type rotor [15]. On the other hand, the use of a spiral shape on the surface of the navel could cause a higher friction moment and higher value of false twist compared with other navels [15], which could bring about more penetration of the twist imparted to the yarn forming a zone in the rotor groove. The existence of a notch does not show a positive effect compared with the spiral shape of the navel surface. KN4 shows 45.29% values of twist difference, being the highest value. Besides KN4, Mima2 also has a higher value of twist difference, which could be because of the lower radius curvature of this navel compared with KS, ProFilsS, KSK6, and KSK4. According to ***Table 4***, the navel and rotor type have a significant effect on the twist difference of viscose rotor spun yarns statistically, but their interaction does not show a significant effect. The navel type shows more of an effect than the rotor groove on the twist difference of rotor spun yarns.

Analysis of variance at a 95% confidence level shows a significant effect of the rotor type on tensile properties (As shown in ***Table 4***). Navel type and interaction between the navel and rotor type have no significant effect on tensile properties. As can be seen in ***Figures 2.e and 2.f*** and ***Table 2,*** in most cases rotor spun yarns produced by a T-type rotor show better tensile properties compared with samples produced by a G-type rotor, which could be because of a lower number of imperfections and lower value of mass irregularity (CV_m) of rotor spun yarns produced by a T-type rotor, which has been explained in previous sections. The effect of navel type on tensile properties was not clear and the difference between the samples was marginal. This trend was confirmed by the analysis of variance, which shows an insignificant effect of the navel on tensile properties. According to previous explanations (Based on ***Table 4***), the effectiveness of the rotor type on IPI and CV_m was more than the navel type and this could be the reason for the higher impact of the rotor on tensile properties, obtained using one-way analysis of variance at a 95% confidence level.

Conclusion

The effect of the navel and rotor type as the two main parameters of the rotor spinning process on mass irregularity (CV_m), hairiness (H-value), the total number of imperfections (IPI), tensile properties, and the twist difference value were evaluated experimentally and statistically at a 95% confidence level. The following results were obtained:

1. The navel type showed a significant effect on hairiness (H-value), imperfection (IPI), mass irregularity (CV_m), and twist values of viscose rotor spun yarns, and its effect on tensile properties was insignificant.
2. The rotor type showed a significant effect on the tensile properties, imperfection (IPI), mass irregularity (CV_m), and twist difference of rotor yarns, and its effect on hairiness (H-value) was insignificant.
3. Interaction between the rotor and navel types was statistically insignificant at a 95% confidence level for all parameters.
4. A minimum difference between the nominal and measured twist was obtained for samples produced by ProFilS and KS navels and a maximum twist difference obtained when using a KN4 navel.
5. Samples produced by a G-type rotor showed a lower value of twist difference than a T-type rotor.
6. In all samples produced by a T-type rotor, which has a larger groove radius and angle than the G-type, better CV_m, IPI, tensile properties and hairiness were obtained.
7. A minimum number of imperfections and hairiness belonged to the sample produced by a ProFilS navel and T-type rotor.
8. The effectiveness of using a spiral navel shape compared with notched navels to produce viscose rotor spun yarns and the negative effect of the number of notches were confirmed in this study.

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