Stuides on Denim Fabrics

Part – 1: Frictional Properties

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Abstract:

Enzymes are applied on denim fabrics to improve their aesthetic performance. In this paper, denim fabrics made of ring and rotor spun cotton yarns were treated with acid and neutral enzymes at concentrations ranging from 0.5% to 5% and their frictional properties were investigated by both sledge and Kawabata surface roughness testers. Enzyme treatment has led to a drop in friction which implies that the handle has improved. Ring spun yarns with acid enzyme have shown a significant improvement in the handle of denim fabric. The friction factor has been found to be a useful parameter in the evaluation of friction.

Key Words:

Enzymes, acid and neutral, KES-F, sledge, friction.

Introduction:

Frictional properties of fabrics play an important role in the handle of fabrics, tailorability and serviceability. For denim fabrics, enzyme treatment is given to improve the feel and absorbency. The quality of the fabrics is assessed by subjective and objective methods. A major upsurge on the objective evaluation took place in the 1970s with the development of the Kawabata evaluation system for fabrics (KESF). Coefficient of friction is measured in this system and alsothere are several methods which are available for measuring it, Enzymes enhance the surface appearance and reduce the friction of fabrics by hydrolysis of cellulose.The recent book by Gupta, Ajayi and Kutsenka [1] on frictional properties of textile materials discusses the theory and measurement of friction succinctly. It is extremely important to quantify the changes in the surface properties of enzyme treated fabrics. Research on the effect of acid and neutral enzymes to the denim fabrics made from ring and rotor spun yarns has not been reported.

It is the practice to use a horizontal platform method for characterizing fabric to fabric and fabric to other surface frictions. The most popular method of measuring fabric friction is based on the principle of rectilinear motion of a sled over a horizontal platform. The assembly is made of a platform, and a sled is connected to a constant rate of elongation tester. Ramkumar et al [2] used an ingenious device for measuring friction in that the movement of the sledge can be reverted and frictional behavior over a number of cycles of reciprocating traverse can be examined. These authors constructed a probe which is made of polyvinylsiloxane and which simulated human finger. The geometrical area of contact between the finger – shaped probe and the fabric was determined with an ink impression of the former on a plane surface.

In Kawabata surface tester, the coefficient of friction is measured by a probe which has a width 5mm and consists of ten wires. The probe is pressed onto the fabric with a constant force of 50 gf. The coefficient of friction, μ, given by the ratio of the force registered in the transducer, attached to the friction probe, to the normal force is plotted as a function of the traverse distance. The mean value of μ (MIU in the KES system) is given by the average height of the curve.

$$\text{MIU} = \frac{1}{X}\int \mu dx$$

Where,x is the traverse length. In the KES tests, mean deviation of μ from the average MMD is also assessed to obtain an index of variation in the value

$$\text{MMD} = \frac{1}{X}\int /\mu - \bar{\mu}/.\, dx$$

The properties of a fabric surface are very important both in terms of psychological and physical effects on human being. For example, the sensations received from the contact of clothing with the skin can greatly influence the overall feeling of comfort. This property is measured using

Kawabata surface tester which measures the height of the surface of fabric over a 2-cm length (forwards and backwards) along forward and backward directions. This gives two values for geometrical roughness SMD warp and SMD weft.

The geometrical roughness (SMD) is a measure of the surface contour of the fabric and increase in SMD suggests an increase in surface variation of a fabric.

Later in 1985, an instrument was introduced by Perner et al [3] which moved the fabric by means of a turntable in order to measure the heights around a 360˚ rotation.

Although the KES-F and FAST measure a number of fabric mechanical properties, the FAST system does not quantify the frictional properties and the KES-F system does not quantify friction in a logical way. Ramkumar at el [4] have made a breakthrough in characterizing the frictional properties. He has suggested a parameter R, which is equal to C/n, where C is the friction parameter in Pa^{1-n} and n is the friction index. This parameter has been successfully used by him and his colleagues for representing smoothness of enzyme treated and non woven materials.

Butler et al [5] have reported on the design of a cloth profile recorder. This is meant for assessing the fabric faults such as repping and the differences in pick spacing along the warp direction. Since this early work, there has been no reported work that describes the objective measurement of surface roughness until the KES system was introduced by Kawabata [6]. Amirbayat and Cooke[7] developed a multipurpose tester for the measurement of surface properties and their variation during wear. Having realized that there is force imposed when testing which affects the measurements of the roughness in KES surface tester, Ramgulam [8] reported a non-contact method of surface assessment using laser triangulation techniques.

Kawabata [6] separated the coefficient of surface friction into two parts. The first part is associated with the friction between the fabric and the surface of a rigid body. The second component comes from other causes. It is assumed to be related to energy losses caused by inter fibre friction from compressional deformations occurring when a fabric is subjected to rubbing, denting and crushing. The relative importance of these two terms varies with the type of surface contact and with the applied load. The deviation of the coefficient of friction (MMD) is a measure of slip-stick behavior. As the probe sticks and binds on the irregular fabric surface, the frictional force changes giving deviations from the mean value of friction. The KESF provides these parameters to represent surface properties. In this paper, denim fabrics woven with ring and rotor spun cotton yarns were treated with acid and neutral enzymes. Both the sliding friction and Kawabata surface tester have been used to test friction of fabrics. A refined friction parameter developed by Ramkumar

[4] was used to quantify the changes in the surface properties of a set of enzyme – treated cotton denim fabrics made from ring and rotor yarns and this paper reports the findings.

Experimental:

Denim Fabrics

The materials used were denim fabrics made from ring and rotor spun cotton yarns. Details of the fabric samples are given Table - 1.

Table 1. Details of the woven fabric samples.

Sample No.	Weave Structure	Warp (ends/cm)	Weft (Picks/cm)	Warp count (Ne)	Weft count (Ne)	GSM	Yarn Type
1	Plain	32	17	16	16	227	Ring
2	Plain	32	17	16	16	224	Rotor

Fabrics were produced on an air jet loom with 167cm width and with weft insertion rate of 1400m/min and machine speed 400picks/min. The warp is dyed and weft is undyed.

Enzyme Treatment:

Following pre wetting and desizing treatment, the denim samples were treated with acid and neutral enzymes at nine different concentration levels – The time and temperature of the treatments were maintained constant at 30 min and 50˚C. Denim washing machine was used to apply enzyme in fabrics.

While a pH of 5.2 was maintained for acid enzymes for 35 minutes, a pH of 6.5 was maintained for neutral enzymes. Following this treatment, the fabrics were cold washed three times and subsequently hot washed; the enzyme concentration was varied from 0.5% to 5.0% both for acid and neutral enzymes. Tables 2 and 3 show the codes given to the fabrics and processing details.

Table – 2 - Process Details:

Weight of sample	W
Concentration of enzyme (% owf)	X
M – L Ratio	1:20
Wetting agent (% owf)	1
Time of treatment (min)	30
Temperature ˚C	50
pH	5 (acid) 6.5 neutral

Table – 3 - Enzyme concentration level on fabrics

FabricCode		Enzyme level
Acid	Neutral	
A_0	B_0	0.0
A_1	B_1	0.5
A_2	B_2	1.0
A_3	B_3	1.5
A_4	B_4	2.0
A_5	B_5	2.5
A_6	B_6	3.0
A_7	B_7	3.5
A_8	B_8	4.0
A_9	B_9	5.0

A – Ring Spun, B – Rotor Spun

Friction Evaluation:

The simple sliding friction apparatus was used to evaluate the frictional properties and to obtain the two frictional parameters C and n. The former is frictional parameterand the latter is called friction index. The method is similar to the one used by Ajayi [9] and Ramkumar et al [2]. Frictional properties of the enzyme – treated fabrics were measured over a range of different normalloads using a standard friction substrate on a sledge. Bovine leather sledge was used as standard substrate. The standard sledge was pulled at a constant rate by an inextensible thread which was attached to the crosshead of Instron tensile tester. The maximum capacity of the load cell in the Instron tensile tester used was 25kg. The fabric was attached to a platform over which the standard sledge slides at a constant velocity of 100 mm/min. The sliding experiment was conducted at five different normal loads. The minimum and maximum loads use of were 37g and 76g, respectively. The load was increased in steps of 10g. The apparent area of contact between the bovine leather sledge and fabric was $20cm^2$.

Using the frictional force values, friction parameters were derived from the friction force and normal load using the following formula as suggested by Ramkumar:

$$F/A = C(N/A)^n,$$

Where, F is the friction force, A is the apparent area of contact ad N is the normal applied load. Regression analysis was carried out using $\log_{10}$ (F/A) and $\log_{10}$ (N/A) values. The intercept represents the friction parameter 'C', and the slope represents the friction index 'n'. The friction parameters 'C' and n are then used to obtain friction factor 'R'. The higher the value of 'R', the higher is the friction of fabrics and vice versa. The same comments hold good for SMD values obtained from Kawabata surface tester. Fabrics were conditioned for 48 hr at 25 ± 2˚C and 65± 2% RH friction to conduct the experiments. Fabric surface properties were evaluated by Kawabata surface tester which provides MIU, MMD and SMD parameters.

ResultsandDiscussion:

Weight Loss:

Weight loss ranged between 0.44% to 14.9% for acid enzymes, while for neutral enzyme, they ranged between 0.87% to 15.7% for ring spun denims. It was found that these were more or less the same for rotor spun denim fabrics.

Frictional Properties:

Table - 4 shows the MIU, MMD and SMD values obtained from KES surface tester for the fabrics.

Table - 5 shows that enzyme treated fabric have lower R values indicating that the smoothness of enzyme – treated fabric is higher than that of the untreated fabric. Figure - 3 shows that enzyme application generally reduces the friction of fabrics.

With the exception of a few cases, it is apparent that the MIU values show a decrease when compared with the control. A good correlation between MIU and SMD is noticed. One major point is that the denim fabrics made from ring yarns and treated with both the types of enzymes show a consistent reduction following enzymatic treatments. The reduction in friction is not noticed in the denim fabrics made out of rotor yarns. This may be due to their greater area of contact in comparison with ring spun yarns. Values of SMD in respect of fabrics produced from rotor yarns generally show an increase compared to their counterparts. The type of enzyme used does not seem to affect the coefficient of friction or surface roughness as both the values are equivalent. Figures 1 and 2 illustrate the trends.

Table -5 shows the values of 'R' for denim fabrics produced from ring and rotor yarns. It is apparent that neutral enzyme has led to a substantial reduction in friction. A concentration of 2.5% seems to be optimum. What is striking is that there is a substantial improvement in smoothness of denim fabrics following enzyme treatments. This may be due to the enzyme action on fabrics which results in more surface degradation. Denim fabrics woven with ring spun yarns and treated with acid enzymes show a better handle in comparison with rotor spun yarns. It should be noted that even at enzyme levels as high as 2.5% friction values are much lower than that for the untreated fabric. The sliding friction apparatus has been found to be successful in reflecting the improvement in the surface characteristics of fabrics. It is possible to use the friction method to detect the changes that have occurred in the surface properties of fabrics that have been given different treatments such as enzyme finishing. Also, a good correlation between 'R' and MIU is observed. The results obtained in the current study are encouraging as they demonstrate the subtle differences in the frictional properties.

Conclusions:

This study examined the frictional properties of denim fabrics made from ring and rotor spun cotton yarns and subsequently treated with acid and neutral enzymes. There is a good correlation between coefficient of friction and surface roughness. Friction shows a reduction with enzyme treatment and neutral enzyme gives better results in respect of denim fabrics made from ring spun yarns. The simple sliding friction method has been found to be a useful and a reliable tool to evaluate the frictional properties. Frictionparameter is capable of differentiating and quantifying subtle changes in the surface properties of fabrics. These factors will prove to be a valuable tool for denim production and quality control activities.

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Table – 4 - Surface properties of control and treated denim samples

Properties	Sample	Enzyme Concentration (%)									
		Control	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**5.0**
	Code	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
Mean Co-efficient of Friction (MIU)	Ring (Acid)	0.20	0.16	0.15	0.14	0.16	0.20	0.20	0.21	0.16	0.16
	Ring (Neutral)		0.19	0.20	0.20	0.20	0.19	0.21	0.20	0.20	0.16
	Code	B_0	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
	Rotor (Acid)	0.20	0.19	0.20	0.20	0.20	0.19	0.21	0.20	0.20	0.16
	Rotor (Neutral)		0.19	0.18	0.20	0.19	0.19	0.20	0.19	0.20	0.19
Mean Deviation of Friction (MMD)	**Code**	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
	Ring (Acid)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Ring (Neutral)		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Code	B_0	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
	Rotor (Acid)	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Rotor (Neutral)		0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Surface Roughness µm (SMD)	**Code**	A_0	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
	Ring (Acid)	7.77	5.57	5.41	5.77	5.71	5.83	5.63	5.73	5.61	5.35
	Ring (Neutral)		5.41	5.74	5.33	5.62	5.27	5.23	5.50	6.19	5.70
	Code	B_0	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
	Rotor (Acid)	5.31	6.30	4.73	6.40	6.25	6.20	6.41	6.39	6.00	6.31
	Rotor (Neutral)		6.60	6.16	5.77	6.10	6.14	5.96	6.16	6.16	6.65

Table – 5 - Friction factor of Denim Samples

Sample	Code	Average friction index n	Average friction parameter $C[Pa^{(1-n)}]$	Friction factor $R[Pa^{(1-n)}]$	Average friction index n	Average friction parameter $C[Pa^{(1-n)}]$	Friction factor $R[Pa^{(1-n)}]$
Control	A_0	0.98	0.88	0.90	0.98	0.88	0.90
		Ring – Acid			**Ring - Neutral**		
0.5%	A_1	0.97	0.70	0.72	0.99	1.27	1.28
1.0%	A_2	0.97	0.68	0.70	0.99	1.12	1.13
1.5%	A_3	0.97	0.66	0.68	0.98	1.00	1.02
2.0%	A_4	0.96	0.63	0.66	0.97	0.90	0.92
2.5%	A_5	0.99	0.49	0.49	1.00	0.49	0.49
3.0%	A_6	0.97	0.67	0.69	0.98	0.80	0.82
3.5%	A_7	0.97	0.66	0.68	0.97	0.74	0.76
4.0%	A_8	0.97	065	0.68	0.99	0.29	0.29
5.0%	A_9	0.97	0.66	0.69	1.00	0.42	0.42
		Rotor – Acid			**Rotor – Neutral**		
Control	B_0	0.98	0.88	0.90	0.98	0.88	0.90
0.5%	B_1	0.98	0.82	0.84	0.99	1.30	1.31
1.0%	B_2	0.98	0.80	0.82	0.99	1.14	1.15
1.5%	B_3	0.98	0.77	0.79	0.98	0.96	0.98
2.0%	B_4	0.98	0.75	0.77	0.97	0.88	0.91
2.5%	B_5	1.00	0.68	0.69	1.00	0.49	0.50
3.0%	B_6	0.98	0.80	0.82	0.98	0.78	0.80
3.5%	B_7	0.98	0.79	0.81	0.97	0.68	0.70
4.0%	B_8	0.98	0.78	0.80	1.00	0.40	0.40

5.0%	B_9	0.98	0.79	0.81	1.00	0.53	0.54

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These figures are coming under Results and Discussion.

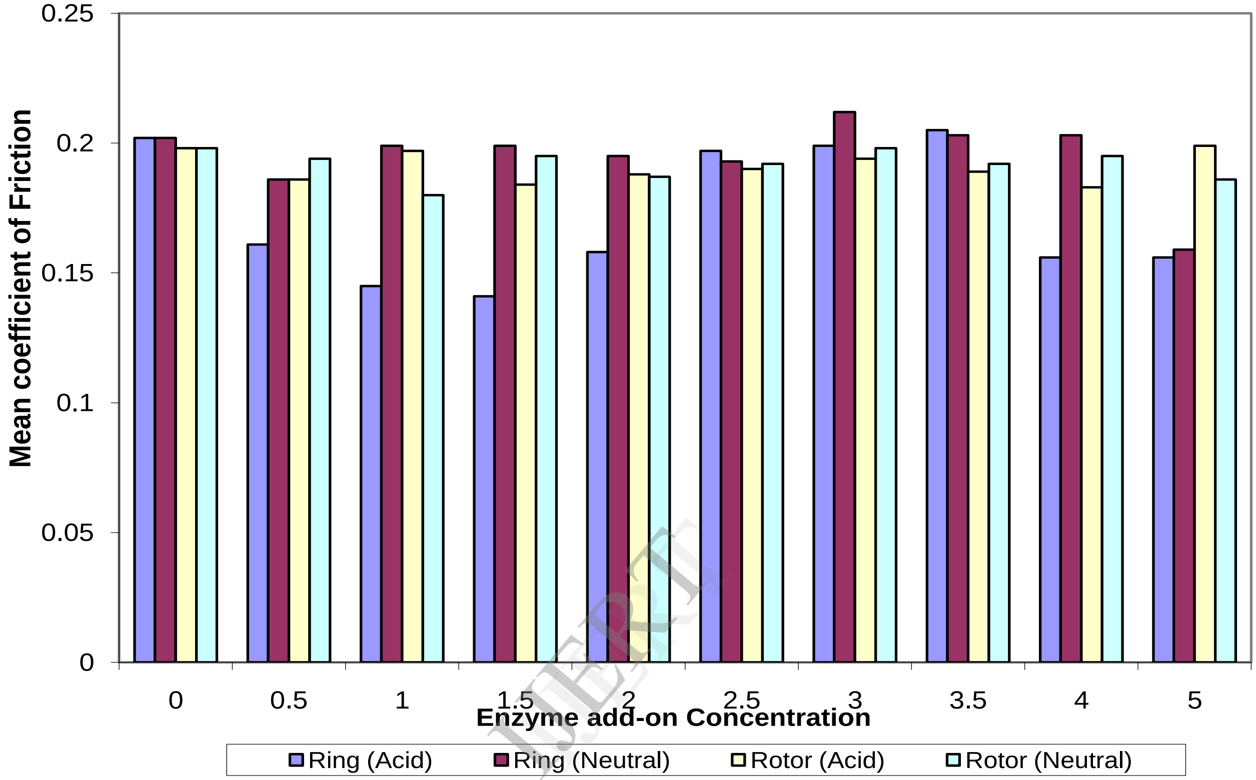

Figure – 1 Mean coefficient of Friction (MIU)

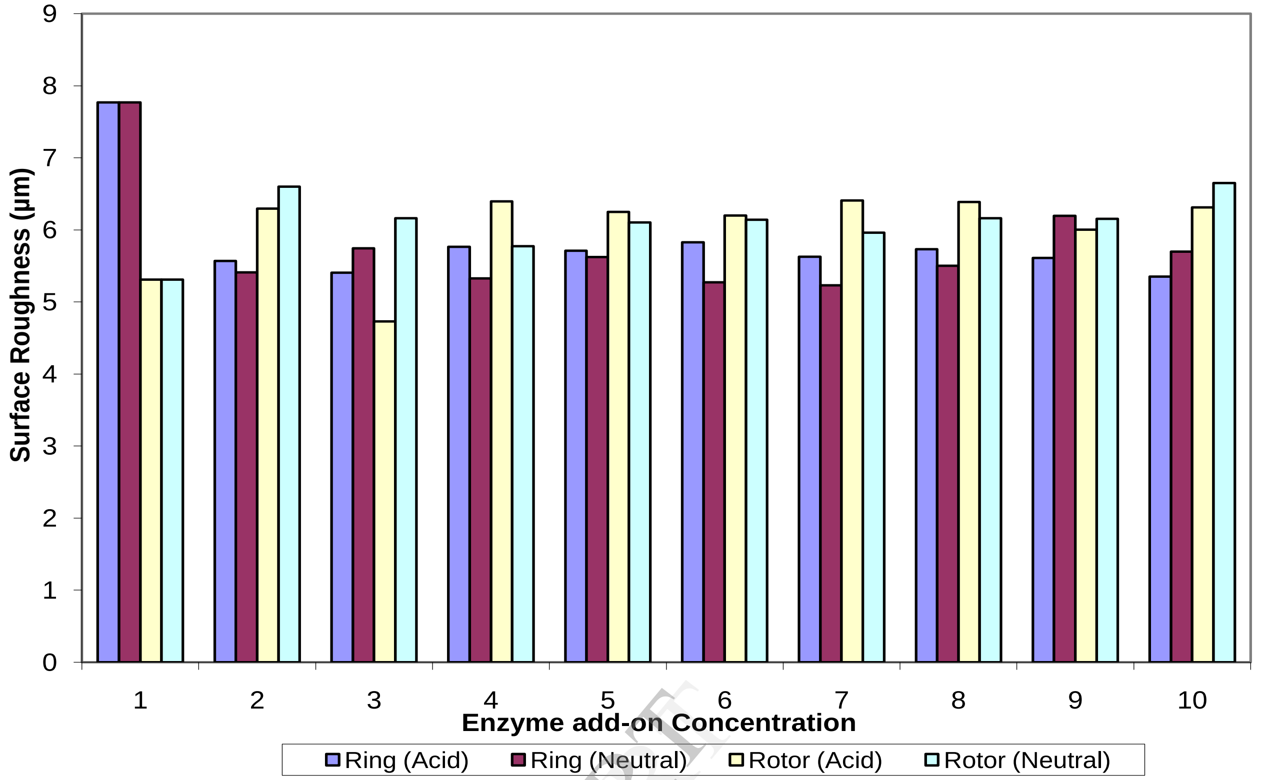

Figure – 2 Surface Roughness Deviation – SMD (µm)

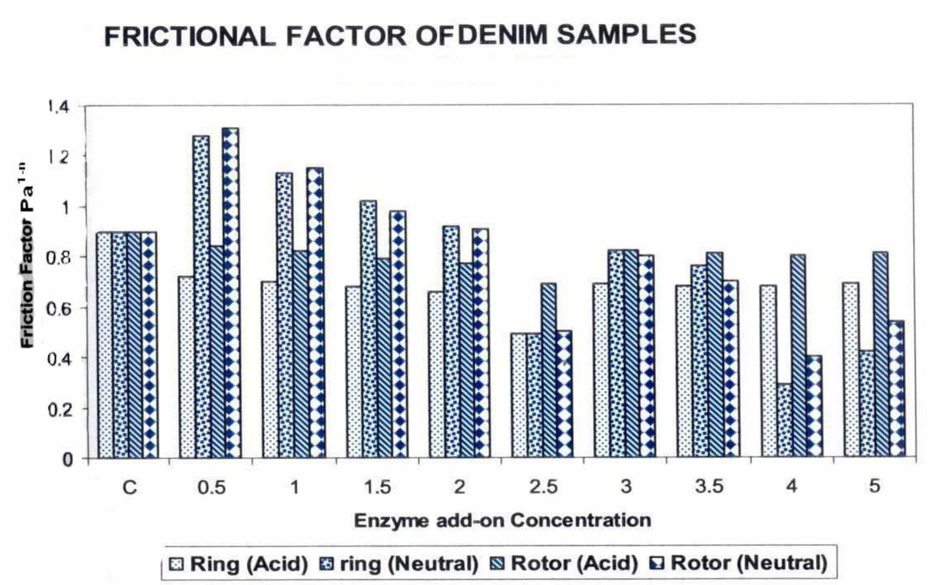

Figure – 3 - Frictional factor of denim fabric samples