Study on Tactile Comfort Characteristics of School Uniforms

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ABSTRACT
The present work has its aim in examining tactile comfort properties of summer school uniform fabrics related to frictional characteristics. Surface characteristics play a significant role in comfort, as the fabric of clothing comes in contact with skin. Students while wearing uniforms have to perform many activities which demand different body movements and postures; therefore, their uniform clothing should not create clothing distress. Surface properties of different summer uniform fabrics are tested on Kawabata Evaluation System, KES FB-4. The coefficient of friction (MIU), deviation from the coefficient of friction (MMD), and Geometric roughness (SMD) have been tested and analyzed statistically. Shirting fabrics of summer school uniforms are divided into two groups based on fabric sett; one group has a relatively higher sett than another. The statistical analysis of test results found significant for fabric sett; it is observed that higher fabric sett has better surface properties. This may be assigned to a more continuous surface offering lower asperities on higher sett fabrics. Trouser fabrics of summer school uniforms are divided into two categories based on their weaves, viz. plain weave and twill weave. The effect of weaves was found significant for trousers fabrics. School uniform manufacturers may use small twill weave in shirting fabrics of summer school uniforms, to enhance the tactile comfort of clothing.

Keywords: *Asperity, Comfort, Correlation, Friction, Functional Clothing, Kawabata Evaluation System, Low Mechanical Properties, Tactile Comfort, School Uniform*

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1. Introduction

This is the age of competition and students are expected to involve in a variety of activities. It has been a matter of discussion, in many countries whether school uniform should or should not be mandatory. If a uniform clothing policy is not applied then schools face many problems including poor academic achievements and attendance [1]. On the other hand, some cognitive consequences of formal clothing are also studied [2].Clothing comfort is one factor that may influence the performance of the wearer. School uniforms may be considered as functional clothing because these are required to perform many functions other than the basic function of clothing. Tactile comfort is largely determined by surface and frictional properties. Tactile comfort is the combination of low mechanical properties and surface properties. Sensorial comfort has been studied since early 1990s, initially, most of the studies were based on subjective tests and now the focus is on objective tests of sensorial comfort [3].

Subjective study for comfort assessment is done by delineation of clothing attributes and descriptors derived from several attributes. Descriptors are used on different rating scales and responses received are analyzed by data analysis techniques [4]. A multidisciplinary approach to comfort prediction has also been suggested but not widely applied because of the diverse nature of the data acquisition requirements [5]. Some literary work introducing bench-type instruments to measure friction properties of the fabric is also available. A study suggested that from very dry to normal skin conditions, the increase of friction happens to be higher in women than men and they also found that when friction was measured against wet fabric it was more than two times higher than in natural skin condition [6]. The frictional interaction between fabric and skin during contact are the key factors determining some of the important tactile sensations which are the perception of roughness, smoothness and scratchiness. The mechanoreceptors located in the human skin **Fig.1** are primarily responsible for touch sensations experienced by a person [7]. A study concluded that humans can ignore significant levels of discomfort in the short term, i.e., up to 2 hours, to maintain necessary task performance [8], however, students have to wear school uniform for long hours. Uncomfortable uniform will adversely affect students' cognitive performance. Uncomfortable clothing may cause prickly, sticky and clammy feelings to the wearer; such feelings further adversely affect the performance of the wearer. The comfort properties are a function of many variables like sett of the fabric, the weave of the fabric and other constructional parameters. A twill-woven fabric has been found preferable as compared to a plain-woven fabric in all aspects of comfort. The sensory perceptions are also influenced by the psychological and physiological state of the individual wearer and the external environment [9] [10]. Skin is the largest organ of the human body and tactile comfort is mainly associated with the response of mechanoreceptors. The tactile comfort is associated with skin tribology. Skin tribology is the field that deals with the collection of phenomena related to contact of skin against itself or foreign surfaces and accompanying frictional loading, tissue damage and sensory outcomes produced by such contact [11]. In a study, skin surface friction has been measured and correlation with other physiological parameters is studied to evaluate the potential of physical measurement of tactile sensation [12]. Another study focused on friction behaviour of skin concluded that there is a positive correlation between the coefficient of friction and vibrotactile sensation on nano-scale and macro scale [13]. This information highlights that prickle sensitivity increases with the moisture content of the skin, as water can soften the stratum corneum and allow the protruding fibres to penetrate more readily [14]. Fabric parameters do influence somebody response such as the state of hydration [15]. There are references of test methods and instruments which claim to measure fabric roughness, some of those are contact type [16] while some others are non -contact type which makes use of optical theories to measure roughness. The tactile comfort is dependent on the surface and frictional properties of the fabric [17]. The school uniforms can be considered as a functional garment since students are required to perform many activities while wearing them. Thus, it can be derived that uniform clothing has the potential to affect the performance of the wearer, and tactile clothing comfort becomes vital for unimpeded performance. Roughness and smoothness affect the tactile comfort of the clothing hence its evaluation is important. This paper aims to study surface characteristics of summer school uniforms concerning tactile comfort.

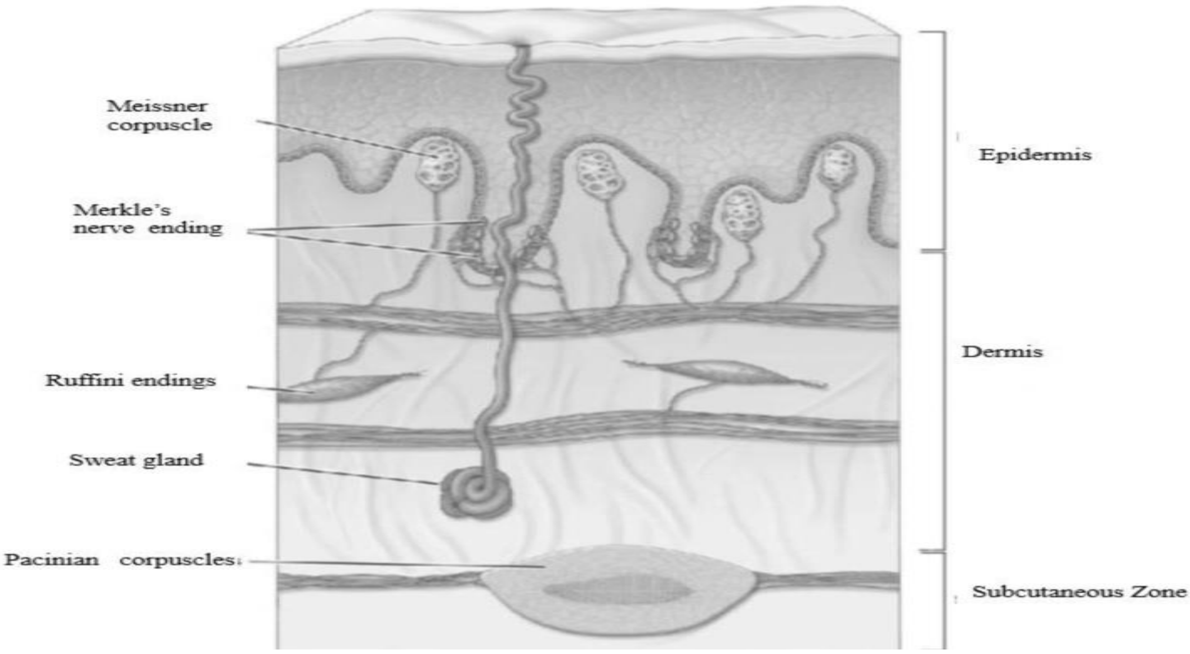


Figure 1: Mechanoreceptors in skin [7]

2. Material and method

2.1 Material

Summer uniform fabric samples were collected from uniform suppliers after taking source details from schools. Here, eight shirting and six trousers fabric of summer uniform are selected, these samples are coded S1 to S8 and T1 to T6 respectively.

2.2 Methods

2.2.1Physical Parameters

This study is focused on frictional characteristics of summer school uniform and their association with physical parameters of uniform clothing. The samples were conditioned as per ASTM D1776 (standard practice for Conditioning and Testing Textiles). The constructional and dimensional parameters of conditioned samples are recorded. The fabric sett is measured by pick glass, following ASTM D3775 test method. The yarn number is measured by following ASTM, D 1059: 2017. The GSM is measured by implementing ASTM D3776.These constructional parameters are presented in table 1. The objective test results of tactile comfort have also been analyzed with respect to these parameters.

Table 1: Physical Parameters

Sample code	EPC	PPC	Warp (Tex)	Weft (Tex)	GSM (gm/m^2)	Thickness (mm)	Weave
T1	22	22	43.74	43.74	185.60	0.532	Plain
T2	24	24	40.72	40.72	180.17	0.518	Plain
T3	22	22	42.18	42.18	185.60	0.503	Plain
T4	22	22	42.18	42.18	190.60	0.42	Twill
T5	32	28	43.74	43.74	231.99	0.64	Twill
T6	36	24	31.92	31.92	191.50	0.557	Twill
S1	46	28	11.81	11.81	90.00	0.332	Plain
S2	42	38	13.89	13.89	111.50	0.332	Plain
S3	38	49	10.84	10.84	94.57	0.387	Plain
S4	34	30	17.37	17.37	111.30	0.20	Plain
S5	28	26	26.84	26.84	145.41	0.21	Plain
S6	34	29	16.87	16.87	106.287	0.22	Plain
S7	24	28	25.67	25.67	133.99	0.237	Plain
S8	33	28	24.60	25.13	151.54	0.38	Plain

2.2.2 Categorization of samples

The trousers samples are categorized on the basis of weave, which are plain and twill weaves. The plain-woven samples are coded as T1, T2, T3 and twill woven samples are coded as T4, T5, and T6. Shirting samples are divided into two groups on the basis of their sett, all eight shirting samples were arranged in descending order of sett, and first half is categorized as group A and second half as group B. The samples of higher fabric sett group A are coded as S1, S2, S3, and S4. The samples of lower fabric sett group B are coded as S5, S6, S7, and S8.

2.2.3 Objective test parameters for tactile comfort

Roughness and smoothness of school uniform clothing is largely decided by the surface and frictional characteristics of fabric the uniform is made of. The surface properties related to tactile comfort are tested on Kawabata Evaluation System KES FB-4. The roughness and surface properties are objectively tested by three parameters, viz. MIU, MMD, and SMD. MIU is mean frictional coefficient and it is a unitless term. Higher value of MIU means fewer tendencies to slip. Considering tactile clothing comfort, a high value of MIU is not desired.

MMD is Deviation from coefficient of friction; it is also a unitless term. This is a measure of fluctuation of mean frictional coefficient. Higher value of MMD means less smoothness and more roughness and it is not preferred for tactile comfort. SMD is measure of geometric roughness; it is measured in micro meter. Higher values of SMD mean more surface unevenness, and surface unevenness is directly related to its roughness.

2.2.4 Test method for surface properties

The parameters for tactile comfort of summer uniform fabrics are tested on Kawabata Evaluation System KES FB-4. An image of instrument is shown in **Fig. 2** and working principle of this instrument is presented in **Fig. 3**. This instrument has a sensor unit which facilitates a load and surface treatment that mimics a human fingertip. The sensor unit has two probes, one measures dynamic friction and it is called friction contact probe and another measures roughness and it is called roughness contact probe. These probes are set on suitable position automatically, when machine is switched on. A sample size of 20 cm x 20 cm is standard for this testing instrument. Measurement of friction and roughness recorded simultaneously on this instrument.

The friction and roughness signals are converted to voltage, and indicated as numerical value. This instrument displays values of MIU, MMD, and SMD numerically; hence it quantifies a very complex qualitative feature of tactile clothing comfort.

Figure 2: KES FB-4 [18]

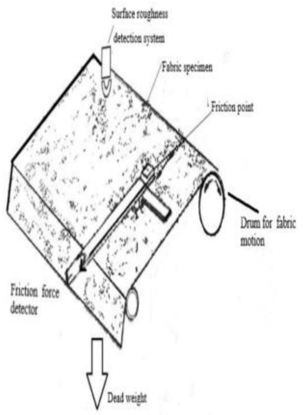


Figure 3: Principle of KES FB-4 [7]

3. Result and discussion:

Tactile comfort pertaining to touch can be anticipated to an extent by observation of these objective test results. The mechanoreceptors in the human body skin [7] are mainly responsible for tactile sensation. Skin sensory responses are simulated by testing instrument, and this can be understood that tribological interaction sensed by the brain leads to form a perception of clothing comfort.

3.1 Effect of fabric grain direction on the surface and frictional properties

The test results of all samples are presented in Table 2. **Fig. 5(i)** is presenting the MIU of trousers fabric along warp-ways and weft-ways, and **Fig 6(i)** is showing the MIU of shirting fabric along warp-ways and weft-ways. It has been observed that MIU is generally higher in weft-ways than warp-ways for both, trousers and shirting fabrics.

Fig. 5(ii) is presenting the MMD of trousers fabric along warp-ways and weft-ways, and **Fig. 6(ii)** is presenting the MMD of shirting fabric along warp-ways and weft-ways. This is observed that MMD is lower in warp direction than it is in the weft direction. The difference between warp-ways and weft-ways MMD has also been analysed for both, shirting and trousers. It is found that the difference between warp-ways and weft-ways MMD is very high in trousers fabrics than shirting fabrics.

The SMD for trousers fabric along warp-ways and weft-ways presented in **Fig. 5(iii)** and for shirting fabric it is presented in **Fig. 6(iii)**.The SMD values in trouser samples are higher in weft-ways than warp-ways, in all the samples while it is not the case with shirting fabric samples.

The tactile comfort related parameters are tested and analysed in their relation with the grain line of the trousers and shirting samples. Surface characteristics are found better in warp direction than in weft direction in the majority of samples and it can be due to higher crimp in the weft -ways. This may be understood in light of the higher resistance offered to the probes due to the higher crimp of the weft.

Table 2: Surface properties measured on KES FB-4

		Sample Code	**MIU**		**MMD**		**SMD (µm)**	
			Warp	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**
TROUSERS	PLAIN WEAVE	T1	1.87	1.94	0.137	0.141	10.81	11.5
		T2	1.52	1.63	0.134	0.14	9.87	10.28
		T3	1.8	1.86	0.138	0.141	10.95	11.76
	TWILL WEAVE	T4	1.63	1.72	0.134	0.139	9.85	10.2
		T5	1.45	1.39	0.131	0.133	8.04	8.18
		T6	1.47	1.52	0.133	0.137	8.43	9.1
	GROUP	S1	0.86	1.05	0.11	0.115	4.66	4.72

SHIRTING	A	S2	0.79	1.03	0.109	0.114	4.77	4.19
		S3	0.7	0.68	0.112	0.099	3.92	3.11
		S4	1.01	1.16	0.112	0.117	4.8	4.99
	GROUP B	S5	1.32	1.34	0.123	0.125	6.69	7.01
		S6	1.21	1.25	0.118	0.122	5.27	5.9
		S7	1.39	1.36	0.127	0.121	6.98	7.19
		S8	1.28	1.31	0.121	0.124	5.44	6.01

3.2 Effect of weave on surface and frictional properties

The twill -woven and plain-woven uniform trousers fabrics are studied for their tactile comfort properties. T1, T2, and T3 are plain-woven while T4, T5, and T6 are twill woven samples. **Fig.** 5(i) shows the MIU of trousers samples, this is observed that plain-woven fabrics have higher MIU than twill woven fabric samples. **Fig. 5 (ii)** shows the MMD of trousers samples, this is observed that plain-woven fabrics have higher MMD than twill woven fabric samples. This is found that MMD is lower in both, warp and weft direction for twill than it is in plain-woven samples. The comparison in SMD for these two weaves can be observed from **Fig. 5(iii)** for warp ways and weft ways respectively. The SMD values are higher for plain weave samples than twill weave samples. The higher values of MIU, MMD and SMD for plain structures can be assigned to higher asperities due to a greater number of interlacements. The fabric geometry of these weaves justifies this explanation.

3.3 Effect of fabric set on the surface and frictional properties:

Shirting fabrics' group A is having a higher sett than group B. The test results of shirting fabrics for all three tactile comfort parameters are presented in table 2. The test results for MIU of shirting samples are shown in **Fig. 6(i),** it is found that higher sett group A has better MIU properties than lower sett group B.

The test results for MMD of shirting samples are shown in **Fig. 6(ii),** it is observed that the MMD is higher in Group B samples in both, warp-ways and weft-ways.

The SMD for shirting group A and B has been studied and results are presented in **Fig. 6(iii)** for warp ways and weft ways. This is observed that Group B having samples of lower sett has higher SMD values in the weft direction.

This may be attributed to the gaps between yarns of fabric structure leading to enhancement of asperity and resulting in higher values of the SMD. Fabrics with higher sett have better surface properties this may be assigned to fewer surface variations in depth.

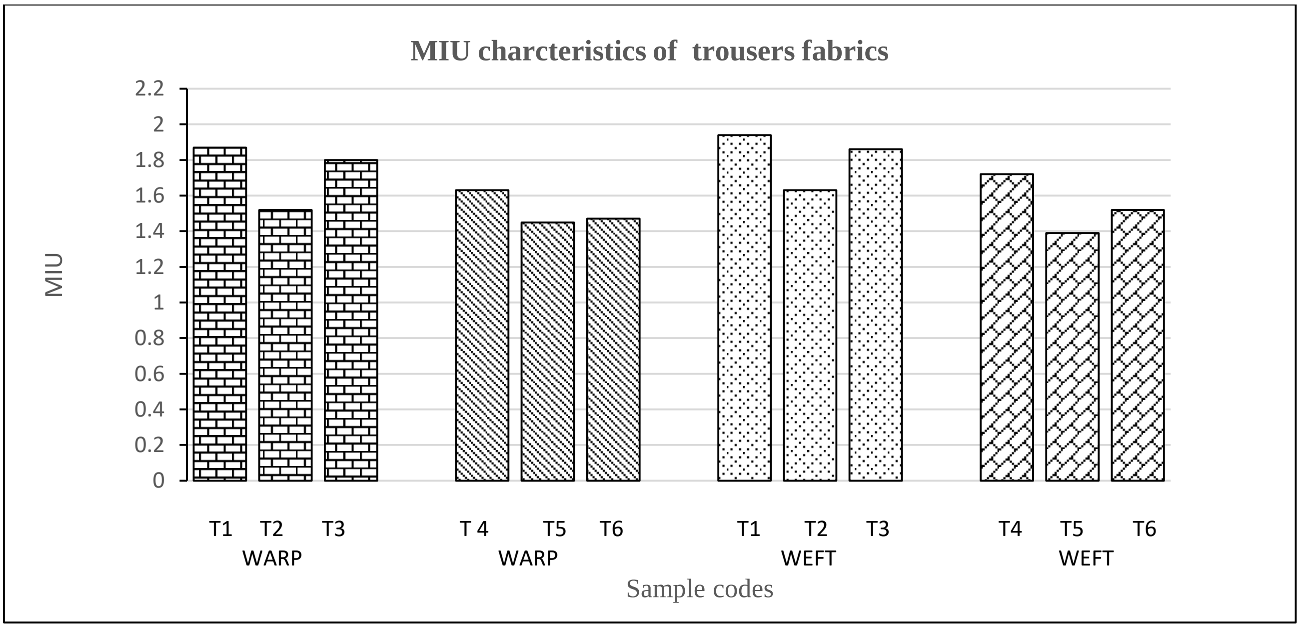


Figure 5(i): MIU of trousers fabric along warp and weft ways

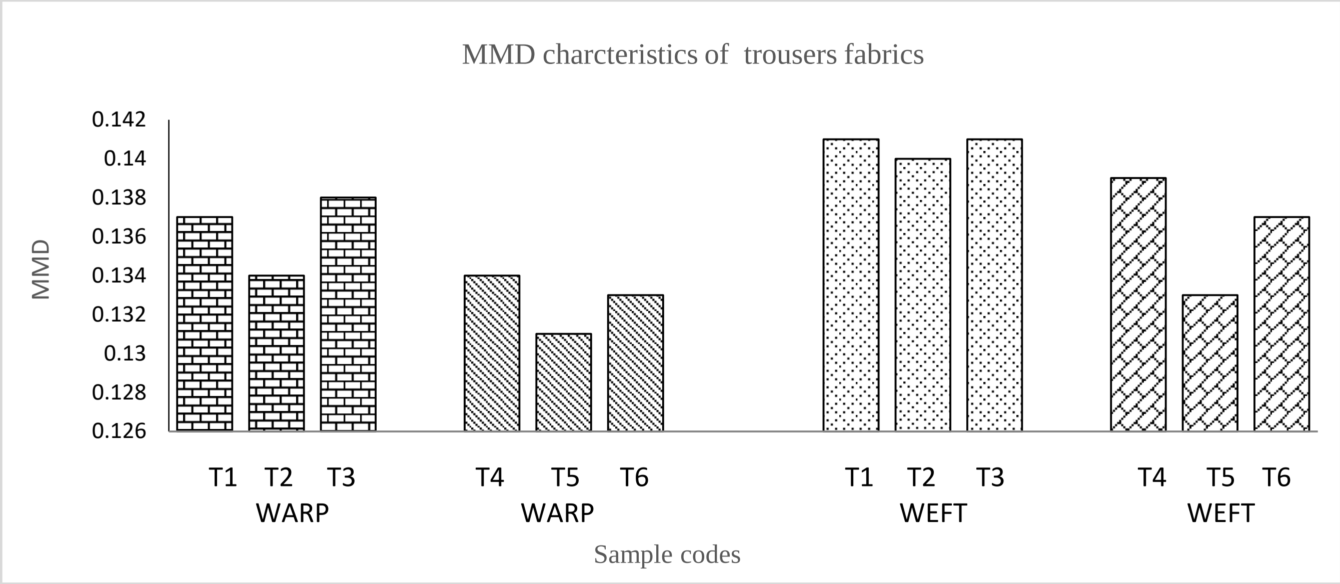


Figure 5 (ii): MMD of trousers fabric along warp and weft ways

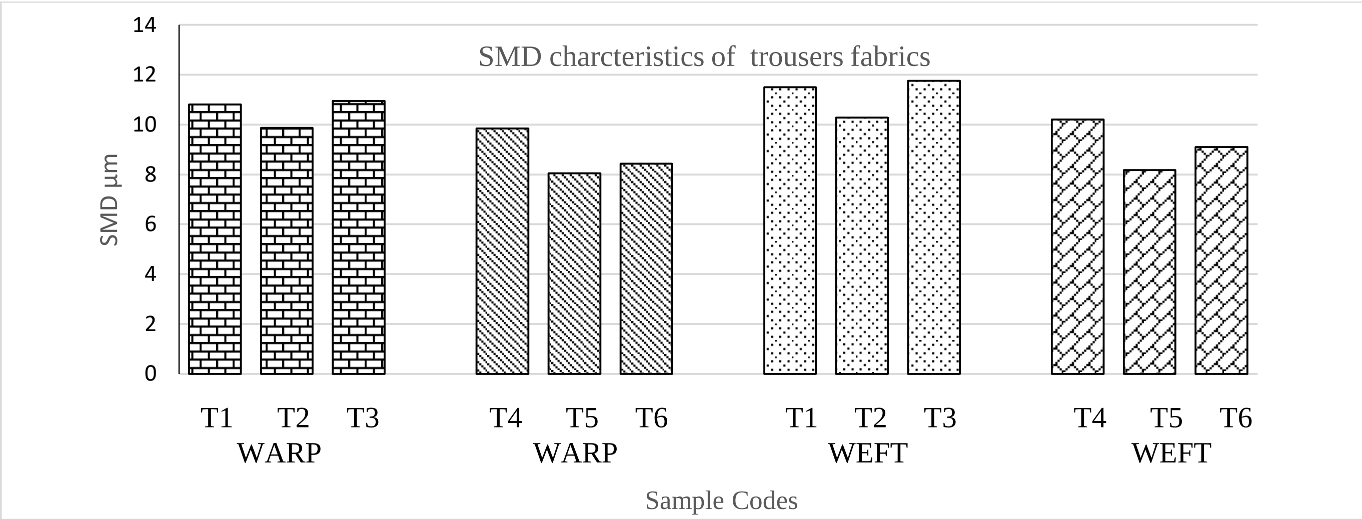
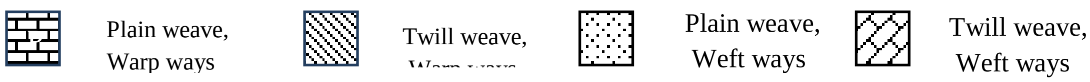


Figure 5(iii): SMD of trousers fabric along warp and weft ways

For Fig.5 (i),(ii) and(iii



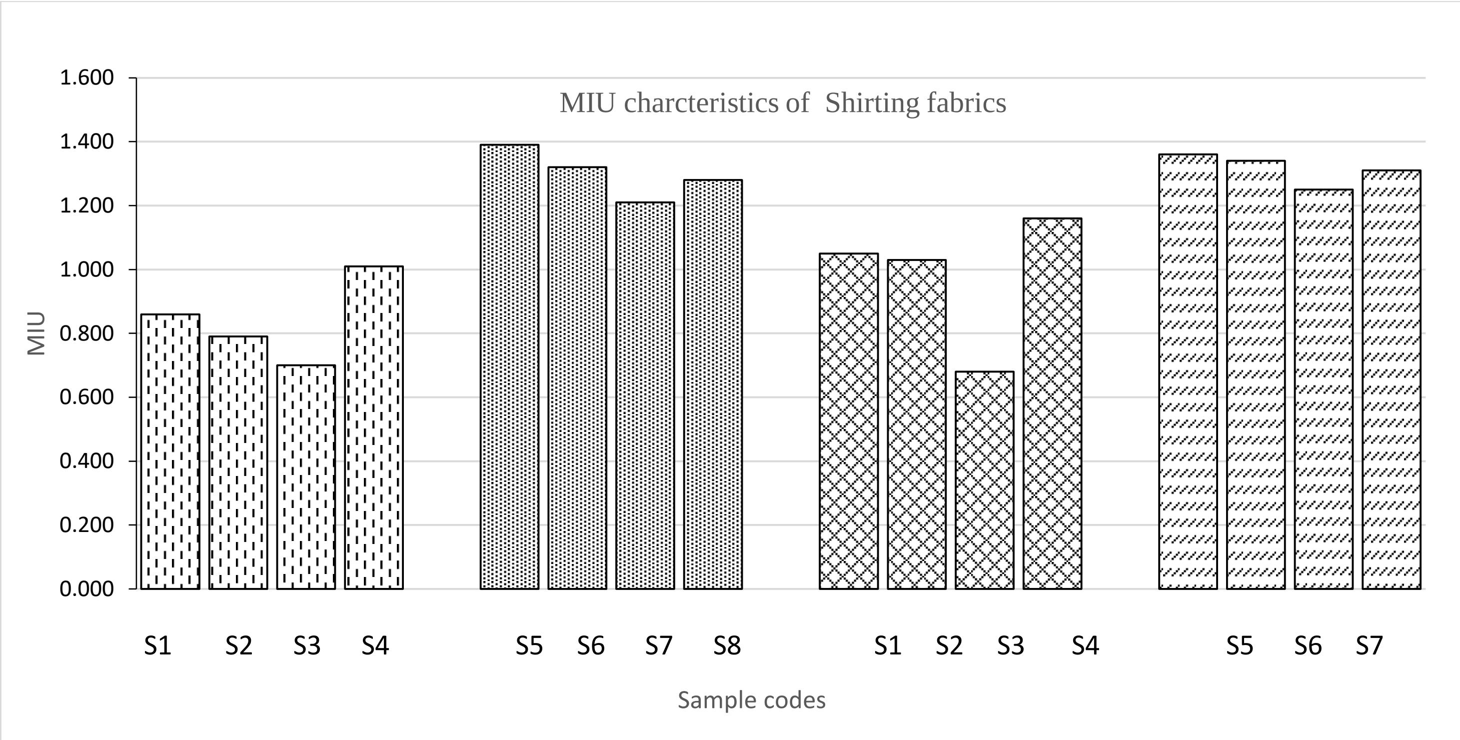


Figure 6(i) MIU of shirting fabric along with warp and weft

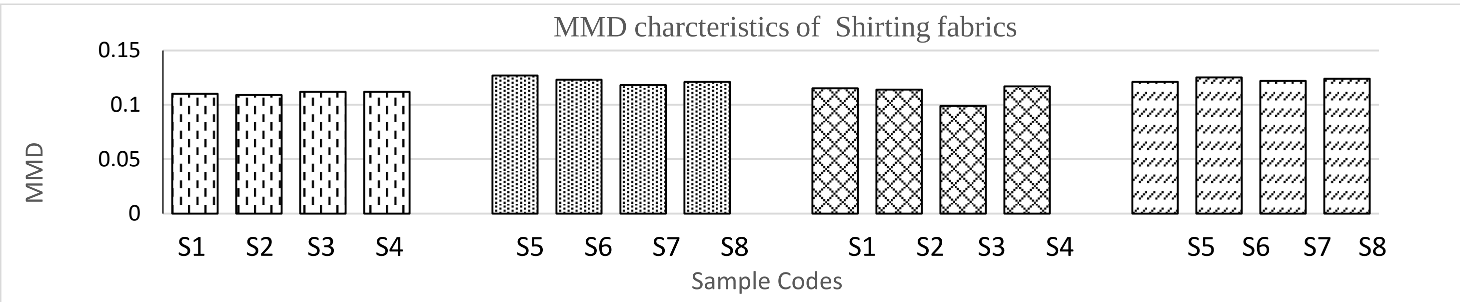
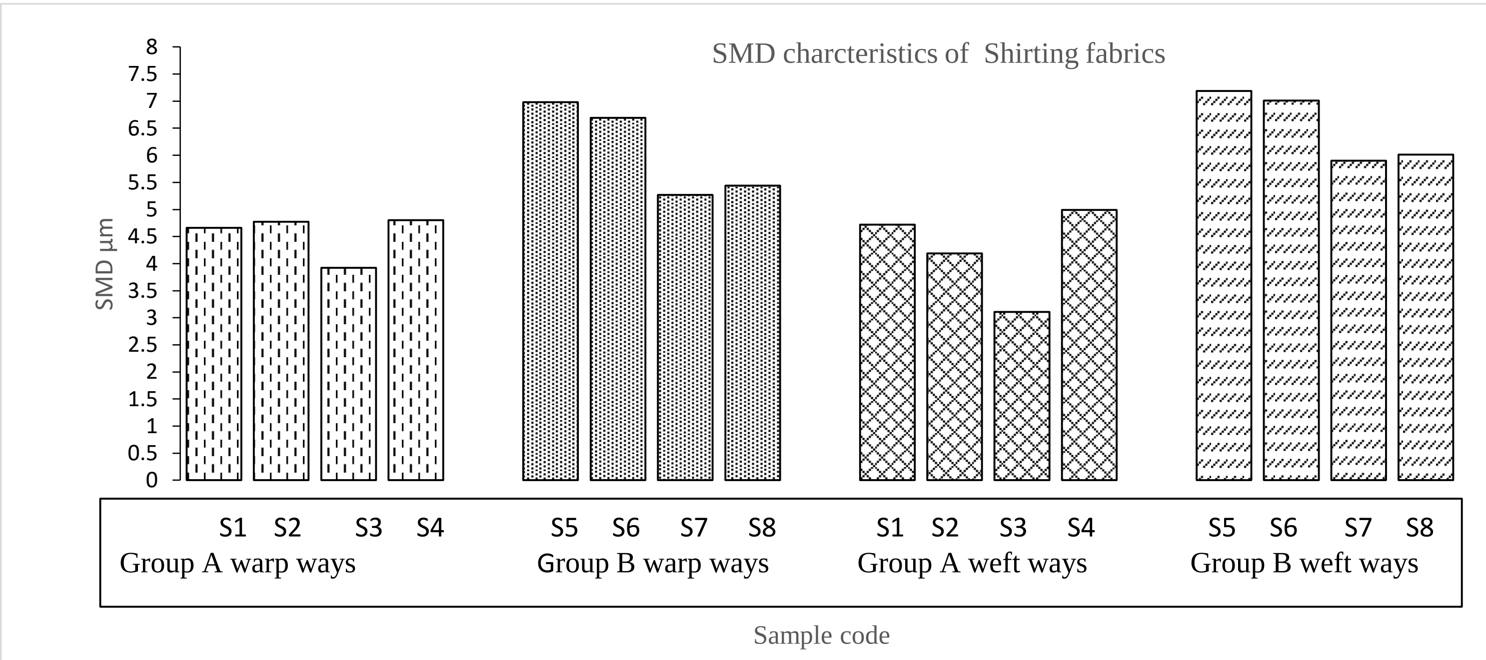
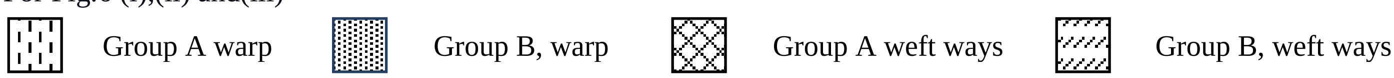


Figure 6(ii): MMD of shirting fabric along warp and weft ways



For Fig.6 (i),(ii) and(iii)



3.4 Effect of Constructional parameters and surface related comfort characteristics

Fabric comfort characteristics have been analyzed with respect to constructional parameters viz. GSM, EPC, PPC and thickness. A significant correlation found between these constructional parameters and all tested comfort characteristics**;** MIU, MMD and SMD, this is presented in table 3.GSM and thickness have positive while EPC, PPC have negative correlation with all tested characteristics. It is pragmatic for tested samples that beyond 150 GSM, comfort properties decrease and a thickness little less than 0.40 mm may be considered adequate after 0.40 mm values of MIU, SMD and MMD rise which is not desirable for comfort of clothing.

Table 3: Correlation between constructional variables and comfort factors

Correlation between constructional varible and comfort factors	**GSM (gm/m^2)**	**EPC**	**PPC**	**Thickness (mm)**	**Correlation between Warp and Weft**
MIU	0.801	-0.857	-0.877	0.512	0.9727
MMD	0.888	-0.827	-0.887	0.643	0.9156
SMD	0.828	-0.809	-0.810	0.630	0.9917

This is also observed that a twill structure with slightly lower sett can offer better tactile properties than a plain structure having higher sett, this may be practically applied to reduce material cost, i.e. twill weave with lower sett may be preferred to some extent over plain weave with higher fabric set.

Frictional and surface properties are found better warp ways than weft ways. The role of asperity of surface is important and extent of its fluctuation decides surface profile which governs roughness and friction behaviour. This is found that twill woven fabrics have better tactile properties than plain woven fabrics for trousers. Further, it may also be concluded that higher sett group of shirting has better surface properties than that of lower sett group.

3.5 Statistical analysis

The tactile comfort-related, surface and friction properties are tested, and test results are analyzed statistically for their significance. ANOVA results for all three tactile comfort characteristics are presented in table 4. A very low value of P is observed in all the ANOVA tests. The critical value of F is lower than F in all the analysis of variance tests, therefore the significance of the factors can be accepted for tactile comfort of the fabrics. The effect of weave is found significant for the trousers and the effect of the sett is found significant for shirting fabric samples.

Table 4: ANOVA results

ANOVA single factor	**Comfort feature**	**F**	**P-value**	**F critical**
Trousers' sample weave twill and plain	MIU	9.4627	0.0371	7.7086
Trousers' sample weave twill and plain	SMD	22.9100	0.0087	7.7086
Shirting group A and B	MIU warp	37.1228	0.0009	5.9874
Shirting group A and B	SMD warp	10.5234	0.0176	5.9873
Shirting group A and B	MIU Weft	9.8515	0.0201	5.9873
Shirting group A and B	SMD Weft	18.24036	0.0052	5.9874

4. Conclusion

Summer school uniform fabric samples were tested and analysed for their surface characteristics. Surface properties are mainly related to the friction properties of fabrics, in this study, these are tested on Kawabata Evaluation System FB-4. Fabric is subjected to real fingertip-like contact conditions simulated through sensors.

It is observed that twill woven fabrics have better surface and frictional properties than plain-woven fabric. This may be assigned to a more continuous surface of the twill woven fabric than plain-woven fabric. It is found that there is a negative correlation between fabric sett and tactile comfort parameters, higher sett fabrics have better surface and frictional properties than lower sett fabrics. This is also observed that there is a very high positive correlation found between all warp and weft surface properties.

The roughness and frictional surface properties of summer school uniform fabrics are found negatively correlated with fabric sett; higher fabric sett has better surface properties related to tactile comfort, this fact may be applied while planning fabric structure. It is known that fabric manufacturing cost is largely governed by the cost of pick insertion.

Based on the results of this study, the EPC may be made higher and pick density may be lowered to an extent, without compromising on comfort characteristics and body of the fabric. Use of small twill in shirting fabrics may be recommended to school uniform manufacturers for enhancing tactile comfort of shirting clothing.

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