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Effect of variation of pick density on the properties of jute fabric samples woven in S4A loom and a comparative study with the standard fabric (*IS 12650: 2003 2nd revision*)

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ABSTRACT : *The variation of pick density of the jute fabric samples, woven in multiphase, shuttleless S4A loom, effecting the physical, mechanical and hydraulic properties of those fabric samples have been investigated in this article. An attempt has been made in this work to make a comparative study between the properties of jute fabric samples woven in S4A loom with respect to that of the standard fabric used to manufacturejute bags for packing 50 kg of foodgrains as per Bureau of Indian Standards (IS 12650: 2003 2nd revision).*

Keywords –*pick density, breaking strength, bursting strength, apparent opening size, BIS.*

I. INTRODUCTION

Textile products play a vital role in meeting man's basic needs [1]. The backdrop of growing global concern for environment concomitant with the alarming danger of carbon foot-print generation amalgamated with non-biodegradability and higher toxicity generation from the use of synthetic fibres have created an urge to come back to natural fibres, thereby opening new market opportunities [2]. The growing disinclination to use artificial fibres and an increasing preference for natural fibres is reviving the importance of the latter like jute, cotton, flax, sisal, hemp, coir etc. [3].The Textile Industry should attempt to play a pathfinder's role to facilitate natural fibre competitiveness in a global context. For orienting natural fibres from its present status of struggle against other alternatives, mainly synthetics, in the area of packaging to a positively prospering commodity having diverse applications, the Industry shall have to appreciate the versatility and all the positives of natural fibres, overcoming their deficiencies and evolving commercially viable product lines for their use in the future. To meet the dynamics of ever-changing demand-driven market the Textile Industry will have to orient and sensitize the manufacturers, researchers, technologists, end-users, stake-holders towards new design, products and technological innovation [4]. That would require not only the identification of the potential products made out of natural fibres but also urges development of specifications in consultation with manufacturers and end-users. Good quality fabrics and high weaving efficiency cannot be achieved unless a suggested woven fabric construction is weavable and does not exceed the limit, that is, the maximum number of ends and picks per unit length that can be woven with given yams and weave [5]. When trying to weave a fabric with construction close to the limit or higher than the limit, the fell of the cloth would creep beyond the reed's furthest forward position and bumping would occur. This is because the fabric would build up more rapidly at the fell of the cloth than the take-up motion could accommodate. Obviously with such unrealistic fabric constructions, the loom parts may be overstressed and damaged, and frequent warp end breaks may occur due to excessive wear and high beat-up forces, resulting in low weaving efficiency and poor fabric quality [6]. Since the last century, many researchers have been attracted to the subject of maximum constructions. Extensive empirical investigations have derived relationships expressing the maximum ends and picks per unit length in terms of warp and filling yarn counts and weave design [7]. An additional concurrent objective of the earlier work was to develop a numerical dimensionless parameter that describes a woven cloth relative to a standard or reference fabric. The ultimate goal behind this development was to relate the degree of tightness to fabric properties [8].

This correlation between tightness and fabric properties could be used to construct comparable fabrics that might vary in one or more fabric parameters and, equally important, to predict fabric properties and hence develop structures to fit specified end uses. The production of modern woven fabrics demands developing strategies considering new structures. It is clear that a new fabric structure should have the desired quality at minimum production costs, and the highest possible weaving efficiency. Fabrics are designed to fit different projected demands in order to be suitable for their end use [9]. For a fabric constructor it is essential that the relationships between the constructional parameters of fabrics and their individual properties, i.e. those that should fit the desired quality, are well defined. The mechanical properties are of considerable importance to fabric end use, so a lot of research has been dealt with them and there have been a number of efforts to try to define different models. Usually, several types of looms are used in factories. It was noticed that, properties of fabrics with the same setting parameters, but woven with various looms in various companies are different. It is well-known that the woven fabric's qualities are closely dependent on its structure. The tensile qualities of woven fabric have been researched by Nikolic [10] and others. He has proposed investigating woven fabric's strength as a function of thread strength, fabric density and thread strength coefficient. It was established that as thread strength increases, the woven fabric's strength also increases. While investigating woven fabrics of different weaves, it was established that plain weave has the maximum strength. Frydrych [11] et al. investigated the influence of woven fabric finishing, weft setting and raw materials on the elongation at break.

II. MATERIALS AND METHODS

Both the warp yarns, weft yarns have been procured from a reputed commercial Jute Mill of West Bengal, India. The fabric samples have been manufactured from these procured yarns in the S4A loom in the Department of Jute and Fibre Technology, University of Calcutta. The specification of the S4A loom that has been employed in this study has been provided in the table 1. Two number of fabric samples i.e. Fabric Sample - 1 (FS-1) and Fabric Sample – 2 (FS-2) have been produced. The particulars of the fabric samples have been given in the table 2.

Table 1: Particulars of the Loom used in the study

Loom Type	Shuttleless multiphase curvilinear rapier loom
Make	ZHEJIANG GOLDEN EAGLE CO. LTD.
Speed of the loom	710 ppm
Type of weft carrier	Semi-circle tube type rigid rapier
Picking mechanism	Both side double weft insertion picking

Table 2: Particulars of the Woven Fabric Samples

Fabric samples	Warp Count (lbs/spy)	Weft Count (lbs/spy)	Warp Crimp (%)	Weft Crimp (%)	Ends/ dm	picks/ dm	Converted gsm at 20 % M.R.	Thic kness (mm)	Total Fabric Cover factor	Moistur e Regain %
FS-1	14.43	14.98	5.33	3.40	47.01	62.99	618.60	2.32	82.28	11.00
FS-2	14.43	16.60	4.76	3.20	46.77	54.88	620.00	2.53	81.34	10.50

2.1. Conditioning of test fabric samples

The entire range of woven fabric samples were conditioned using standard temperature (21˚ C ± 2˚ C) and humidity (65% ± 2 % relative humidity) for 24 hours before commencement of any testing work.

2.2. Selection of fabric samples for testing work

Small size samples used for normal textile testing cannot generally be regarded as appropriate for technical textile testing. These small samples have only a limited usefulness in assessing the properties of a fabric relative to its engineering end use, samples tested on modified or specially developed apparatus provide much more appropriate data. Therefore, test samples have been selected in such a way that it could represent the whole population of the fabric and the piece of fabric cut out for the laboratory test has been at least one meter long with full width of the fabric. No samples have been taken from nearer than 50 mm to the selvedge of the fabric samples.

2.3. Measurement of the count of the warp and weft yarns

The yarn package has been unwinded to a length of 75 yards by using wrap reel instrument after which this particular length of the yarn is weighted in the electronically weighing balance. The count of the jute yarn is expressed in grist and calculated by applying the formula {(Weight of the yarn in pound × 14400) ÷ (Length of the yarn in yard)}. Ten number of observations has been taken for both warp and weft yarns each. The average values of warp and weft yarn counts have been provided in table 2.

2.4. Measurement of weight per unit area of the fabric samples

The specifications for mass per unit area for any woven fabric sample have direct influence on its physical, mechanical, hydraulic and other geotechnical properties. From each fabric sample, ten number of test samples of each 10 cm. × 10 cm. dimension have been cut from various locations over the full width of the fabric and then weighed in precision electronic balance. The average mass per unit area has been calculated for all the test samples. The average weight per unit area of the fabric samples have been converted at 20% moisture regain and the value is expressed in gsm and shown in table 2.

2.5. Measurement of fabric thickness

Thickness is one of the basic physical properties used to control the quality of woven fabrics. The normal thickness of a woven fabric sample is determined by observing the perpendicular distance that a moveable plane is displaced from a parallel surface by a specified pressure 2 kPa for fabric specimen. The accuracy level for determination of fabric thickness is very essential as this data is pre-requisite input for determining some important fabric parameters of geotextile fabrics, such as permeability of both of the air and water, permittivity, porosity etc. The thickness of the fabric samples in this study was measured using thickness tester of AIMIL Ltd. (Model AIM-241), New Delhi make, which is suitable for determining maximum thickness of 10 mm or 25 mm, provided with two dial gauges, one for the range of 10 mm with accuracy of 0.002 mm and the other for the range from 11 to 25 mm with accuracy of 0.01 mm under a pressure foot area of 31.66 cm^2 having standard pressure of 20 $g/cm^2$for a compression period of 20 seconds. For accurately determining the thickness of the fabric, it was cut in such a fashion that the material extended by 1.0 cm in all directions beyond the edge of the pressure foot. Ten such observations for each sample were taken randomly from different parts of the sample and the average has been calculated and furnished in table 2.

2.6. Measurement of thread density of the produced fabric samples

In woven fabric the warp yarns are commonly referred to as 'End' and the number of warp threads per inch width of cloth is defined as 'Ends/inch'. The threads of weft are called 'Picks' and the number of weft threads per inch width of cloth is defined as 'Picks/inch'. The determination of the thread density has been carried out by unraveling a known width of the fabric sample and then the threads are counted in every one inch interval of the fabric sample at different places of the same using a counting glass magnifier. The different readings are recorded and the average of the threads/inch is noted and shown in table 2.

2.7. Determination of crimp and crimp percentage of the produced woven fabric samples

When warp and weft yarns are interlaced in the fabric they follow a wavy or corrugated path. Crimp percentage is a measure of this waviness in yarns. Peirce in his paper on cloth geometry, states that, crimp geometry is the percentage excess of length of the yarn axis over the cloth length. In order to straighten the thread, tension has been applied, just sufficient to remove all the kinks without stretching the yarn. Two cuts are made in the fabric sample and the distance between them has been noted. Threads are removed and placed over the scale, one end of each detached thread held by the fore finger and the thread smoothed along with the fore finger, and the straightened length has been observed. In this way several readings from different ear-marked areas of the fabric samples have been recorded and the average of these is provided in the table 2. The crimp percentage has been calculated mathematically by using the equation [{(Straightened length of yarn)-(Length of the yarn in the fabric)} ÷ (Length of the yarn in the fabric)] × 100. The average values of warp and weft crimp percentages are given in table 2.

2.8. Calculation of the fabric cover factor of the produced fabric samples

One of the most important applications of cloth geometry is to calculate the cover factor of a cloth. In practice, this is given by a suitable factor based on the proportional area of the fabric covered by the projection of the threads. In case of jute fabric, the cover factor K has been calculated by multiplying threads per inch by the square root of yarn linear density expressed in lb/spyndle. If p is the spacing between the threads, then the fabric cover factor, $K= nC^{1/2} = d/p$, where, n is the thread density expressed in ends/inch and picks/inch while C is the yarn linear density expressed in lb/spyndle. It appears from the above equation that when the cover factor is 120, the thread must touch where they cross from one face of the cloth to the other. The cloth cover K is expressed by $Kc = (K_1+K_2) - (K_1 \times K_2/120)$ where $K_1$and K_2 are the warp and weft cover factors respectively. The total fabric cover factors of both the samples are provided in table 2.

2.9. Determination of breaking strength of the jute woven fabric samples following ravelled strip method (IS 9113: 1993)

The fabric sample used in ravelled strip method is 100 mm wide piece of fabric prepared by initially cutting the fabric to a width of 120 mm and removing threads from its both sides until the width has been reduced to 100 mm. The gauge length between the clamps is kept at 200 mm and the fabric strip is cut to a length of 350 mm for smooth and stable gripping of the fabric at both ends. The speed of the moving jaw has been set at 460 mm per minute. Five number of observations have been taken both in the warp and weft directions of the fabric samples. The average breaking strength values, both in the warp and weft directions, of the fabric samples FS-1 and FS-2 are provided in tables 3 and 4 respectively.

2.10. Determination of bursting strength of the jute woven fabric samples following IS: 7016 (Part 6)-1984 test method

The conditioned fabric sample is placed over the rubber diaphragm of the apparatus. The clamp ring is tightly secured over the fabric sample to hold the sample firmly in place. Then the power supply is switched on and the display of the digital pressure indicator is allowed to stabilize. The pressure on the rubber diaphragm is gradually increased by introducing the liquid (glycerin) into the chamber until the test sample burst. The upper surface of the fabric sample under test is observed constantly. As soon as the sample fails, cam switch mark '0' has been switched off. The test sample is released and remove from the holding clamps. The time taken for bursting of the sample is noted. The same process is repeated without clamping the fabric sample. Six numbers of such observations have been made. The pressure required to distend the rubber diaphragm for the average time taken for bursting the fabric sample is noted. The average bursting strength values of the fabric samples FS-1 and FS-2 are provided in tables 3 and 4 respectively.

2.11. Measurement of air permeability of jute woven fabric samples

The air permeability of the jute woven fabric samples produced in this study has been measured using PROLIFIC Air Permeability Tester which consists of an arrangement to hold the test specimen between two flat faces so as to expose an area of 10 cm^2 to the flow of air through it. There is a vacuum system to draw air through the exposed area of the test sample, and arrangement to measure the volume of air flowing through the test sample and arrangement to measure the pressure drop between the two faces of the test sample as a result of flow of air. The test specimen is held between two annular ring shaped grips. The grips are lined with rubber gaskets to reduce flow of air through the edges. The suction pipe is connected on the right hand side of the equipment to the suction hose of the vacuum pump. Water is filled in the upper of the two transparent plastic cups provided on the left hand side of the equipment. Sufficient water has been filled to make its level reach the zero mark on the lower manometer tube. Water in the lower plastic cup is drained out through the drain valve at its lower end. The drain valve is closed fully. The equipment has been levelled with the help of four levelling bolts provided so that the upper face of the sample mounting platform lies in a horizontal plane. In this position the water level in the two lower manometer tubes remains the same. The power supply is provided to the equipment from 220 volt single phase AC supply. The conditioned fabric sample is placed centrally between the grips. Sufficient tension has been provided to the fabric sample to prevent it from wrinkling and it is also taken care to look after the fact that the fabric sample does not get distorted in its own plane. The upper grip has been lowered to hold the fabric firmly. Adequate holding pressure has been applied to prevent slippage of the fabric and also to eliminate any leakage of air through the gripping faces. The flow of air is now slowly opened adjusting the valve of the first rotameter from the left, increasing the air flow rate till either the desired pressure drop is obtained on the manometer tube or the air flow rate reaches the maximum capacity of the rotameter. The pressure drop is indicated by the level of water column in one of the three upper manometer tubes. The rotameter reading has been recorded. The air permeability is then calculated by multiplying a correction factor of 0.01667 with the rotameter reading and expressed in in $m^3/m^2/min$ as shown in table 5.

2.12. Measurement of Apparent Opening Size (AOS) of the jute woven fabric samples following ASTM D4751-12

The fabric sample is secured in a taut condition (without any wrinkles or bulges) in the sieve pan of the dry sieve test apparatus by wedging between the sieve frames. Again the fabric sample is not over stretched or deformed such that it changes or distorts the openings in the fabric. Prior to each use, the glass beads are sieved in the laboratory verifying the size of the beads. The test is carried out with glass beads of different sizes expressed in microns. 50 gm of a particular sized glass beads are placed on the center of the geotextile. The cover and pan are placed on the sieve frame and the assembly is then placed in the shaker. The sieve is shaken for a duration of 10 minutes by electric energy. The glass beads that passed through the specimen are weighed and recorded. The above procedure is repeated using the next larger bead size fraction. The trial is repeated using succeeding larger bead size fractions until the weight of the beads passing through the sample is 5 % or less. The trials are performed such that the percentage of glass beads passing decreases from a value greater than 5 % to a value less than or equal to 5 %. After that, the Apparent Opening Size (AOS) O_{95} value is determined from the co-ordinate graph by plotting the values of percentage of beads passing the sample versus the bead size used for each sample in the y-axis and x-axis respectively. The average AOS values of the samples FS-1 and FS-2 are shown in table 6.

III. RESULTS AND DISCUSSION

The test results of the mechanical and hydraulic properties of the woven jute fabric samples manufactured in the Department of Jute and Fibre Technology, University of Calcutta, have been furnished in tables 3 and 4 and a comparative analysis of the test results of the same with that of the standard fabric used to manufacture jute bags for packing 50 kg of food grains as per Bureau of Indian Standards (IS 12650:2003, 2nd Revision) has been carried out.

Table 3: Mechanical Properties of the Jute Woven Fabric Samples (FS-1) produced in S4A Loom, Dept. of Jute and Fibre Technology, University of Calcutta, India

Sl. No.	Breaking Strength (N)		Average Breaking Strength (N)		Breaking Elongation (%)		Average Breaking Elongation (%)		Bursting* Strength (kg/cm^2)	Average Bursting Strength (kg/cm^2)
	Warp Way	Weft Way	Warp Way	Weft Way	Warp Way	Weft Way	Warp Way	Weft Way		
1	2020	3210	2319	3021	6.0	5.0	6.4	4.5	23.80	24.88
2	2540	3240			7.0	4.0			25.60	
3	2060	3100			6.0	4.0			19.00	
4	2710	3280			8.0	4.0			25.10	
5	2210	2690			6.0	4.0			24.20	
6	2300	3050			6.0	5.0			29.40	
7	2340	2800			6.0	5.0			28.30	
8	2420	3030			7.0	5.0			24.10	
9	2240	2670			6.0	4.0			24.90	
10	2350	3140			6.0	5.0			24.40	

**Diaphragm correction factor = 4.3 kg/cm^2*

Table 4: Mechanical Properties of the Jute Woven Fabric Samples (FS-2) produced in S4A Loom, Dept. of Jute and Fibre Technology, University of Calcutta

Sl. No.	Breaking Strength (N)		Average Breaking Strength (N)		Breaking Elongation (%)		Average Breaking Elongation (%)		Bursting* Strength (kg/cm^2)	Average Bursting Strength (kg/cm^2)
	Warp Way	Weft Way	Warp Way	Weft Way	Warp Way	Weft Way	Warp Way	Weft Way		
1	2390	3440	2249	2905	7.0	4.0	6.5	4.4	22.2	21.9
2	2230	2980			6.0	4.0			18.1	
3	2270	3300			6.0	4.0			19.4	
4	2250	2670			8.0	5.0			23.2	
5	2090	3030			6.0	4.0			25.0	
6	2150	2750			7.0	5.0			23.8	
7	2250	2860			7.0	5.0			19.9	
8	2270	2570			6.0	5.0			20.9	
9	2250	2650			6.0	4.0			24.2	
10	2340	2800			6.0	4.0			22.3	

**Diaphragm correction factor = 4.1 kg/cm^2*

Table 5: Hydraulic Properties (Air Permeability) of the Jute Woven Fabric Samples produced in S4A Loom, Dept. of Jute and Fibre Technology, University of Calcutta

Sl. No.	FS-1		FS-2	
	Rotameter reading	Average Air Permeability ($m^3/m^2/min$)	Rotameter reading	Average Air Permeability ($m^3/m^2/min$)
1	8250	7850 × 0.01667 = 130.85	8500	8425 × 0.01667 = 140.44
2	8500		8250	
3	7500		8750	
4	8000		8750	
5	8000		8500	
6	8750		7000	
7	7500		8750	
8	7500		8500	
9	7000		9000	
10	7500		8250	

**Measured at exposed surface area 10 cm^2 and 10 mm water column.*

Table 6: Hydraulic Properties (Apparent Opening Size) of the Jute Woven Fabric Samples produced in S4A Loom, Dept. of Jute and Fibre Technology, University of Calcutta

Fabric samples	Sl. No.	Glass bead used (micron)	Weight of glass bead (gm)	Weight of Glass bead passes through the fabric (gm)	% of Glass bead passes through the fabric
FS-1	1	1400	50	46.52	93.04
	2	1700	50	3.72	7.44
	3	2000	50	0.05	0.10
	Average AOS (O_{95})= 1720micron				
FS-2	1	1400	50	8.27	16.54
	2	1700	50	0.79	1.58
	Average AOS (O_{95})= 1630micron				

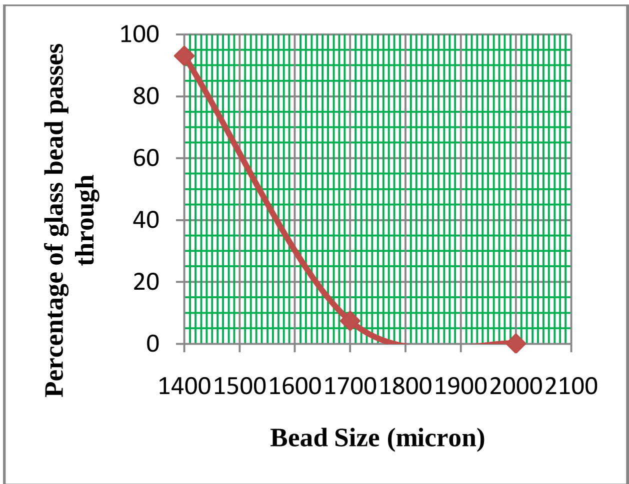

Fig-1: AOS Curve for FS-1

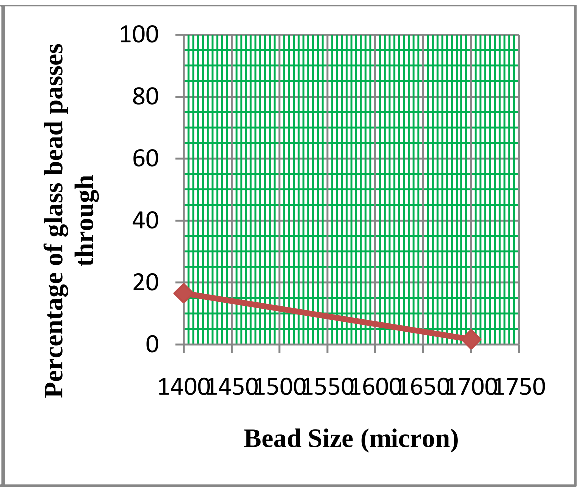

Fig-2: AOS Curve for FS-2

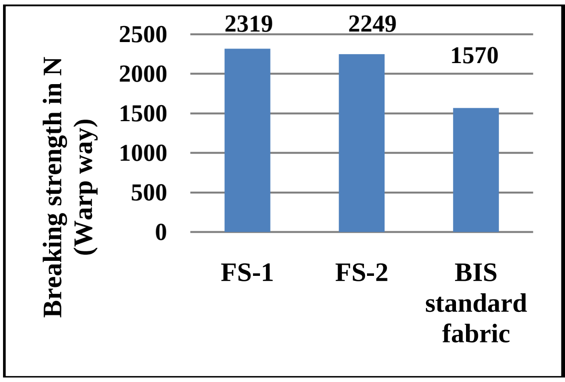

Fig-3: Graphical comparison of the warp way breaking strength in N of different samples

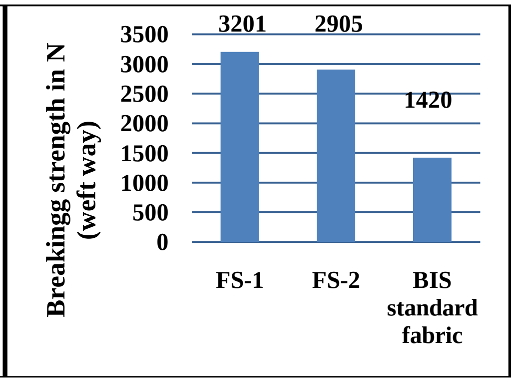

Fig-4: Graphical comparison of the weft way breaking strength in N of different samples

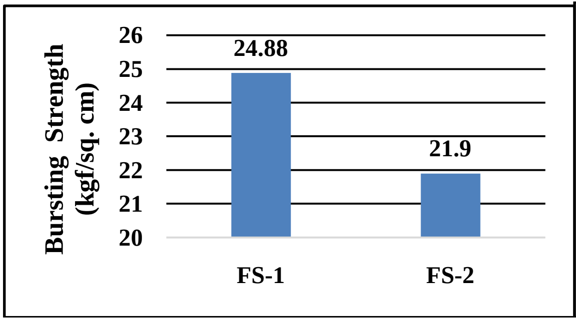

Fig-5: Graphical comparison of bursting strength in kg/cm^2 of produced samples

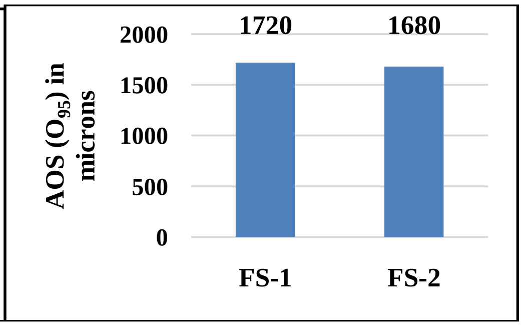

Fig-6: Graphical comparison of AOS (O_{95}) in microns of produced samples

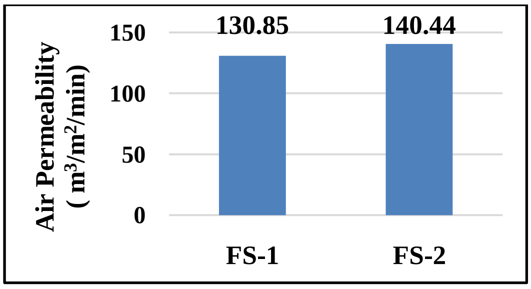

Fig-7: Graphical comparison of Air Permeability in m^3/m^2/min of producedsamples

3.1. Comparative analysis of the mechanical properties of FS-1 and FS-2 fabric samples

The test results of the two number 2/1 Twill Jute woven fabric samples, FS-1 and FS-2 produced in the multi-phase shuttleless S4A Loom of the Department having area densities 618.6 gsm and 620 gsm respectively when compared among themselves, show that there is a decreasing trend in the unidirectional warp way and weft way breaking strengths of the fabric samples. FS-1 shows a comparatively high breaking strength of 2319 N as against 2249 N of FS-2 in the warp direction while the breaking strength of 3021 N of FS-1 scores over the breaking strength of 2905 N of FS-2 in the weft direction. This trend has been represented graphically in fig. 3 and 4. While fig. 5, related to the multi-directional bursting strength values of the two tested fabric samples, shows that the bursting strength value of FS-1 (24.88 kg/cm^2) supersedes the bursting strength value of FS-2 (21.9 kg/cm^2). While no significant differences have been observed in the values of the hydraulic properties of the two fabric samples and the findings have been supported by the figs. 6 and 7 respectively. The variation of the pick density of the two jute fabric samples FS-1 and FS-2, (recorded as 62.99 and 54.88 picks / dm respectively in table 2) keeping their area densities almost same (618.60 and 620 gsm) are found not to produce any significant difference in the warp way (2319 N and 2249 N) and weft way (3021 N and 2905 N) breaking strengths of the samples.

3.2. Comparative analysis of the mechanical properties of the fabric samples produced (FS-1 and FS-2) with the standard fabric sample required for producing Jute Bags for packing 50 kg food grains as per IS 12650:2003, 2nd Revision

The test results of the two number 2/1 Twill Jute woven fabric samples, FS-1 and FS-2 produced in the multi-phase shuttleless S4A Loom having area densities 618.6 gsm and 620 gsm respectively show higher breaking strength values of the produced samples than that of the standard fabric sample required for producing Jute Bags for packing 50 kg food grains as per IS 12650:2003, 2nd Revision, and this is clearly observable in figs. 3 and 4 respectively. The values obtained are 2319 N, 2249 N for sample FS-1 and 3021 N, 2905 N for sample FS-2 in warp and weft directions respectively against the breaking strength values of 1570 N, 1420 N of the standard fabric in the warp and weft directions respectively.

IV. CONCLUSIONS

The two number 2/1 Twill Jute woven fabric samples, FS-1 and FS-2 produced in the multi-phase shuttleless S4A Loom having area densities 618.6 gsm and 620 gsm respectively when compared with the standard jute sacking fabric specified in IS 12650:2003, 2nd Revision and woven in conventional Jute Sacking Loom, show higher breaking strength values both in the warp and weft directions which supports the fact that better quality of jute sacking fabrics can be woven in S4A loom than in the conventional jute sacking loom with higher weaving efficiency. It can be also stated here that considering from the end-use point of view, a jute fabric is more likely to fail by bursting than by a straight tensile fracture therefore the determination of the bursting strength of the jute woven fabric samples along with its hydraulic properties are equally important for finding out the stress developed in all the directions at the same time. It is quite significant to determine fabric air permeability which co-relates to its geometric structure strongly as well as to the path of air streamlines for smooth flow through the structure helping thereby to keep the packed food grains fresh and healthy.

The variation of the pick density of the two jute fabric samples FS-1 and FS-2, keeping their area densities almost same is found to be not producing any significant difference in the breaking strengths both warp way and weft way of the samples. The authors are of the opinion that the study can be further extended to determine the effect of loop length on air permeability of the fabric. Similarly, the effect of fineness of the yarns on the size of the pores which eventually affects the air permeability of the fabric can be also counted as a good future scope of further extending this study. Moreover, formulations of stitch density, stitch length or yarn diameter influencing the pore size values also demands further research. Due to the differences between ideal and real geometry and the random variation of the fabric structure there are no exact dependence between experimental air permeability and predicted air permeability valuesan area which will also be explored. All these possible areas of research will be carried out and compiled in the upcoming article.

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