

Study of the Effect of Weft Parameters on the Properties of Jute Fabrics Produced in S4A Loom Woven from Single and Plied Weft Yarns

Prof. Swapan Kumar Ghosh¹, Satyaranjan Bairagi², Rajib Bhattacharyya³

Professor, Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India ¹

Senior Research Fellow, Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India ²

Teaching Associate, Department of Jute and Fibre Technology, University of Calcutta, Kolkata, West Bengal, India³

ABSTRACT: This paper delineates to carry out a detailed investigation of the effect of variation of pick density on the physical, mechanical and hydraulic properties of three categories of jute fabric samples woven from single weft yarns, plied weft yarns and weft yarns running parallel in the fabric. The constituent weft yarns are varied in their counts, keeping fabric weight, warp count and warp yarn density unaltered in all the three categories of the woven fabric samples. Altogether seven number of fabric samples have been prepared in multi-phase, curvilinear and shuttleless S4A loom. The physical, mechanical and hydraulic properties of all these produced fabric samples have been determined and the effect of variation of pick density on these properties have been observed.

KEYWORDS: Pick density, Count, gsm, Plied yarn.

I. INTRODUCTION

Jute being coarser, low cost, agro-renewable and biodegradable [1,2] and eco-friendly natural bast fibre, is being utilized as pack-textiles since long past. With the advent of low cost and lighter weight synthetic packaging materials from polyolefin, conventional Jute Industry is facing a severe threat in both domestic and international market [1]. However, global consciousness on environmental protection and eco-friendliness of all products, Jute Industry has again regained some of its lost share in the market and also captured some newer marketing areas by product diversification, where geotextiles and decorative fabrics from jute are mention worthy [3]. However uses of jute as agrotexile, geotextiles, automotive textiles, eco-textiles and home textiles (furnishing fabrics) are relatively newer [4]. Hence, though those products from jute have already been introduced commercially, but not well engineered as per end use requirement for specific applications. The standard specifications of such newer products of jute are yet not available. The most important issue is to utilize and capitalize the advantages of jute fibre as technical and industrial fibre in suitable product engineering by eliminating or reducing some of its drawbacks and deriving maximum possible benefits from its advantageous property parameters [5]. Jute has many inherent advantageous properties [6, 7] like high strength and modulus, low elongation at break, high moisture absorption capacity, excellent hydraulic properties, good heat and sound insulation properties, good drapability along with biodegradability, environment friendliness and agro-renewability. Some of the advantageous property parameters like high strength and specific modulus, high abrasion resistance, good thermal stability, low extensibility [8], good dimensional stability, ability to withstand initial stresses of road construction, heaviness / coarseness with appreciable thickness / vegetation mass, good draping quality, harshness / stiff body preventing differential settlement on soil, high permittivity and transmittivity, higher co-efficient of friction with irregular surface morphology preventing lateral and rotational slides, high water absorption performing well in filtration and drainage and soil consolidation (caking) functions, soil friendliness and ability for addition of nutrients to the soil after degradation, eco-compatibility, vegetation support, easy availability, low cost and agro-renewability has made this jute fibre to be considered as suitable raw material for making end-use specific technical

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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textile [9,10] products potentially applicable in the field of geotextiles, filter fabrics, agrotextiles, coated textiles, rigid / flexible composites and automotive parts etc. Due to biodegradability, high water absorption capacity, high strength and high modulus make jute extremely suitable for different geotextile as well as agrotextile products in specific cases. However, some of the major draw backs [11, 12] of jute like susceptibility to microbial attack under moist conditions, tendency to photo yellowing and degradation under exposure to ultra violet light/sun-light and on long storage, medium to poor wet strength, poor abrasion resistance and high fibre shedding, brittleness, varying fineness (diameter) and length of fibres posing processing difficulty, short branching after splitting the interconnecting mesh structure of jute reed in resultant spinner's fibre after carding imposing more fibre non-uniformity and variability and lower surface cohesiveness even with higher co-efficient of friction etc. are to be partially reduced or to be eliminated with proper treatment / chemical modification or coating / impregnation with suitable agents like bitumen etc., as well as the optimum balance of advantages and disadvantages of jute are to be achieved for engineering any technical textile products [13] from jute. So, the recent trend of research on jute and allied fibre technology is to explore the vast potential of jute by different ways of fabric engineering vis-a vis study of effect of variation of any one or more essential property parameters like pick density on the physical, mechanical and hydraulic properties of the manufactured woven jute fabric samples. In the recent years exhaustive research work has been accomplished on the influence of different weaves and pick densities on the different properties of fabrics like their thermal properties [14, 15]. In their work they have represented a new domain of research and development on various comfort aspects of woven fabric manufactured with cotton and polypropylene (PP) yarns by changing pick densities and weave of fabric. M Karahan and R Eren have carried out an experimental investigation to determine the effect of fabric parameters on static water absorption in terry fabrics [16-19]. Their study has shown that terry fabrics produced with two-ply ring-carded yarns have the highest percentage of water absorption, and terry fabrics produced with two-ply open-end yarns have the lowest percentage water absorption. It is also shown that an increase in warp and weft densities decreases the percentage water absorption of terry fabrics, and an increase in pile length increases it. V. Sankaran and V. Subramaniam have carried out an extensive study on effect of weave structures on the low stress mechanical properties of woven cotton fabrics [20-23]. In this study two groups of fabrics comprising different weaves with the same warp and weft count and sett were produced. Five fabrics in the first group and eleven fabrics in the second group were considered. The fabrics were evaluated for low stress mechanical properties, and correlation coefficients were calculated between the various parameters and properties. While the results showed that the correlation between shear, crease recovery, tensile, and air permeability was very good, the correlation between the hand value and parameters was poor. Bending rigidity and hysteresis were well correlated with the parameters in the second group of fabrics. Md. Mahbubul Haque in his work has focused on effect of weft parameters on weaving performance and fabric properties [24-27]. He has shown that threads per inch and yarn count are some of the most important parameters that affect both weaving performance and fabric property. Experimental studies were conducted by weaving fabrics with three different picks per inch (PPI) and weft counts. The study shows that weaving performance is affected by the too high cover factor. Cover factor was calculated by dividing the threads/inch by the square root of the English cotton count and end breakage was taken as an indication of weaving performance. It was observed that when the count as well as threads/inch of one series of yarn changes the crimp% i.e. the consumption of both series of yarns are affected. It was also observed that, as expected, when the threads/inch increases the fabric strength also increases but at higher threads/inch the gain in strength is relatively more. B.K. Behera et.al. have established some interesting mathematical relationships between thread density, yarn fineness, crimp, weave so as to enable the fabric designer and researcher to have a clear understanding of the engineering aspects of woven fabrics. Their work can be considered to be an attempt to transform from an experience based designing into an engineered approach to model woven fabric constructions [28]. It can be concluded from their work that the structure and properties of a woven fabric are dependent upon these constructional parameters. M.K. Singh and A Nigam have reported comfort performance of woven structures made of various types of ring spun yarns like carded, combed, and compact spun yarns [29-32]. Their observations conveyed that comfort performance of clothing greatly depends on the structure and properties of fibre and yarn used. H. Özdemir and E. Mert have studied the effects of fabric structural parameters on the breaking, bursting and impact strengths of diced woven fabrics [33-36]. The aim of their work was to investigate the various physical properties of certain diced woven fabrics such as breaking strength, bursting strength and impact strength and their behaviours such as deformation, contact duration and absorbed energy during impact tests and to compare them with those of plain

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woven fabric, the basic weave. It was observed that bursting and impact strengths of diced woven fabrics were higher than those of plain woven fabric, however breaking strengths of plain woven fabric along both warp and weft directions were higher than those of diced woven fabrics. In addition, the increases of yarn densities improved these physical properties of diced woven fabrics. The effects of the weave pattern, warp and weft densities on these physical properties of plain and diced woven fabrics were also evaluated in their study. J. Hayavadana et. al. have investigated effect of pick density and primary treatment conditions on mechanical properties of 100% PET fabrics as understood through alkaline hydrolysis [37]. M. Matsudaira et. al. have studied the effects of weave density, yarn twist and yarn count on fabric handle of polyester woven fabrics by objective evaluation method. "Koshi" and "hari" increase with weft yarn density and "shinayakasa" and "shari" decrease with the density. The effect of the density on "fukurami" and "kishimi" is small [38-40]. The effect of yarn twist is revealed remarkably on dechine and yoryu. "Koshi" and "hari" decrease and "shinayakasa" and "shari" increase with the twist in the case of dechine; however, all the primary handles increase a little with the twist for yoryu. "Kishimi" of yoryu increases greatly with the twist. "Koshi" and "hari" increase and "shinayakasa" decreases with yarn count for taffeta and georgette. The effect of the count on "fukurami" and "kishimi" is small for both fabrics. These results are expected to provide useful information to design ideal fabrics having desirable handle. K. Bilisik has studied the stick-slip properties of dry polyester plain, ribs and satin woven fabric weaves [41-43]. He found that the amount of stick-slip force was related to the number of interlacement points in the fabric, whereas the amount of accumulative retraction force was related to fabric structural response. Stick-slip force and accumulative retraction force depend on fabric weave, fabric density, the number of pulled ends in the fabric and fabric sample dimensions. The weft directional single and multiple yarn stick-slip and accumulative retraction forces of dry plain fabrics in fabric edge and centre regions were higher than those in the satin fabric due to fabric weave. In addition, the warp directional single and multiple yarn stick-slip and accumulative retraction forces in the dry wide and long satin fabric in fabric edge were higher than those in the weft direction due to fabric density. Stick-slip and accumulative retraction forces of polyester fabric in the multiple yarn pull-out test were higher than those of the single yarn pull-out test. P. Paul et.al have investigated on effect of weft yarn type and pick density on tearing strength of woven fabric. The present study was to acquire an understanding of the manner in which the yarn type and pick spacing contribute to the tear resistance of woven fabrics as measured by the Elmendorf Tear Test [44, 45]. Three different types of weft yarn and three different pick spacing for each sample were taken to carry out the tear strength. The result shows that with increase in the pick spacing warp way tearing strength increases. Tearing strength of fabric produced from polyester filament weft is maximum followed by fabric produced from P/V blend and cotton yarn weft. B.M.D. Dauda and M.P. Bandara have studied the effect of loom settings on fabric cover and beat-up force [46]. They have explained that beat-up is fundamental in woven fabric production and has significant influence on fabric quality and cover. R. K. Nayak et.al. have studied the effects of polyester content, pick density and weave on the thermal comfort and tactile properties of polyester / viscose blended yarn fabrics by measuring the low stress mechanical properties on Kawabata Evaluation System [47,48]. The fabrics with higher polyester content also show lower extensibility; the extensibility in warp direction is higher than in weft direction and Twill woven fabric give higher extensibility than the plain woven fabrics. N. E. Shahabi et.al. have studied effect of fabric structure and weft density on the Poisson's Ratio of worsted fabric under uniaxial tension. It was found that there is an exponential correlation between warp and weft crimp during fabric extension [49,50]. For the worsted fabrics used in this research in all the fabric structures, fabrics with higher weft yarn density have higher value of Poisson's ratio. It was also concluded that for the fabrics with the same condition but only different in structures, this ratio is related to the structural firmness of fabric. In all three fabric structures the value of the Poisson's ratio were following the same pattern of twill 2/2, twill 3/1 and hopsack 2/2 from highest to lowest value. It was revealed that there is a high linear correlation between the crimp interchange ratio and Poisson's ratio.

II. MATERIAL AND METHODS

2.1 Raw Materials

The warp and weft yarns required to fulfil this project work for producing jute twill fabric samples of desired specifications in the multiphase shuttleless S4A Loom, have been procured from a reputed Jute Mill of West Bengal.

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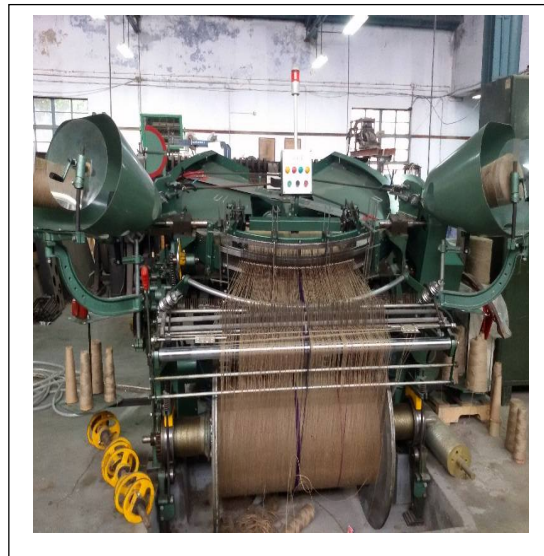
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The particulars of the laboratory scale Jute Twisting Frame which has been employed to produce the plied yarns is specified in table 1 and the isometric views of the frame are shown in Figures 1 and 2 respectively.

Table 1: Particulars of Mini Jute Twisting Frame

Make	New Central Jute Mills co. Ltd (Machinery Division) Calcutta, India
No. of Spindles	6 (Six)
Pitch of the Spindle	5 ½ inches
Speed of Spindle	2470 r.p.m.
Speed of Motor	1440 r.p.m.
Twist Constant	86
Twist capacity	2 ply, 3 ply, 5 ply



The particulars of the produced jute woven samples of weave construction 2/1 Twill are furnished in table 2.

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Table 2 Particulars of the Produced Jute 2/1 Twill Fabric Samples

Fabric samples	Warp Count (lbs/spy)	Weft Count (lbs/spy)	Warp Crimp p (%)	Weft Crimp (%)	Ends /inch	pick/ inch	Converted gsm at 20 % M.R.	Thickness (mm)	Total Fabric Cover factor
S-1	14.43 (SY)	14.72 (SY)	7.0	3.5	12	17	621.6	2.05	86.03
S-2	14.43 (SY)	15.02 (2 PY)	7.3	3.0	12	17	656.4	2.47	86.42
S-3	14.43 (SY)	17.20 (SY)	6.5	3.0	12	16	628.4	2.49	86.73
S-4	14.43 (SY)	16.91 (2 PY)	6.5	2.5	12	16	642.5	2.40	86.98
S-5	14.43 (SY)	18.01 (SY)	7.0	2.5	12	15	626.6	2.46	85.31
S-6	14.43 (SY)	18.01 (2 PY)	7.0	2.5	12	15	615.1	2.45	85.06
S-7	14.43 (SY)	8.00 (SY)	8.05	1.87	12	30	605.0	2.64	99.49

SY – Single Yarn, PY – Plied Yarn

2.2 Conditioning of test fabric samples

The entire range of Woven Fabric Samples was conditioned using standard temperature ($21^{\circ}\text{C} \pm 2^{\circ}\text{C}$) and humidity ($65\% \pm 2\% \text{ R.H.}$) for 24 hours before commencement of any testing work.

2.3 Selection of fabric samples for testing work

Test samples were 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 should be at least one metre long with full width of the fabric. No samples have been taken from nearer than 50 mm to the selvedge of the fabric sample.

III. RESULTS AND DISCUSSIONS

In this project work seven numbers of different jute fabric samples have been woven in the shuttleless multiphase S4A loom by varying pick density, weft yarn count and ply of weft yarn in the Department of Jute and Fibre Technology, University of Calcutta. The test results of mechanical and hydraulic property parameters of produced jute fabric samples are provided in the tables that are appearing in the foregoing pages.

3.1 Effect of variation of pick density on the wide-width tensile strength of the produced fabric samples

Generally, an increasing trend is observed in the fabric strength values with an increase in the jute weft yarn count values and picks per inch of the jute woven fabrics. But in this project work, the test results of the tensile strength of the produced jute fabric samples, in the warp direction and weft direction, as provided in tables 3 and 4 respectively and it is observed that variation of pick density does not produce any significant difference in the values. S6 shows the maximum wide-width tensile strength value of 19.6 kN/m, in the warp way, while S5 shows the minimum wide-width tensile strength value of 13.76 kN/m in the same direction. While the third category of woven fabric sample S7 shows a

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tensile strength value of 18.51 kN/m in the warp direction. Since the warp count and ends/inch of all the produced fabric samples have been kept constant at 14.43 lb/spyndle and 12 respectively, therefore there is no notable difference observed in the tensile strength values of the produced fabric samples in the warp way. Considering the tensile strength values of the fabric samples S1, S3 and S5, made of single weft yarns, it has been observed that the strength of fabric sample S3 is greater than that of fabric sample S1 which may be accounted for an increase in the weft count values. But, the tensile strength value of fabric sample S5 is lower than that of S3 which may be due to lower picks per inch (15) than that of S3 fabric sample whose picks per inch is 16. The same reason may be attributed for the fabric samples S2, S4 and S6 made from 2 plied weft yarns. While, S7 fabric sample shows a tensile strength value of 36.24 kN/m in the weft direction which is at par with that of the S4 fabric sample.

Table 3 Wide Width Tensile Strength in kN/m of the different produced jute woven fabric samples in warp way

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	18.342	13.106	17.748	19.065	13.928	17.199	17.141
2	19.141	16.172	17.718	18.853	11.845	18.358	19.592
3	17.01	16.565	17.338	17.092	14.312	20.208	18.261
4	17.924	13.955	19.079	18.03	12.893	20.63	19.752
5	18.357	18.892	19.904	19.814	15.828	21.795	17.823
Average	18.1548	15.738	18.3574	18.5708	13.7612	19.638	18.512

Table 4 Wide Width Tensile Strength in kN/m of the different produced jute woven fabric samples in weft way

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	22.301	35.927	34.212	40.796	31.642	30.61	37.276
2	23.415	37.774	29.355	38.631	32.333	29.616	35.314
3	23.415	38.976	29.093	37.516	29.005	29.491	34.245
4	22.921	36.259	33.383	36.236	28.026	32.214	37.285
5	24.135	38.432	32.409	39.812	30.802	31.011	37.066
Average	23.2374	37.4736	31.6904	38.592	30.3616	30.5884	36.2372

3.2 Effect of variation of pick density on the elongation at break of the produced fabric samples

Generally, there is an increasing trend in the fabric extension values with an increase in the jute weft yarn count and picks per inch of the jute woven fabric. But in this project work, the test results of elongation at break of the produced jute fabric samples, in the warp and weft way, as provided in tables 5 and 6 respectively and it show that variation of pick density does not produce any significant difference in the values. S5 shows the maximum breaking elongation of 9.96% in the warp direction while S1 shows the minimum breaking elongation of 8.1%. While S7 shows an elongation value of 9.94% in the warp direction which is at par with that of the value of S5 fabric sample. Considering the extension values of the fabric samples S1, S3 and S5, made of single weft yarns, it has been observed that the extension of fabric sample S3 is greater than that of fabric sample S1 which may be accounted for an increase in the weft count values. But, the extension value of fabric sample S5 is marginally lower than that of S3 which may be due to lower picks per inch (15) than that of S3 fabric sample whose picks per inch is 16. The same reason may be attributed for the fabric samples S2, S4 and S6 made from 2 plied weft yarns. Fabric sample S7 shows minimum breaking elongation of 3.96%.

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Table 5 Breaking elongation percentage of the different produced jute woven fabric samples in warp way

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	8.296	9.826	10.002	8.543	9.982	8.654	10.272
2	7.659	9.842	9.819	9.125	10.012	8.267	10.364
3	8.465	9.865	9.718	9.153	9.878	8.732	9.430
4	8.251	9.365	9.701	9.102	9.983	8.602	9.247
5	7.953	9.342	9.825	9.237	9.953	8.451	10.405
Average	8.124	9.648	9.813	9.03	9.961	8.541	9.943

Table 6 Breaking elongation percentage of the different produced jute woven fabric samples in weft way

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	5.185	4.523	5.462	5.029	5.267	4.404	3.847
2	5.248	4.367	5.311	5.087	5.295	4.409	4.205
3	5.351	4.365	5.352	4.846	5.307	4.447	3.947
4	4.975	4.577	5.231	4.924	5.317	4.515	4.022
5	5.142	4.662	5.394	4.872	5.314	4.375	3.797
Average	5.180	4.4988	5.350	4.9516	5.300	4.430	3.963

3.3 Effect of variation of pick density on the tenacity of the produced fabric samples

Fabric tenacity can be defined as the breaking load divided by the linear density of the yarn constituting the fabric. Increase in linear density of the yarns constituting the fabric requires greater breaking load. In this project work, the warp yarn count and ends per inch have been kept constant for manufacturing all the fabric samples. The tenacity values of the produced jute fabric samples in the warp and weft directions are furnished in tables 7 and 8 respectively. Therefore, tenacity of the fabric samples S1 to S7 is not significantly affected by variation in pick density. S6 fabric sample shows a maximum tenacity value of 3.2 cN/tex while fabric sample S5 shows a minimum tenacity value of 2.24 cN/tex in warp direction. The tenacity value of S7 fabric sample (3.06 cN/tex) in the warp direction is almost the same as that of S6 fabric sample. Considering the tenacity values of the fabric samples S1, S3 and S5, made of single weft yarns, it has been observed that the tenacity of fabric sample S3 is greater than that of fabric sample S1 which may be accounted for an increase in the linear density of the constituent weft yarn. But, the tenacity value of fabric sample S5 is lower than that of S3 sample which may be due to lower picks per inch (15) than that of S3 fabric sample whose picks per inch is 16. The same reason may be attributed for the fabric samples S2, S4 and S6 made from 2 plied weft yarns.

Table 7 Tenacity in cN/tex of the different produced jute woven fabric samples in warp way

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	2.756	2.961	2.715	2.865	2.249	3.226	3.019
2	2.742	2.954	2.729	2.898	2.462	3.154	2.958
3	2.923	2.862	2.706	2.794	2.113	3.187	2.79
4	2.62	2.753	2.652	2.658	2.125	3.279	3.201
5	2.714	2.972	2.765	2.893	2.236	3.156	3.331
Average	2.751	2.9004	2.7134	2.8216	2.237	3.2004	3.0598

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Table 8 Tenacity in cN/tex of the different produced jute woven fabric samples in weft way

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	4.214	5.356	5.952	6.024	4.952	5.201	5.837
2	3.678	5.237	5.475	6.397	4.801	5.682	6.161
3	3.851	6.267	6.227	5.858	5.742	4.763	6.25
4	4.134	4.876	5.892	6.671	5.287	5.800	5.836
5	3.014	6.025	5.302	6.427	5.851	5.181	5.868
Average	3.778	5.555	5.769	6.275	5.326	5.325	5.9904

3.4 Effect of variation of pick density on the bursting strength values of the produced fabric samples

The bursting strength values of the produced fabric samples, as provided in table 9 and it show that S2 has the maximum value of 32.32 kg/cm² and S1 shows a minimum value of 23.74 kg/cm². S7 shows a bursting strength value of 31.2 kg/cm² which is very close to the maximum bursting strength value of fabric sample S2. This may be accounted for the contribution of two weft yarns in the strength of fabric, inserted in the same shed during the manufacturing of the fabric samples S2 and S7.

Table 9 Bursting strength in kgf/cm² of the different produced jute woven fabric samples

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	FS-7
1	22.70	31.50	27.20	34.00	29.50	30.00	33.2
2	27.00	34.10	23.30	26.50	26.40	28.00	29.1
3	20.50	34.00	30.90	29.90	31.10	30.90	27.6
4	25.50	30.00	32.00	33.50	27.50	28.60	32.7
5	23.00	32.00	25.50	34.00	28.50	30.00	33.4
Average	23.74	32.32	27.78	31.58	28.6	29.5	31.2

3.5 Effect of variation of pick density on the index puncture resistance values of the produced fabric samples

The index puncture resistance values of the produced jute fabric samples as listed in table 10 and it show that the fabric sample S2 having maximum fabric weight of 656.4 gsm exhibits maximum index puncture resistance of 0.56 kN while fabric sample S5 shows minimum index puncture resistance of 0.37 kN. The index puncture resistance of fabric sample S7 shows a value 0.45 kN which lies between the maximum and minimum values. The other fabric samples, S1, S3, S4 and S6 do not show any definite trend in their index puncture resistance values

Table 10 Index Puncture Resistance (kN) of the different produced jute woven fabric samples

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	0.39	0.68	0.46	0.34	0.44	0.45	0.49
2	0.33	0.62	0.43	0.48	0.24	0.49	0.48
3	0.52	0.54	0.48	0.69	0.31	0.38	0.49
4	0.43	0.48	0.48	0.37	0.47	0.62	0.47
5	0.53	0.49	0.73	0.52	0.40	0.44	0.34
Average	0.44	0.56	0.52	0.48	0.37	0.48	0.45

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3.6 Effect of variation of pick density on the static puncture resistance values of the produced fabric samples

The static puncture resistance values of the produced jute fabric samples as displayed in table 11 and it show that the fabric sample S3 exhibits maximum static puncture resistance of 2.87 kN while fabric samples S1 and S4 show minimum static puncture resistance of 2.29 kN each. The static puncture resistance of fabric sample S7 shows an intermediate value 2.50 kN. The other fabric samples, S2, S5 and S6 do not show any definite trend in their static puncture resistance values.

Table 11 Static Puncture Resistance (kN) of the different produced jute woven fabric samples

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	2.34	2.66	2.76	2.25	2.66	2.56	2.60
2	2.13	2.60	2.97	2.50	2.47	2.41	2.50
3	2.34	2.44	2.78	2.13	2.43	2.42	2.49
4	2.15	2.79	2.63	2.27	2.57	2.43	2.28
5	2.49	2.59	3.17	2.29	2.82	2.72	2.63
Average	2.29	2.62	2.87	2.29	2.59	2.51	2.50

3.7 Effect of variation of pick density on the dynamic perforation resistance values of the fabric samples

It has been investigated and inferred that several properties of a woven fabric influence its resistance to dynamic perforation. Considering the values obtained for all of these fabric properties, as provided in table 12, it has been observed that amongst the fabric samples S1, S3 and S5, manufactured from single weft yarns, S3 fabric sample shows maximum resistance to dynamic perforation. While, the tested value of dynamic perforation resistance of the fabric sample S7 shows the maximum resistance amongst all the fabric samples considered in this work. This may be accounted for the highest value of picks per inch (30), thickness (2.64 mm) and cover factor (99.49) of fabric sample S7 amongst all the fabric samples. No definite trend has been observed in the dynamic perforation resistance values of fabric samples S2, S4 and S6 which are manufactured from 2 plied weft yarns.

Table 12 Dynamic Perforation Resistance (mm) of the different produced jute woven fabric samples

No. of Observations	S-1	S-2	S-3	S-4	S-5	S-6	S-7
1	12.00	14.00	12.00	13.00	10.00	10.80	8.50
2	13.00	15.00	12.00	11.00	11.00	11.90	9.00
3	12.00	14.00	12.00	12.00	10.00	11.50	12.50
4	13.00	14.00	11.00	13.00	11.00	12.10	8.00
5	12.00	15.00	13.00	11.00	10.00	11.70	8.50
Average	12.40	14.40	12.00	12.00	10.40	11.60	9.30

3.8 Effect of variation of pick density on the apparent opening size (AOS) values of the produced fabric samples

The apparent opening size values of the produced fabric samples, have furnished in table 13 and it considering the AOS values of the fabric samples S1, S3 and S5, manufactured from single weft yarns, it has been observed that the AOS value of S3 is minimum amongst all these three samples. The cover factor of S3 is the highest amongst that of the fabric samples S1 and S5 which may be the probable reason for the minimum AOS value of the fabric sample S3. The same reason may be attributed for the fabric sample S4 amongst the fabric samples S2, S4 and S6, manufactured from 2 plied weft yarns. S4 fabric sample, having highest cover factor amongst the fabric samples manufactured from 2 plied weft yarns, shows minimum AOS value. But, considering all the fabric samples S1 to S7 it has been observed that S7 fabric sample, having maximum cover factor, shows the minimum AOS value.

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Table 13 Apparent Opening Size (ϕ_{95}) in micron of the different fabric samples

Sl. No.	Fabric Sample	AOS (ϕ_{95}) in micron
1	S-1	975
2	S-2	840
3	S-3	711
4	S-4	650
5	S-5	1105
6	S-6	1120
7	S-7	555

IV. CONCLUSION

This work has aimed to carry out a detailed investigation of the effect of variation of pick density on the physical, mechanical and hydraulic properties of three categories of jute fabric samples woven from single weft yarns, plied weft yarns and weft yarns running parallel in the fabric. The constituent weft yarns are varied in their counts, keeping fabric weight, warp count and warp yarn density unaltered in all the three categories of the woven fabric samples. Altogether seven number of fabric samples have been prepared in multi-phase, curvilinear and shuttleless S4A loom. The physical, mechanical and hydraulic properties of all these produced fabric samples have been determined and the effect of variation of pick density on these properties have been observed and recorded. Based on the observations the following conclusions can be drawn. Amongst the fabric samples S1, S3 and S5, made of single weft yarns, it has been observed that S3 scores over S1 and S5 with respect to its physical, mechanical and hydraulic properties namely its strength, tenacity, index and static puncture resistance and bursting strength. Considering the fabric samples S2, S4 and S6, made of 2 plied weft yarns, the test results of their properties reveal that S4 ranks above S2 and S6 with respect to its physical, mechanical and hydraulic properties. While, S7 fabric sample shows a tensile strength value in the weft direction which is at par with that of the S4 fabric sample and Considering the extension values of the fabric samples S1, S3 and S5, made of single weft yarns, it has been observed that the extension of fabric sample S3 is greater than that of fabric sample S1 which may be accounted for an increase in the weft count values. But, the extension value of fabric sample S5 is marginally lower than that of S3 which may be due to its lower picks per inch than that of S3 fabric sample. The same reason may be attributed for the fabric samples S2, S4 and S6 made from 2 plied weft yarns. Fabric sample S7 shows minimum breaking elongation. Tenacity of the fabric samples S1 to S7 is not significantly affected by variation in pick density. S6 fabric sample shows a maximum tenacity value while fabric sample S5 shows a minimum tenacity value in warp direction. The tenacity of S7 fabric sample in the warp direction is almost the same as that of S6 fabric sample. Considering the tenacity of the fabric samples S1, S3 and S5, made of single weft yarns, it has been observed that the tenacity of fabric sample S3 is greater than that of fabric sample S1 which may be accounted for an increase in the linear density of the constituent weft yarn. But, the tenacity value of fabric sample S5 is lower than that of S3 sample which may be due to lower picks per inch than that of S3 fabric sample. The same reason may be attributed for the fabric samples S2, S4 and S6 made from 2 plied weft yarns. The bursting strength values of the produced fabric samples, show that S2 has the maximum strength and S1 shows a minimum bursting strength. S7 shows a bursting strength which is very close to the maximum bursting strength value of fabric sample S2. This may be accounted for the contribution of two weft yarns in the strength of fabric, inserted in the same shed during the manufacturing of the fabric samples S2 and S7 and the index puncture resistance values of the produced jute fabric samples show that the fabric sample S2 having maximum fabric weight exhibits maximum index puncture resistance while fabric sample S5 shows minimum index puncture resistance. The index puncture resistance of fabric sample S7 lies between the maximum and minimum values. The other fabric samples, S1, S3, S4 and S6 do not show any definite trend in their index puncture resistance values and the static puncture resistance values of the produced jute fabric samples show that the fabric sample S3 exhibits maximum static puncture resistance while fabric samples S1 and S4 show minimum static puncture resistance. The static puncture resistance of fabric sample S7 shows an intermediate value 2.50 kN. The other fabric samples, S2, S5 and S6 do not show any definite trend in their static puncture

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resistance values. The tested value of dynamic perforation resistance of the fabric sample S7 shows the maximum resistance amongst all the fabric samples considered in this project work. This may be accounted for its highest value of picks per inch, thickness and cover factor amongst all the fabric samples. Considering all the fabric samples ranging from S1 to S7, it has been observed that S7 fabric sample, having maximum cover factor, shows the minimum AOS value amongst all fabric samples produced in this project work.

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