Fibres and Textiles **29**(3), 2022, 78-85 DOI: 10.15240/tul/008/2022-3-008

EFFECT OF DIFFERENT CRIMP METHOD OF JUTE FIBRE ON STRENGTH AND ELONGATION PROPERTIES OF JUTE YARN AND WOVEN FABRIC

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ABSTRACT

Yarn and fabric strength is one of the most important parameters to predict the uses of the end product. Fabric strength mostly depends on yarn strength and yarn strength is prejudiced by fibre strength or fibre properties. Crimp is one of the essential parameter that influences the fibre properties. In this research, crimp box and gear crimp methods were used to introduce crimp into jute fibre. It was found that crimps were irregular in size, shape and number produced from crimp box method. On the other hand, crimps produced from gear crimp method were comparatively regular in size, shape and number. Yarn and fabric strength tests were carried out according to testing standard. It was revealed that yarn strength and elongation at break of gear crimp method were higher than that of crimp box method. Apart from this, fabric strength and elongation were also improved for a regular and increased number of crimps for gear crimp method.

KEYWORDS

Fibre crimp; Mechanical crimp; Crimp box method (CBM); Gear crimp method (GCM); Woven fabric; Tensile strength and elongation.

INTRODUCTION

Jute fibres are environmentally friendly, non-biodegradable, cheap and available natural fibres. They exhibit better physical, mechanical and thermal properties compared to other natural jute allied fibres like hemp, kenaf and banana fibres and the end product made of jute fibres also exhibit higher performance for the mentioned properties[1]. Jute fibre is a natural fibre having no crimp. Crimp is the waviness of a fibre. Crimp is defined as the condition in which the axis of a fibre proceeds from a straight line and tracks a simple or a complex or an irregular wavy path in the same phase [2]. Crimp plays an important role to increase the cohesion between fibres and also helps to spin them. So, mechanical crimp has to be imparted into jute sliver to make it suitable for spinning. This crimp influences yarn properties as well as fabric properties. It was found that jute yarn properties like yarn hairiness, irregularities were improved and yarn strength was increased due to the increased number of imparted crimp into jute sliver during drawing in the draw frame machine [3].The main mechanical properties of a woven fabric are its strength and elasticity. The breaking force and elongation at break are the most common characteristics of the mentioned fabric properties. These breaking force of yarns and woven fabrics are interrelated and increased when the elongation at break increases[4]. The tensile strength of fabric also deals with the required force to break a large amount of yarns simultaneously in either warp or weft direction. The force at which the yarn breaks is directly proportional to cross-section or diameter of the yarn. The tensile force verified at the moment of rupture is termed as the tensile strength at break [5]. The breaking strength and elongation are the two prime quality aspects of any spun yarn. The tensile strength and elongation of a yarn are essential to the process ability of the yarn in the subsequent processing and operational life of the end product made of the yarn. The strength of any staple yarn is determined by different fibre properties, yarn structural geometry, spinning process and parameters. It is revealed that yarn strength increases with the increase of crimp in the fibre, as fibre to fibre interconnectionimproves the fibre bonding [3, 6]. It was also revealed that warp and weft yarn parameters influence the fabric'sbreaking force. Various properties of yarn such as raw material, lineardensity, and structure influence the character of the stress–strain curves and the breaking force of fabric in the warpand weft directions [7, 8].The breaking force and elongation at break of fabric were

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Received April 25, 2022; accepted October 18, 2022

depended on the breaking force and elongation of yarn [9]. Crimp and as well as fabric structure also help to extend the yarn and fabric more [10]. It was also obtained that the fibre properties, the type and parameters of spinning affect the yarn properties such as strength, while the fabric properties are affected by warp and weft density, count of the warp and weft yarn of the woven fabrics and weave structure. The mechanical properties of fabrics are also influenced by the weaving conditions such as weaving speed, warp insertion rate, weft beat-up force, the way of shed opening, warp preparation for weaving, warp and weft tension, number of threads in reed dent etc. The properties of raw fabrics consequently also depend on the construction and technological parameters of spinning and weaving [11]. Azeem et al. [12] evaluated the effect of spinning technologies and weave on the fabric's mechanical and surface properties. Ring spun (combed, carded) and open-end techniques were used to manufacture yarns. Plain, twill, and satin weaves were used for the fabrics. Once the fabric stiffness increases, elongation at break also increases. A significant effect of the spinning technique and weave on these properties was established. Kumpikaitė and Sviderskytė [13] attained the dependencies of breaking force and elongation at break for different weave factors. They showed that there is no correlation between breaking force and elongation at break of fabric, but elongation at break depends on the weave factors of fabric, i.e., if the fabric stiffness increases, elongation at break will also increases. Dependencies of breaking force and elongation at break on the weft setting were recognized as well. The results show that with the increases of weft setting, the breaking force slowly decreases and the elongation at break increases. Another paper [14] described that twist multiplier and woven structure are largely responsible for the strength of woven fabrics in greige and as well as finished fabrics. They worked on blended raw materials and different weave structure and showed its effect on fabric strength and elongation. It is also explored that the influence of different compositions of different cotton fiber blends on the tensile properties of yarns from these blended yarns. It was recognized that the composition of the cotton blend influences the properties of yarn [15].

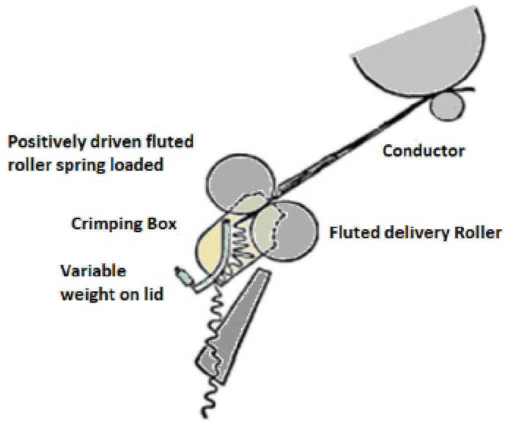
Therefore, after the literature analysis, it was concluded that the breaking force and the elongation at break were previously analyzed for yarns and woven fabrics of different raw materials, yarn densities, and blended materials with different material ratios; but the effect of regular crimp on the properties of yarn and fabrics were not analyzed. Therefore, the aim of this research was to find the effect of fibre crimp on the breaking force and elongation of yarns and woven fabrics.

MECHANISM OF CRIMP METHODS

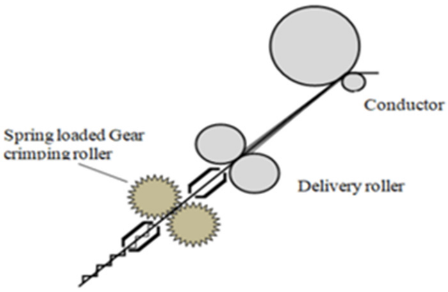
The crimp box method (CBM) is regularly used to introduce mechanical crimp into jute fibre during the drawing process. In this research work, the newly developed gear crimp method (GCM) for jute fibres is also used to impart mechanical crimp into jute sliver.

In the CBM, in Figure 1(a), the sliver leaves the nip of the drafting rollers and passes the sliver plate into the nip of a pair of fluted delivery rollers, the upper roller of the pair is spring-loaded and positively driven. A lid is needed in the crimping box to impart crimp into the sliver. Some weight is applied to the lid and it generates a pressure or load on the sliver in the crimp box. As a result, fibre is compressed or compacted under pressure and irregular crimp is produced into jute sliver. The length of time on any particular place of sliver remains in the crimp box can be controlled by means of different weights which can be added to the lid. Due to the use of different weight on the lid, the crimp produced into sliver also gets changed. A heavyweight causes a greater mass of sliver in the box for lifting it up and develops more crimp in the jute sliver [16]. This crimp causes inter-fibre cohesion which is very important for jute processing and also for subsequent processing. In CBM, produced crimps are irregular in size and shape. Therefore, the number of crimps per inch also becomes irregular. On the other hand, for GCM, in Figure 1(b), two crimping rollers are responsible to impart crimp into sliver. In this machine, there are two feed rollers, two guide rollers, two retaining rollers, one jockey roller, two pinned rollers, one drawing roller, one pressing roller, two fluted delivery rollers and two crimping rollers. Four pairs of crimp gears with different number of teeth were also developed to impart crimp into sliver. The slivers enter into the machine by passing over two feed rollers and two guide rollers. Then they pass between the retaining rollers and a self-weighted jockey roller and then meet the pins of the pinning rollers. After that the sliver passes between two fluted delivery roller, they work as guide roller as well as anti-friction roller to reduce the slippage of sliver. Afterward passing the nip of the drafting rollers, it passes over the sliver plate into the nip of a pair of fluted delivery roller, after that, it passes between the nips of the gear crimp rollers, and then crimp is formed in the sliver which is regular in size and shape. The lower crimp roller is positively driven and the upper crimp roller is spring-loaded. The pair of crimp rollers should be changed to change the number of crimps in per unit length [17].

The advantages of GCM are: regular crimp in size and shape and equal length of the fibre in unit length. But the limitation of this method is: maximum five numbers of crimps per inch (5 crimps / inch) can be imparted into sliver.



(a)



(b)

Figure 1. (a) CBM [16] and 1(b) GCM [17].

MATERIALS AND METHODS

Materials used: Bangla White B grade jute fibre was used to produce jute yarns. It is also known as Tossa jute. Reed length of jute fibre was 360 cm and technical length of jute fibre was measured after breaking card operation and it was 27.94 cm. In this research work, CBM and GCM were used for imposing mechanical crimp into jute sliver. Yarns were produced by using the slivers having regular and irregular crimps. Jute woven fabrics were produced by the yarns with $\frac{1}{1}$ plain weave structure in CCI loom. Sample details are given in the Table1, 2 and 3. Figure 2 shows the weave plan and drafting plan of the sample fabrics.

Apron draft spinning frame was used for spinning. The spinning machine was worked with flyer leading principle. Process parameters are in Table 2.

Methods used: Yarn strength and elongation, fabric strength and elongation were measured to accomplish this research work. Test methods and equipment are given below in Table 4.

X		X		X
	X		X	
X		X		X
	X		X	
X		X		X

(a)

			X	
	X			
		X		
X				X

(b)

Figure 2. (a) Weave plan and (b) drafting plan for plain weave.

EXPERIMENTATION

Experimentation of yarn strength test

Yarn strength was measured by using the Universal Tensile Strength Tester machine, James Heal. ASTM D 2256-10, single strand method was used to measure the yarn strength. The tests were carried out with a Machine speed of 300 mm/min, break detection 20%, jaw scheme 5, and jaw separation 250 mm. A sample of 250 mm yarn was gripped between the two jaws. The upper jaw was fixed and the lower jaw was movable. This machine is worked on the constant rate of extension (CRE) principle. The lower jaw moved at constant a rate and the yarn was extended and an increasing tension was developed until the yarn broke down. The load at which yarn breaks down and the elongation percentages were taken from the machine. Time taken for a test was 20 sec. Five samples were tested to measure the yarn strength.

Factors affecting the yarn strength and elongation:

The factors that affect the prediction of yarn strength include fibre properties such as fibre length, length uniformity, strength and elongation, yarn properties such as count and twist. Yarn factors that affect the yarn breaking elongation are the spindle speed, traveler mass, machine draft, yarn count and twist [18].

Table 1. Properties of raw jute fibre.

Statistics		Reed length of jute fibre [cm]	Technical Length of jute fibre [cm]	Fibre Fineness [micron]	Breaking load [kg]	Tenacity [gm/tex]
Mean		360	30.2	51.64	4.52	45.306
Standard Deviation		3.36	1.92	3.28	1.15	12.27
Confidence Interval	Upper Limit	363.35	31.89	53.67	5.53	56.06
	Lower Limit	357.45	28.51	49.60	3.51	34.55

Table 2. Main parameters of spinning frame.

Parameters	Spinning frame
Spindle speed	3200 rpm
Draft	11.30
Drafting system	Apron draft
Yarn per twist (TPI)	5

Table 3. Sample details for different crimping method.

Crimping method	No. of crimps per unit length [inch or 2.54 cm]	Yarn count [tex]	Fabric thickness [mm]	Structure of fabric	Thread density [EPI x PPI]
Crimp box	2.5	210	1.454	$\frac{1}{1}$ Plain weave	16 x 12
	3.5	214	1.606		
	5.0	298	1.616		
Gear crimping	3.0	218	1.622		
	4.0	258	1.634		
	5.0	311	1.688		

Table 4. Test methods for yarn and fabric tensile strength.

Name of the test	Machine used	Test method
Yarn strength and elongation	Universal Strength Tester	ASTM D 2256-10
Fabric strength and elongation	Universal Strength Tester	EN ISO 13934-1:2013

Experimentation of fabric strength test

Jute woven fabrics were tested to measure the fabric strength by using the standard test method EN ISO 13934-1:2013, part-1, determination of maximum force and elongation at maximum force using the strip method. The tests were carried out with a Machine speed of 100 mm/min, break detection 10%, jaw scheme T27, and jaw separation 200 mm. A sample of 50.8 mm width and 200 mm was gripped between the two jaws. The upper jaw was fixed and the lower jaw was movable. This machine is worked on the CRE principle. The lower jaw moved at a constant rate and the yarn was extended and an increasing tension was developed until the sample broke down. The load at which the sample breaks down and the elongation percentages were taken from the machine. Five samples were tested to measure the fabric strength.

Factors affecting the fabric strength and extension:

Factors that are important for fabric strength and elongation are type of fibres or blend use, twist amount and twist direction of yarn, yarn count, yarn setting, weave design and float length [19, 20].

RESULTS AND DISSCUSION

The main parameters of tensile tests for yarns and fabrics are the breaking force and elongation at break or extension %. Maximum force, yarn tenacity or strength and the extension% of yarns are given below in table 5 and fabric strength and extension % is given in table 6 and 7. Standard deviation and confidence intervals for 95% are also shown in the table with upper and lower limits.

Yarn strength

Strength is a very important property of yarns. Yarn strength is the force required to break a strand of a single yarn. It is expressed in N. The strength of yarn gives an idea that how much load can be applied to it and it is very important for different processes of yarns such as weaving and knitting. It is established that the tensile strength of a fabric depends not only on the strength of the component yarn, but also on the yarn structure, yarn bending performance, fabric geometry, tensile properties such as tensile force and tensile elongation of used yarns [21]. The breaking tenacity of yarns was also calculated. From Figure 3, it is found that yarn strength is increasing with the increasing number of crimps per inch. As crimp increases, the yarn becomes bulk, more regular and more quantity of fibres accumulates in the unit length of yarn, as a result, the strength increases. Strength increases in every stage of increasing crimp. It is also found that yarn strength is higher for GCM compared to CBM.

Table 5. Different parameters of yarn for various crimp method.

Crimp method	No. of crimps per unit length (2.54 cm)	Max. Force [N]	Yarn Strength				Yarn Elongation			
			Tenacity [cN/tex]	Standard Deviation	Confidence Intervals		Elongation [%]	Standard Deviation	Confidence Intervals	
					Upper Limit	Lower Limit			Upper Limit	Lower Limit
Crimp box method	2.5	23.07	111.42	26.50	134.67	88.21	1.25	0.28	1.57	1.07
	3.5	24.63	117.20	26.63	140.47	93.78	1.49	0.30	2.38	1.85
	5.0	40.39	130.80	17.02	145.75	115.92	1.94	0.26	3.26	2..80
Gear crimp method	3.0	25.86	120.46	2.96	123.60	117.87	1.44	0.32	2.41	1.84
	4.0	32.71	128.74	3.21	131.56	125.93	1.51	0.38	3.51	2.83
	5.0	45.75	149.56	3.11	152.29	146.84	2.06	0.23	4.02	3.62

Table 6. Fabric strength for various crimp methods.

Crimp method	No. of crimps per unit length	Fabric Strength Max. Force [N]		Standard Deviation		Confidence Intervals		Confidence Intervals	
						Upper Limit	Lower Limit	Upper Limit	Lower Limit
		Warp	Weft	Warp	Weft	Warp		Weft	
Crimp box method	2.5	865.79	593.71	9.17	2.43	889.02	842.56	616.94	570.48
	3.5	1038.93	740.77	35.43	21.74	1062.16	1015.69	763.99	717.53
	5.0	1232.24	914.38	6.29	8.43	1255.47	1209.01	939.41	892.95
Gear crimp method	3.0	1112.31	814.42	7.41	9.89	1135.54	1089.08	837.65	791.19
	4.0	1278.01	988.04	7.06	9.20	1301.24	1254.78	1011.27	964.81
	5.0	1342.88	1151.29	8.59	8.06	1366.11	1319.64	1174.52	1128.06

Table 7. Fabric elongation for various crimp methods.

Crimp method	No. of crimps per unit length	Fabric Elongation [%]		Standard Deviation		Confidence Intervals		Confidence Intervals	
						Upper Limit	Upper Limit	Upper Limit	Lower Limit
		Warp	Weft	Warp	Weft	Warp		Weft	
Crimp box method	2.5	1.72	2.85	0.105	0.176	1.824	1.639	2.994	2.685
	3.5	3.01	4.38	0.133	0.324	3.151	2.917	4.602	4.033
	5.0	6.54	7.21	0.259	0.259	6.705	6.250	7.783	7.328
Gear crimp method	3.0	3.93	4.97	0.605	0.436	4.450	3.389	5.372	4.607
	4.0	5.35	6.09	0.527	0.488	5.882	4.957	6.873	6.018
	5.0	7.33	8.59	0.259	0.259	7.281	6.826	8.669	8.214

Yarn extension

Elongation at break is the amount of stretch of a yarn that can take before it breaks and the breaking extension is the extension of the yarn at the breaking point expressed as a percentage. It is found in Figure 4 and 5 that yarn extension is slightly more for the yarn produced from gear crimp method. It is also clear that yarn extension% is increased due to the increased number of crimps of yarns. This is due to the strength of the yarn, as strength is more, it takes more load and more time to break. As a result, extension is more.

Fabric strength

Tensile strength and extension % are important parameters of the woven fabric that determines the durability of the textile material. Fabric strength in warp way is mostly influenced by weave structure and yarn density [22]. It is established from Figure 6 and 7 that fabric strength in both warp and weft way is higher for more number of crimps and it is also clear that GCM shows better strength than that of CBM. This is due to regular crimp formation and the length of fibre in the unit length is equal to the GCM.

Fabric elongation

Fabric strength and extension % are the most important characteristics of woven fabrics. Fabric extension at break depends on yarn evenness, strength and also on fabric strength. It is seen from the Figure 8 (a), (b), 9 and 10 that extension% of fabrics in both warp and weft way produced from GCM is more than that of CBM, because the yarns are more regular and even due to regular crimp and fabric strength for is also higher for GCM. It is also found that a higher number of crimp also affect the strength of yarn and as well as fabric strength and extension at break [23].

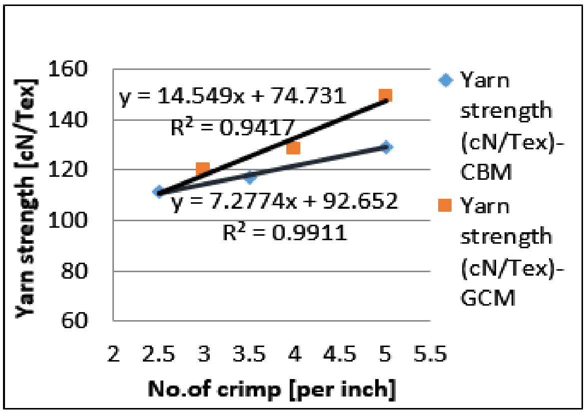


Figure 3. Yarn strength vs number of crimps for CBM and GCM.

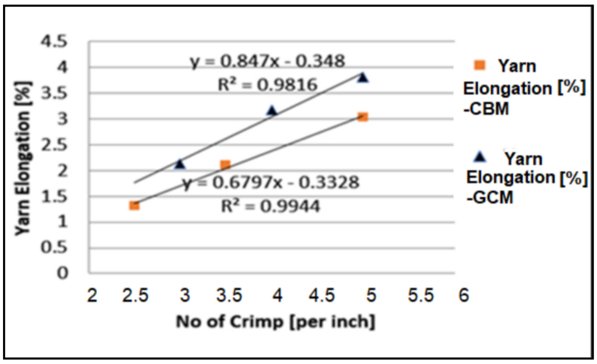


Figure 4. Yarn elongation % vs number of crimps for CBM and GCM.

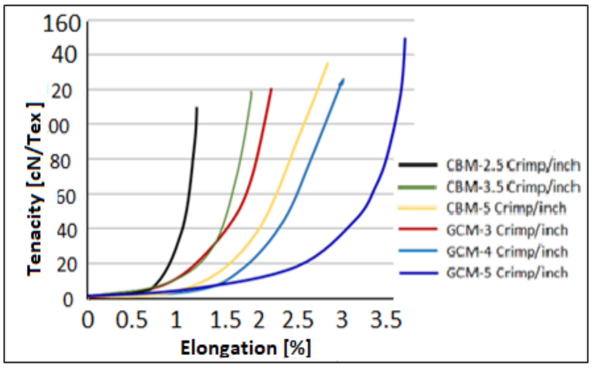


Figure 5. Tenacity – Elongation curve for CBM and GCM.

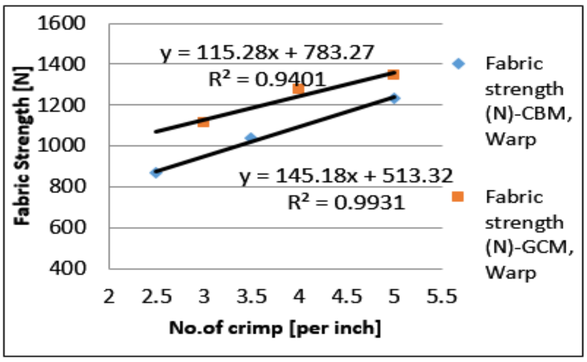


Figure 6. Warp way Fabric Strength vs Number of crimp of different crimp method.

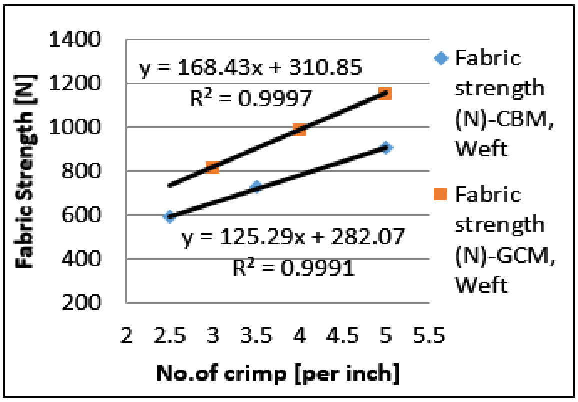
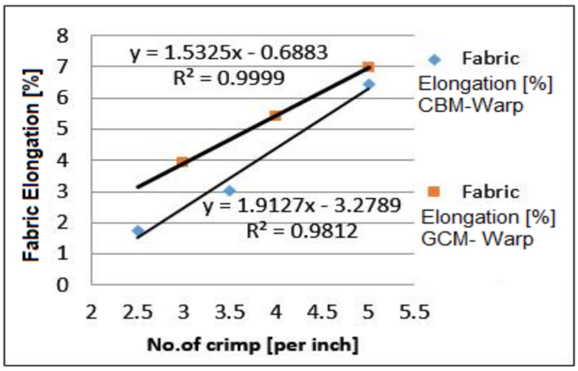
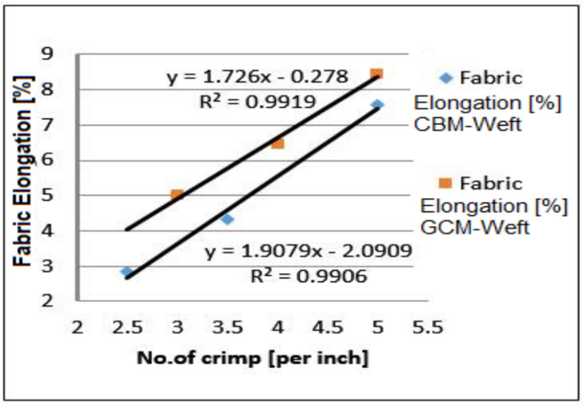


Figure 7. Weft way Fabric Strength vs Number of Crimp of different crimp method.



(a)



(b)

Figure 8. Fabric Elongation vs Number of crimps for CBM and GCM at (a) warp and (b) weft direction.

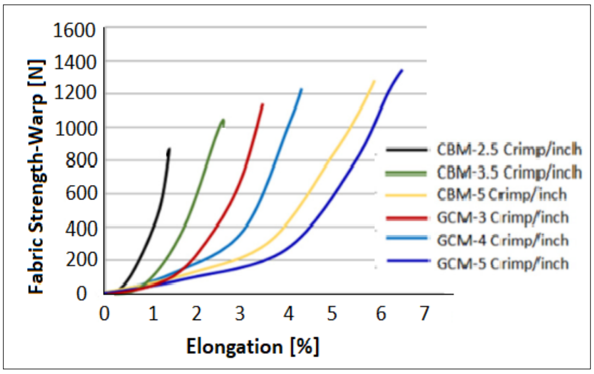


Figure 9. Fabric strength (warp) – elongation curve for CBM and GCM.

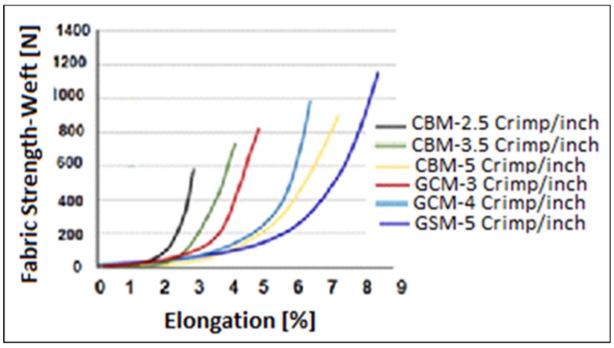


Figure 10. Fabric strength (weft) – elongation curve for CBM and GCM.

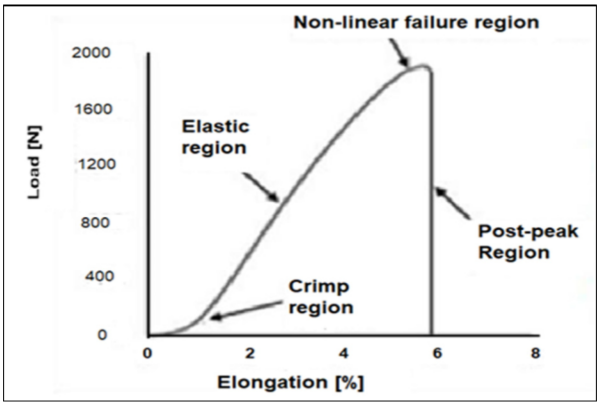


Figure 11. Load-elongation curve.

When a woven fabric is tested and exposed for tensile testing, then it goes over the four regions in a load-elongation curve, which has been enlightened here in Figure 11. The viscoelastic nature of the materials can be observed here as a low slope in the starting phase which is the first region also called the crimp region. It is also observed in first region that the crimp is decreased in one set of yarn during tensioning while it increases in another set of yarn and it is known as the crimp interchange. Therefore, a large increase in elongation at a low load level in the crimp region can also be observed in the load-elongation curve. In the second region of the curve, it rises steeply and when more force is applied to the fabric, more extension is occurred, as the extensions in fibers as well as in the yarns also start. The slope of curve in comparison to previous region increases as the straightened yarns bear more load and it is termed as elastic region. The third region of the load elongation curve is non-linear part and it can be seen before tensile strength is reached. It is due to the random breakage of fibres present in the yarns which are also prior to their localized failure. The last stage is the post-peak region, a rapid decrease in the load beyond the tensile strength can be observed that relates to the increasing yarn failure [15].

CONCLUSION

From the research study and results, it can be seen how different methods and number of crimps or crimp variations of fibres influence the mechanical properties of yarns and fabrics. Yarn strength is higher for GCM. The maximum breaking force in warp and weft direction is exhibited in the fabrics with the highest tensile elongation for higher number of crimps and also for GCM. As it is revealed in the study that the tensile properties of yarn and fabric are higher for the newly developed GCM. So the yarns produced from the GCM can be used to make ropes or braids for load-bearing applications and ship anchoring. Again the fabrics with higher strength can be used as technical textiles as mobil tech for boat hull, geo-textiles where mechanical properties are required and agro textiles for load-bearing application. So, this method can be a new era for producing jute yarns and woven fabrics along with greater tensile properties.

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