Mechanical Properties of Untreated and Alkali Treated Sida Acuta Stem Fibre

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Abstract —The present study is conducted for modifying the fibre surface properties and the characterization of mechanical properties of a sida acuta stem fibre. We propose to measure mass loss, tensile strength, Young's modulus, elongation at break and density. This paper reports the improved tensile properties of Sida acuta stem fibre. Changes occurring in stem fibres when treated with a 5% concentration sodium hydroxide solution for 4 hr's test duration. For modifying the natural fibres requires specific chemical treatments to improve the bonding strength between fibre and matrix in a polymer matrix composite and also can reduce water absorption. In this study we chosen alkaline (NaOH) treatment of different samples at different concentrations was carried. The mechanical properties were studied of treated and untreated samples. Thus we can access to the mass loss, tensile strength, Young's modulus and density. At finally analyse and conclude the results obtained by the mechanical properties of the chemically treated and untreated sida acuta stem fibres. Morphology analysis on fibre for before and after alkali treatment was investigated using Scanning Electron Microscopy (SEM).

Keywords— Alkaline (NaOH) treatment, Mechanical properties, Stem fibre, and Scanning Electron Microscopy.

1 INTRODUCTION

Natural fibres are acts very important role in the field of polymer composites. Natural fibres are subdivided based on their origin's coming from plants, animals or minerals. Human dependence on plant fibres is manifested in a diverse range of products. This includes fibres as spun into filaments, string or rope and fibres matted in to sheets to make products like composite materials. Considering the plant based natural fibre products are of high quality and durable. As compared to synthetic fibres, this can be produced very cheaply and in large quantity with low cost, low density and biodegradable.

Sida acuta is the underutilised plant belong to Malvaceae family, grows abundantly particularly along the road sides, forest edges and waste lands in India. Sida acuta plant is an erect, branched, small shrub and grows up to 150 cm height [1]. This plant is locally called as bheemanakaddi gida. The fibres of this plant generally used for making ropes and the stems of this plant are used for making brooms and baskets. The fibres of this plant are polygonal in structure, spheroidal in shape and distributed in the form of compact radial bonds. The fibre is marguerite yellow in colour, soft and having an appearance like silk [2].

Chemical treatments are considered in modifying the fibre surface properties because it can enhance the fibre tensile strength, fibre thermal stability and bond strength between fibre and matrix [3-5], due to differential hydroxyl group and also can reduce water absorption of the natural fibre and we propose to measure mass loss, tensile strength, young's modulus, elongation at failure and density of the chemically treated fibres. Chemical treatments of natural fibres were investigated by a number of researchers have discussed the effects of alkaline treatment on structure and properties of natural fibres, such as jute [6], sisal [7], flax [8], hemp [9] and kenaf [9]. According to the investigation alkaline (NaOH) treatment is one of the most used treatments of natural fibres when used as reinforcement in thermoplastics and thermosets. In this study, the sodium hydroxide (NaOH) was chosen because of its low cost and effectiveness. In this experiment three different present concentration of NaOH were used to determine the optimum concentration.

2 MATERIALS AND METHODS

Sida acuta fibre is a natural fibre has been separated by tank retting process. After extracting the fibre from the stem of sida acuta plants were washed with fresh warm water and dried at ambient temperature for 24hr's.

2.1 Alkaline (NaOH) treatment

Alkaline (NaOH) treatment is a common pre-processing technique used to remove the impurities like hemicellulose, fat's, waxes and other non-cellulosic substances from the fibre surface in order to improve the bonding strength between fibre and matrix, to increase the surface roughness and to reduce the internal stress between the fibre and matrix when processed in to composite form. In this study sida acuta stem fibre was treated with three different concentration of NaOH solution to determine the optimum concentration. The concentrations used were 1%, 3% and 5% weight/volume. Alkaline treatment was done with sample: liquor ratio of 1:30. Standard procedure used in the institute is as follows [10].

The sida acuta fibres were immersed in NaOH solution at various concentrations for an hour (each test concentration treatment was conducted for 4hr's and 20hr'stime duration respectively) at room under atmospheric pressure.

Alkali (NaOH) treatments of sida acuta stem fibres protocol (1% NaOH solution treatment of sida acuta fibres with test duration 4hr's and 20hr's respectively)

Step-1: Weight out required quantity of fibres (In this test 30 gm's of fibres taken).
Step-2: Preparation of NaoH solution. (As per 1:30 ratio, fibre : liquor ratio)
Example : For 30 gm's of fibre 900 ml of NaoH solution

a) 900 ml of distilled water, 9 gm's of NaoH and 1-2 drops of wetting agent.
b) Mix the solution properly with the help of a glass rod.
c) Add fibres in a beaker such that fibres are immersed in the solution completely; keep it for 4hr's and 20hr's (Separate test) at room temperature.

Step-3: Wash out the fibres with warm water 4 to 5 times.
Step-4: Keep the fibres in 0.1 % (normal) Acetic acid solution for 2 to 4 minutes.
[Preparation of 0.1 N Acetic acid solution, 5.166 ml of Acetic acid mixed with 900 ml of warm water (Standard procedure for 0.1 N acetic acid solution: 5.74 ml of Acetic acid with 1 lit of water)].

Step-5: Wash the fibres with distilled water until the rinsed solution reached neutral (PH7).
Step-6: Dry the fibres at room temperature on a blotting paper for 2 days.

2.2 Mechanical properties of Untreated and Alkali (NaOH) treated sida acuta stem fibre

The extracted fibres from the stem of sida acuta plant by tank retting method will be threaded (S-type) or yarns fibres because of its sub branched and smaller in fibre length, using manual weavers having average diameter of the yarn fibres range between 0.6 – 0.9 mm is calculated using micrometer. In the present study diameter of the each yarn fibre was measured at different positions (more than 10 positions) between the selected lengths of the yarn fibres (total length of the each yarn fibre is 30 cm) and calculated the average diameter of the each yarn fibre. The mechanical properties measured were tensile strength; Young's modulus and elongation at break of the threaded (yarn) sida acuta stem fibre specimens from the stress – strain curve.
The tensile tests of the threaded (yarn) sida acuta stem fibre specimens were performed using an INSTRON tensile testing machine (IS1670:1991, option A) to obtain the breaking tenacity, breaking elongation (%) and Young's modulus of the fibres. The specimens were tested with 200 mm gauge length and 20± 2 seconds time limit at 40 mm/min rate. The tensile tests were carried out at a room temperature of 27^0c with a controlled room humidity of 65%. Each sample of threaded (yarn) sida acuta stem fibre included 9 to 10 numbers of specimens and the average values are reported in the table 2.1. All these testing were carried out for both treated and untreated sida acuta stem fibre.

TABLE 2.1 AVERAGE BREAKING LOAD, TENACITY AND ELONGATION AT BREAK OF THE UNTREATED AND ALKALI (NAOH) TREATED SIDA ACUTA STEM FIBRE WITH TEST DURATION 4HR'S AND 20HR'S RESPECTIVELY

	Concentration of NaOH treatment	Average breaking load in gm's	Average Tenacity in CN/Tex	Average Elongation in %
	0% (Untreated)	33.1	8.3	4.7
NaOH solution with 4 hr's test	1%	42.9	9.9	6.4
	3%	47.7	9.8	5.3
	5%	45.1	11.5	3.6
NaOH solution with 20hr's test	1%	35.1	6.8	5.5
	3%	49.9	9.4	7.3
	5%	25.7	6.4	4.7

2.3 Morphological studies

The surface analyses of the untreated and treated sida acuta stem fibres were observed using a JSM – 6490 LV Scanning Electron Microscope (SEM). The fibre filaments to be observed under the SEM were mounted on conductive adhesive tape, sputter coated with gold palladium and observed under the SEM.

3 RESULTS AND DISCUSSIONS

3.1 Mass loss and Density of the untreated and treated sida acuta stem fibre

In the present study the mass loss of the alkali (NaOH) treated sida acuta stem fibre at different concentrations we have taken approximately 30 gm's of the sida acuta fibre before to the test. The alkali treatment of sida acuta fibre were carried out at different concentration of NaOH solution (1%, 3% and 5%) for 4hr's and 20hr's test duration respectively. The mass loss of the alkali treated sida acuta fibre and density of the fibre was recorded in the table 3.1. In this study the mass of the sida acuta fibre before and after the alkali treatment was measured using electric weighed with a least count of 0.01 gm's. The density of the untreated and alkali treated sida acuta stem fibre was conducted according to the water displacement method. In the present density test of sida acuta stem fibre included three or more specimens. The room temperature tests were carried out at 23^0c ± 2 with a controlled room humidity of 55 ± 5 %. As shown in the table 3.1.

TABLE 3.1 SHOWS THAT THE MASS LOSS AND DENSITY OF UNTREATED AND ALKALI TREATED (1%, 3% AND 5%) SIDA ACUTA STEM FIBRE WITH TEST DURATION 4HR'S AND 20HR'S RESPECTIVELY

	Concentration of NaOH treatment	Mass loss of the Sida acuta stem fibre		Density of the Sida acuta fibre (gm/cc)
		gm's	%	
	0% (Untreated)	---	---	0.8444 ± 0.0417
NaOH solution treated Sida acuta fibre with 4 hr's test duration	1%	0.85	2.833	0.8848 ± 0.0218
	3%	1.98	6.453	0.7760 ± 0.0393
	5%	2.31	7.549	0.8796 ± 0.0709
NaOH solution treated Sida acuta fibre with 20hr's test duration	1%	1.42	4.655	0.8808 ± 0.0011
	3%	3.37	11.049	0.8198 ± 0.0372
	5%	3.8	12.666	0.8476 ± 0.0151

Fig.1. Represents the mass loss versus different concentration of sodium hydroxide treatment with test duration of 4hr's and 20hr's respectively. Fig.1 concludes that the difference between the mass loss of an untreated (0%) and treated sida acuta stem fibre with 1%, 3% and 5% NaOH solution with 4hr's test duration is approximately: 2.833%, 6.453% and 7.549% respectively and it concludes that the difference between the mass loss of an untreated (0%) and treated sida acuta stem fibre with 1%, 3% and 5% NaOH solution with 20hr's test duration is approximately: 4.655%, 11.049% and 12.666% respectively. Finally in the present study we can conclude that the mass loss between untreated and alkali treated sida acuta stem fibre is significantly increased by increase in concentration of NaOH solution and its testing time. Hence the obtained consistent result can conclude by removing of impurities like hemicellulose, fat's, waxes and other non-cellulosic substances from the surface of the stem fibres significantly and due to deep notched grooves (pits) in the fibre filaments resulting increases the mass loss of the alkali treated fibres.

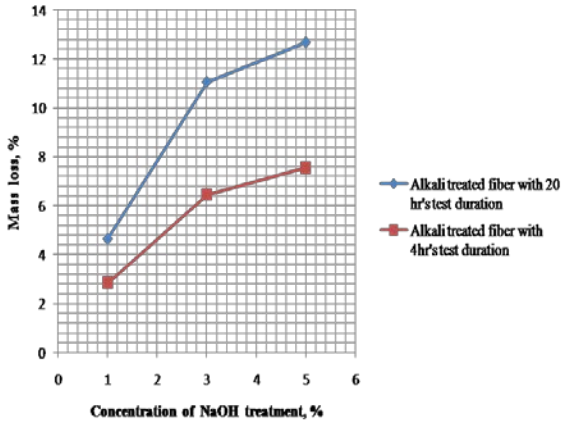

Fig.1. Mass loss of Sida acuta stem fibre with alkali (NaOH) treated with test duration 4hr'sand 20hr's

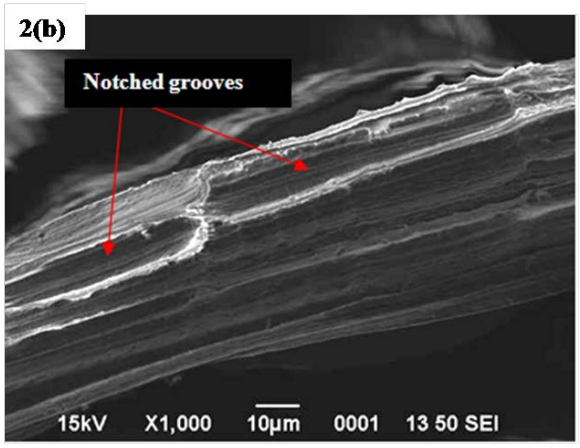

Fig. 2. SEM micrographs of untreated sida acuta stem fibre 2(a) with 0% NaOH and 2(b) with 0% NaOH

3.2 Morphological analysis

Fig. 2 (a, b), 3 (a-c) and 4 (a-c) show the surface morphology of the untreated and alkali treated sida acuta stem fibres at different concentrations (1%, 3% and 5% NaOH) with 4hr's and 20hr's test durations respectively. The sida acuta stem fibres were extracted by tank retting process. The surface of the untreated sida acuta stem fibres contains notched grooves and impurities (hemicelluloses, lignin, pectin and other noncellulosic substances) that covers the strengthened plant fibre content (cellulose) inside as seen from Fig. 2(a) and 2(b).

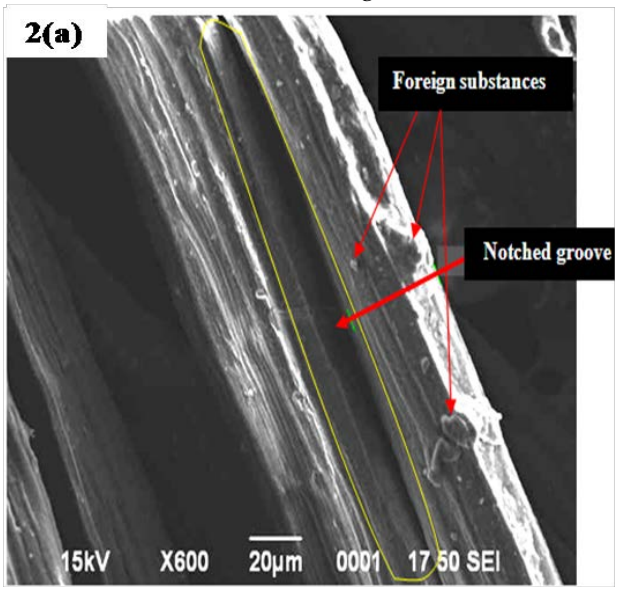

Fig. 2. SEM micrographs of untreated sida acuta stem fibre 2(a) with 0% NaOH and 2(b) with 0% NaOH

The 1%, 3% and 5% alkaline (NaOH) treatment with 4 hr's test duration of the sida acuta stem fibres respectively removes most of the surface substances and some of the surface notched grooves from the surface of the stem fibres resulting in fibres with relatively clean and strengthened fibre is obtained. As show in Fig. 3(a), 3(b) and (c).

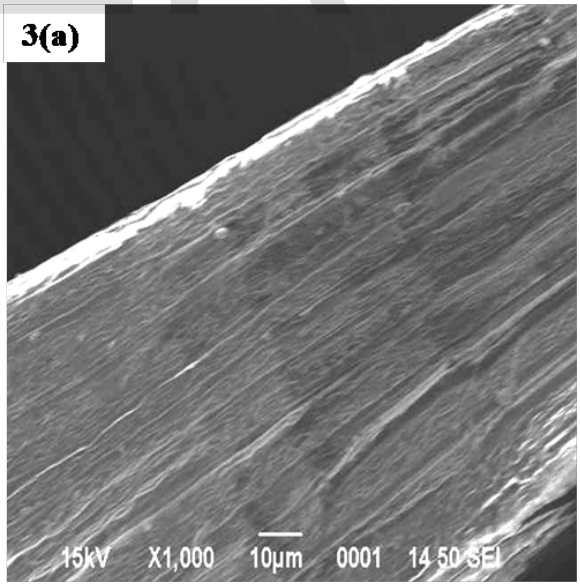

Fig. 3. SEM micrographs of treated sida acuta stem fibre with 4hr's test duration 3(a) with 1% NaOH, 3(b) with 3% NaOH and 3(c) with 5% NaOH

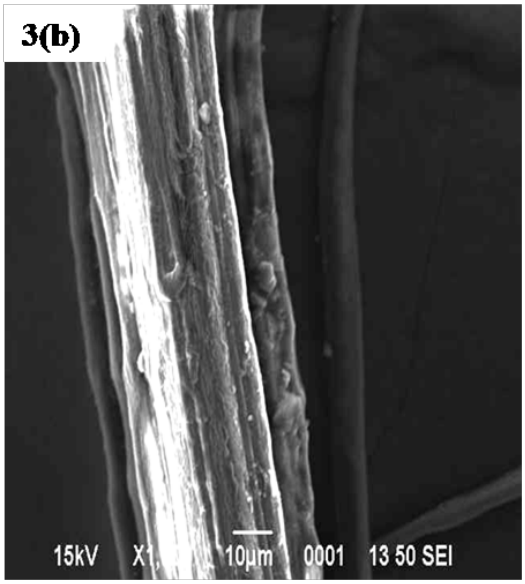

Fig. 3. SEM micrographs of treated sida acuta stem fibre with 4hr's test duration 3(a) with 1% NaOH, 3(b) with 3% NaOH and 3(c) with 5% NaOH

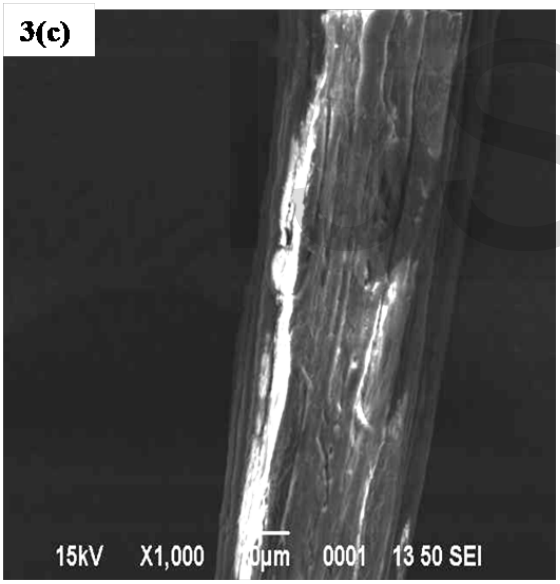

Fig. 3. SEM micrographs of treated sida acuta stem fibre with 4hr's test duration 3(a) with 1% NaOH, 3(b) with 3% NaOH and 3(c) with 5% NaOH

Similarly the 1%, 3% and 5% alkaline (NaOH) treatment with 20 hr's test duration of the sida acuta stem fibres respectively removes most of the surface substances and some of the notched grooves from the surface of the stem fibres and it produces the deep notched grooves in the stem fibre and separates the fibre surface from the main fibre filament resulting the weak fibres obtained than compare to the 1%, 3% and 5% alkaline (NaOH) treated with 4hr's test duration of the sida acuta stem fibres. As shown in Fig. 4(a), 4(b) and 4(c).

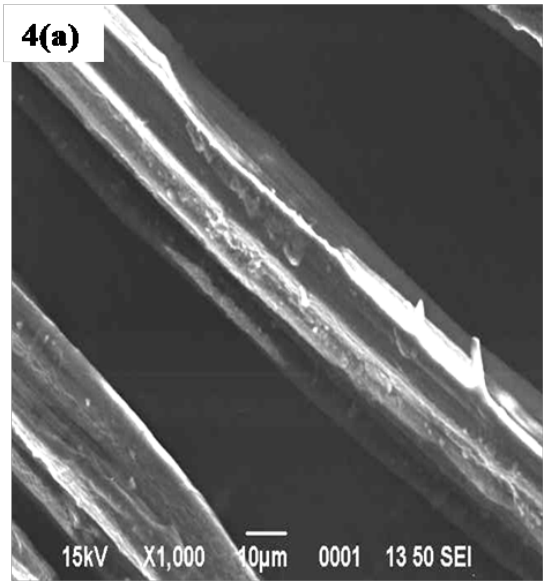

Fig. 4. SEM micrographs of treated sida acuta stem fibre with 20hr's test duration 4(a) with 1% NaOH, 4(b) with 3% NaOH and 4(c) with 5% NaOH

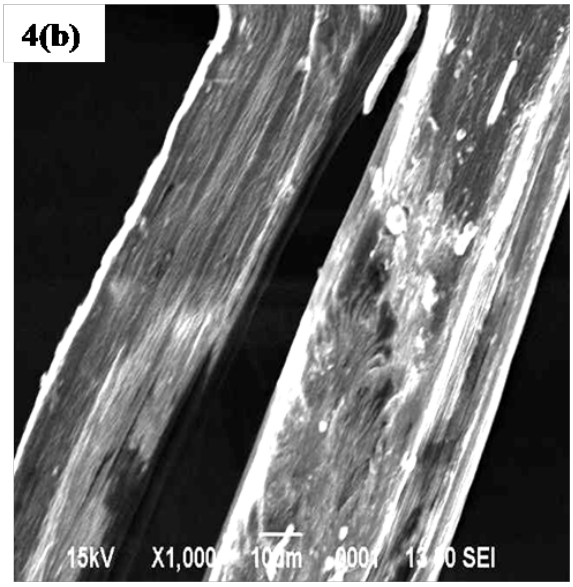

Fig. 4. SEM micrographs of treated sida acuta stem fibre with 20hr's test duration 4(a) with 1% NaOH, 4(b) with 3% NaOH and 4(c) with 5% NaOH

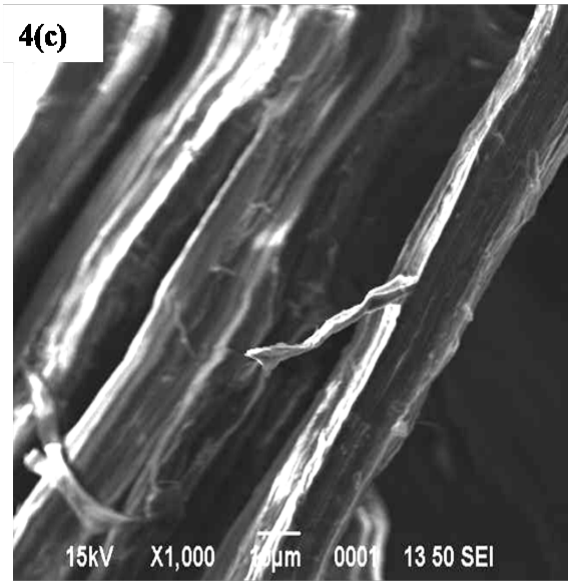

Fig. 4. SEM micrographs of treated sida acuta stem fibre with 20hr's test duration 4(a) with 1% NaOH, 4(b) with 3% NaOH and 4(c) with 5% NaOH

3.3 Tensile strength

The both treated and untreated sida acuta stem fibre specimens were tested for the determination of tensile property. From the obtained consistent results for tensile strength, this proved the effectiveness of the alkaline treatment. The mechanical properties of the sida acuta fibre before and after NaOH treatment at different concentrations are shown in table 3.2.

Fig. 5. shows that the mechanical properties of the untreated and NaOH solution treated sida acuta stem fibre with 4hr's test duration. In this the maximum tensile strength was reported at 5% NaOH treatment. As soda concentration increases the fibre become cleaner of its impurities and later improves the tensile strength from 0% NaOH through 1% and 3% NaOH (with 3.207 MPa decrease in tensile strength between 1% and 3% NaOH treatment) to 5% NaOH treatment to exceed 124.184 ± 0.1986 MPa.

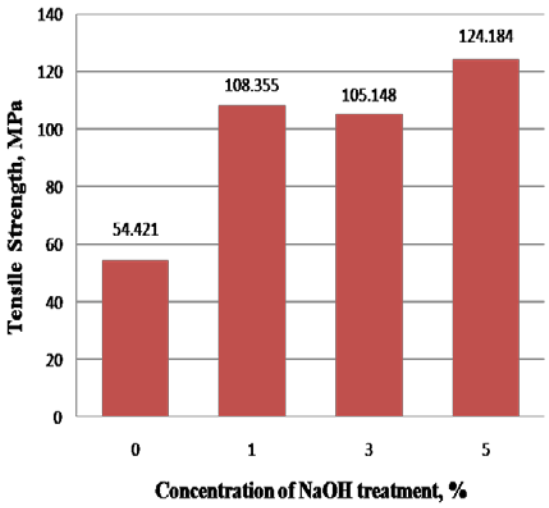

Fig. 5. Tensile Strength of untreated and alkali (NaOH) treated sida acuta stem fibre with 4hr's test duration

Fig. 6. shows that the mechanical properties of the untreated and NaOH solution treated sida acuta stem fibre with 20hr's test duration. In this the maximum tensile strength was reported at 3% NaOH treatment. As soda concentration increases the fibre become cleaner of its impurities and later improves the tensile strength from 0% NaOH through 1%NaOH to 3% NaOH treatment to exceed 86.004 ± 0.8996 MPa and when reaches 5% NaOH treatment the strength of the fibre will reducing because of healing out the surface of the fibre from the main fibre filaments.

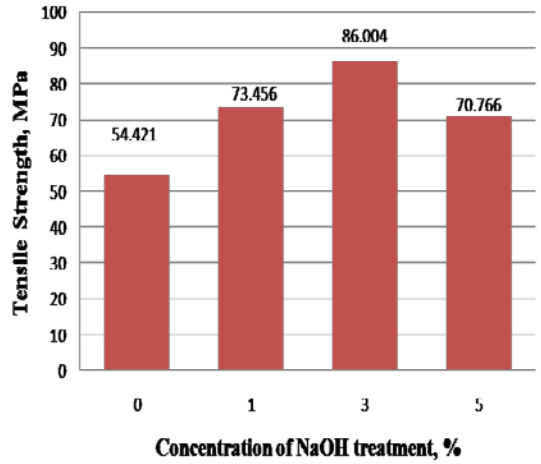

Fig. 6. Tensile Strength of untreated and alkali (NaOH) treated sida acuta stem fibre with 20hr's test duration

The mechanical properties of the NaOH solution treated sida acuta fibre with between 4 and 20 hr's test duration. In this the maximum tensile strength was reported at 5% NaOH treatment with 4hr's test duration and the minimum tensile strength was reported at 5% NaOH treatment with 20hr's test duration. Hence the obtained consistent result can conclude by increasing the test duration of NaOH solution treatment decreases the tensile strength of the sida acuta stem fibre due to deep notched grooves in the stem fibre and separates the fibre surface from the main fibre filaments.

3.4 Tensile modulus

Tensile modulus is a measure of rigidity of the material. The effect of the NaOH solution treatment for the sida acuta stem fibre increases their rigidity for all different alkali concentrations. It means the obtained consistent result of the tensile modulus shows the significant increase in tensile modulus with increase in the alkali concentration. As shown in Fig. 7 and Fig.8.

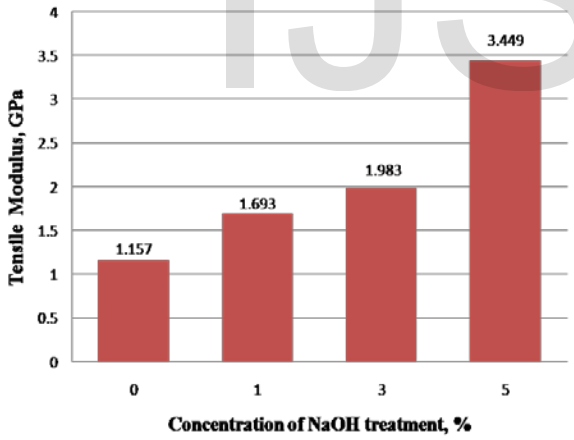

Fig. 7. Tensile Modulus of untreated and alkali (NaOH) treated Sida acuta stem fibre with 4hr's test duration

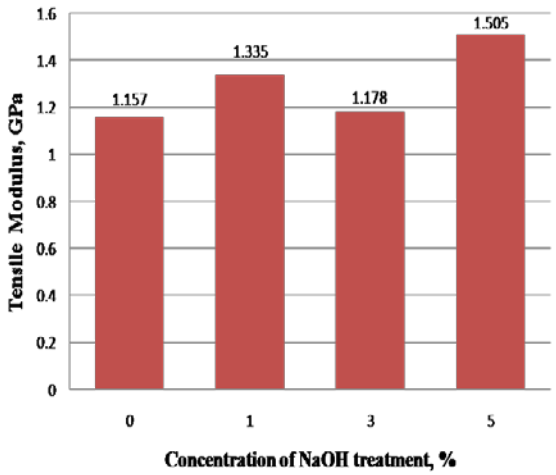

Fig. 8. Tensile Modulus of untreated and alkali (NaOH) treated Sida acuta stem fibre with 20hr's test duration

Rong et al. [11] was reported that the alkali treatment for sisal fibres provides the improved crystallinity of cellulose and removes the impurities (hemi-cellulose and lignin). Then, it suggests that sisal fibre becomes relatively ductile after the removal of some impurities. The fibres can result in higher fibre stiffness due to the increased crystallinity of hard cellulose. Similar reason the significant improvement in the tensile modulus of the sida acuta stem fibre can viewed.

The maximum tensile modulus was provided by 5% alkali treatment with 4hr's test duration. But, the most important conclusion from these results is the significant enhancement of the tensile modulus of sida acuta stem fibre with the different percentage of alkali treatment (1%, 3% and 5% NaOH).

The average and ± one standard deviations of the tensile strength, tensile modulus and elongation at break for each sample of groups (each sample of group includes 9-10 number of specimens) untreated and treated sida acuta stem fibre with alkali treatment were recorded in the table 3.2.

TABLE 3.2.MECHANICAL PROPERTIES OF UNTREATED AND ALKALI (NAOH) TREATED SIDA ACUTA STEM FIBRE (0%, 1%, 3% AND 5%) WITH 4HR'S AND 20HR'S TEST DURATION

	Concentration of NaOH treatment	Tensile Strength (MPa)	Tensile Modulus (GPa)	Elongation at break (%)
	0% (Untreated)	54.421 ± 1.1734	1.157 ± 0.041	4.7 ±1.7823
NaOH solution treated with 4hr's test duration	1%	108.355±0.9809	1.693±0.616	6.4±1.6248
	3%	105.148±0.555	1.983±0.451	5.3±1.1554
	5%	124.184±0.1986	3.449±0.263	3.6±0.5656
NaOH solution treated with 20hr's test duration	1%	73.456±0.2577	1.335±0.128	5.5±1.1597
	3%	86.004±0.8996	1.178 ± 0.187	7.3±1.5215
	5%	70.766±0.5673	1.505±0.177	4.7 ±0.7582

4 Conclusion

In the present study, the extracted sida acuta fibre from the plant stem by tank retting process was treated with alkali (NaOH) solution for different concentrations (1%, 3% and 5% NaOH) with 4hr's and 20hr's test duration. From this study we conclude that the alkali treated sida acuta stem fibre was increase the mass loss of the fibre significantly with increase in percentage of alkali concentration along with increase in its test duration.

From this study, again we conclude that the tensile strength and Young's modulus of the untreated and alkali (1%, 3% and 5% NaOH) treated sida acuta stem fibre with 4hr's test duration was significantly improved due to the removal of impurities (hemicelluloses, lignin and other non cellulosic substances) from the surface of the stem fibre. But the comparison of alkali (1%, 3% and 5% NaOH) treated sida acuta stem fibre between 4hr's and 20hr's test duration the tensile strength and Young's modulus of the sida acuta stem fibre was decrease in alkali treated with 20hr's test duration due to the deep notched grooves in the stem fibre and separates the surface of the fibre from the main fibre filaments.

Finally, the optimal concentration of alkali (NaOH) treatment based on tensile strength, Young's modulus and the better surface morphology of the sida acuta stem fibre is of the order of 5% alkali (NaOH) treatment with 4hr's test duration.

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