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DETERMINATION OF STRESS INTENSITY FACTOR OF SUGARCANE FIBER REINFORCED HYBRID POLYMER MATRIX COMPOSITE

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ABSTRACT

The need for environment friendly nonpolluting technology is the basis for this research. This paper aims at investigating the use of sugarcane fiber as an alternative to synthetic fiber and inclusion of CNSL along with the GP Polyester Resin to make this a partially biodegradable combination. The investigations show that the alkali treatment of the sugarcane fiber with NaOH has greatly improved the stress intensity factor of the composite.

Keywords—sugarcane fiber; CNSL; CNSL polymer matrix; fracture strength; stress intensity factor

INTRODUCTION

Agro fibers are biodegradable natural cellulose materials. They are available all-round the year they are biodegradable and cost less. They are very much suitable for short service life components and when they retire from service they readily decompose without effecting the environment. Several plant fibers have been studied for their suitability with hybrid polymer matrix composites. Sugar cane fiber was chosen because of its abundant availability and degradable property. The key advantages of sugar cane fiber are low density, light in weight, renewable and cheap. To increase the interfacial bond of the fiber, they are treated with NaOH (Alkaline treatment) [1]. This alkaline treatment improves the mechanical properties of sugar cane fibers and helps in improving the demerits of natural fibers such as variable quality, depending on unpredictable influences of weather, moisture absorption which cause swelling of the fibers and lower durability. The surface roughness is increased and the lignin, wax, oils of the fiber are removed [2]. This treatment also helps in improvement of flexural strength with respect to duration of treatment and concentration of NaoH in alkali solution. The CNSL is added with general purpose resin in 5%, 10%, and 15% respectively. The CNSL content enhances the recyclability and bio degradability, but reduces the flexural strength [3]. The increase in CNSL percentage reduces the tensile load applied to the specimen [4].

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METHODOLOGY

Fiber material

After crushing sugarcane during the juice extraction process we are left with the fiber as a waste product which is normally burnt to produce electricity in the sugar mills. This sugarcane fiber has many uses. This fiber can also be used as reinforcement in composite preparation. This fiber has poor wetting properties. In order to improve its adhesion to the matrix it is alkali treated with NaOH solution. For this experiment three different levels of NaOH concentration were used, namely 5%, 10% and 15% NaOH by weight in water. The fiber was treated in NaOH solution for durations of 6, 12 and 24 hour. After treatment, it was thoroughly washed in water and then dried at room temperature for 24 hours. Fibers of average 140mm length and diameter ~2mm were chosen for this experiment.

Polyester resin

Isophthallic unsaturated polyester resin was used for the experiments. This resin has low water absorbing characteristics and excellent bonding and mechanical properties. The properties of the resin are listed in Table 1.

Table I. GP POLYESTER RESIN PROPERTIES

Properties	**Unit**	**Range**
Density	kg/m^3	1125
Specific gravity	-	1.1 - 1.46
Tensile strength	Mpa	18
Tensile modulus	Gpa	0.8-1.1
Flexural strength	MPa	30
Flexural modulus	GPa	1.2-1.5
Shrinkage	%	0.0004-0.008

Cashew nut shell liquid (CNSL)

Cashew nut shell liquid is extracted from the outer cover of the cashew nut fruit. It is a thick greasy liquid. This liquid was mixed with the polymer resin in three different volume levels, namely 5%, 10% and 15% by volume to resin.

Preparation of mold

The mold for casting the specimens was prepared using plastic casings. The specimens were prepared according to ASTM D5045 standard. The Figure 1 shows the mold lay with the sugarcane fiber ready for pouring the resin.

Design of experiment (DOE)

The Taguchi L9 orthogonal array was chosen for the DOE. The table 2 shows the combinations used for the experiments.

Table II. DOE USING TAGUCHI L9 ORTHOGONAL ARRAY

Sample No.	CNSL %	NaOH %	Soak Time (hr.)
1	5	5	6
2		10	12
3		15	24
4	10	5	12
5		10	24
6		15	6
7	15	5	24
8		10	6
9		15	12

The Figure 1 shows the molds with the sugarcane fiber set for molding.

Figure 1. Sugarcane fiber laid in mold.

The Figure 2 shows the molds with the hybrid polymer set for curing. The cast was let to cure at room temperature for 2 days.

Figure 2. Molded specimen.

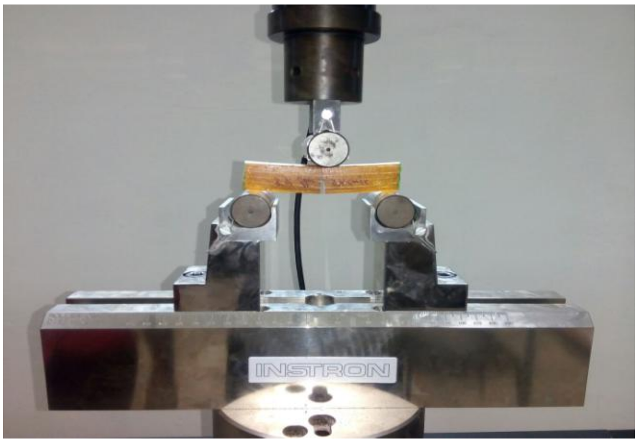

Figure 3. Testing of sample on INSTRON UTM using a 3 point bending fixture.

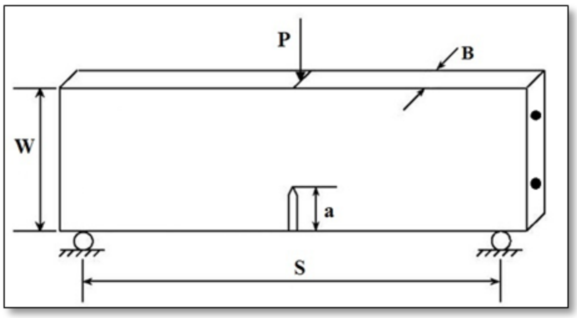

Figure 4. ASTN D5045 standard specimen size.

Testing on UTM

The specimens were made ready according to ASTM D5045 standard as shown in Figure 5. The specimen dimensions were maintained as 5.5 x 22 x 98 mm. A pre-crack (a) of length 10mm was created for the fracture test. The specimens were tested using INSTRON-8801 Universal testing machine. The Figures 3 & 4 show the machine set up. The machine was set up with a 3 point bending fixture as shown in Figure 4 for the 3 point fracture strength testing as per ASTM D5045 standard. The rate of loading was 1mm/min. Flexural strength is the strength under normal stresses and is determined by applying the equation;

RESULTS AND DISCUSSIONS

Taguchi L9 orthogonal array was used for the DOE, which resulted in 9 iterations as per Table III. Table III shows the results of the tests with the stress intensity factor listed for each of the 9 iterations. Sample 3 has the highest stress intensity factor recorded out of the 9 experiments. This was the sample treated with 15% NaOH solution for 24 hours and had a 5% CNSL volume in the resin. The lowest stress intensity factor was recorded with sample 7 which was treated with 5% NaOH solution for 24 hours and had a 15% CNSL volume in the resin.

Table III. Test results

Sample No.	**CNSL %**	**NaOH %**	**Soak Time (hr.)**	**Stress intensity factor**
1		5	6	**6.0**
2	5	10	12	**6.3**
3		15	24	**7.2**
4		5	12	**4.5**
5	10	10	24	**5.5**
6		15	6	**6.3**
7		5	24	**3.1**
8	15	10	6	**4.4**
9		15	12	**5.3**

Comparison of results

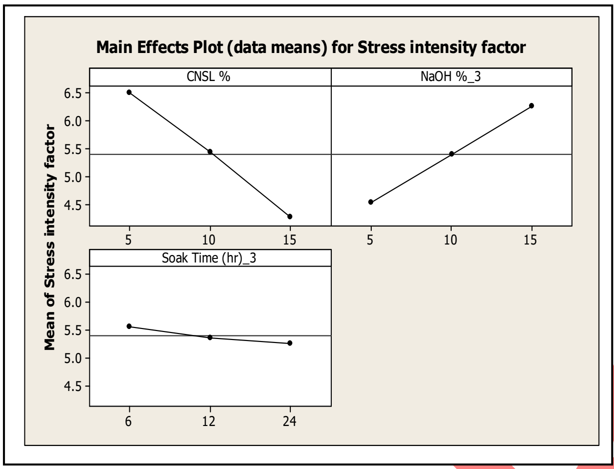

Figure 5. Main Effects plot (data means) for Stress intensity factor.

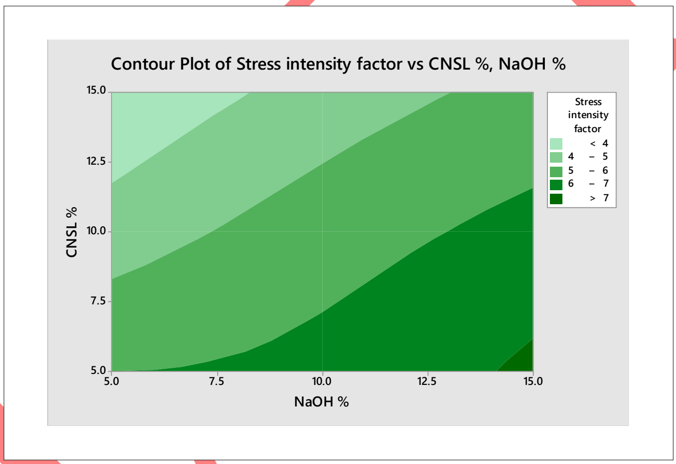

Figure 6. Contour plot of Stress intensity factor Vs CNSL%, NaOH%.

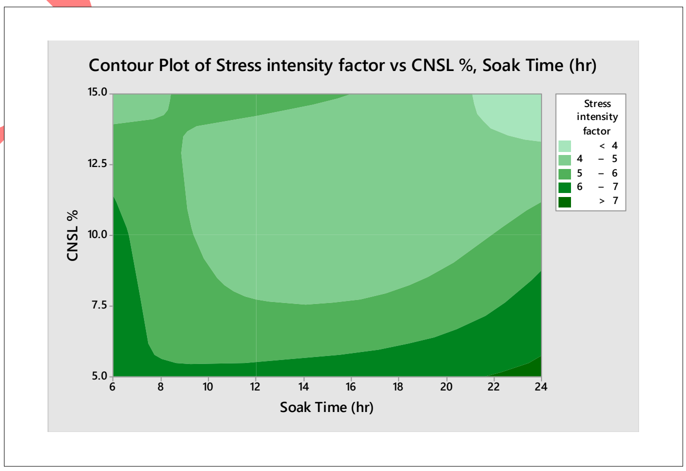

Figure 7. Contour plot of Stress intensity factor Vs CNSL%, Soak time.

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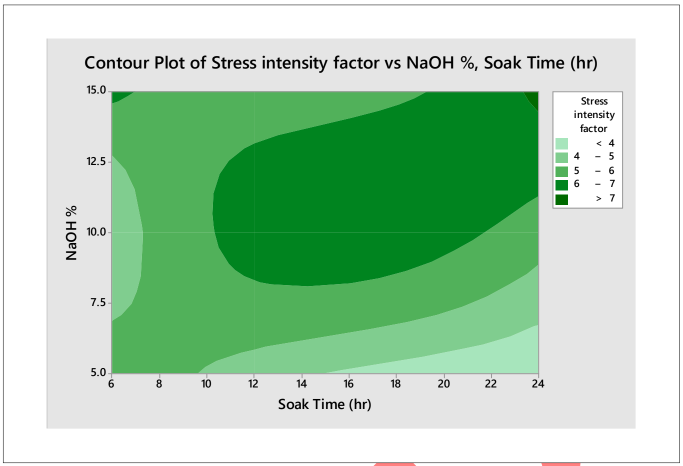

Figure 8. Contour plot of Stress intensity factor Vs NaOH%, Soak Time.

Figure 5 shows the Main effects plot (data means) for Stress intensity factor. The plot clearly identifies the effect of the three variables, NaOH%, CNSL% and soak time on the stress intensity factor. There is a increase in the stress intensity factor as the NaOH percentage is increased along with the soak time, and a decrease in stress intensity with the increase in CNSL%.

Figures 6, 7 & 8 show the contour plot with the stress intensity factor plotted in the Z axis and compared with other variables, CNSL%, NaOH% and soak time.

CONCLUSION

The mean effects plot shows the interaction between the various factors chosen as variables to study their influence on the stress intensity factor of the test specimens. The alkali treatment clearly shows a remarkable improvement and increase in the stress intensity factor. The specimens treated with 15% NaOH solution have a higher stress intensity factor than the 5% NaOH treated specimen. This is a clear indication that the alkali treatment greatly enhances the bonding of the resin with the fiber. As the CNSL volume increases the stress intensity factor decreases. The CNSL% can be adjusted to suit the application needs of the product. This methodology can be adopted to fabricate composite parts which have a short service life and with the fiber being the bulk of the composite would readily decompose leaving behind a small resin fraction.

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