Particle swarm optimization of tensile strength on treated Bermuda grass Fiber as reinforcement in polyester composites

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Abstract. The tensile strength of chemical treated Bermuda grass fiber reinforced polymer composites were assessed in this work. This investigation enhanced the bonding nature of the Bermuda grass fiber through NaOH treatment, which is used as reinforcement in composite material. The difficult of reduced compatibility among fiber and the resin matrix has been diluted by creating rough surface of Bermuda grass fiber through sodium hydroxide (NaOH) solution. The result of surface modification parameters on the tensile strength of Bermuda grass-polyester composite was analyzed and found that it influence majorly in the tensile strength of composites. The value of 19 MPa, was found as maximum tensile strength through NaOH alkali treatment. The Response Surface Methodology (RSM) approach was used to model the mechanical strength of treated Bermuda Grass-polyester composites. The mathematical equation formed using RSM and the Particle Swarm Optimization (PSO) technique is used to find the better mechanical properties.

Keywords: Bermuda grass fiber, polyester, Compression moulding Tensile strength, Particle Swarm Optimization

Introduction

Many of the researchers found the natural fibers are potential alternatives to artificial fibers which available in the market. The natural fiber-polymer composites have the advantages of light weight, high stiffness, less density, ecofriendly, low cost, less tool wearing etc. These unique characteristics are kindle the designer to select the natural fiber composites for their design. The natural fiber composites are exploited for viable applications such as Automobile, Construction, Aerospace, Sports etc. [1] The primary advantages of natural fibers are low density, plentiful in nature, and low cost, easy processing etc., In addition to that they have less energy consumption, and easy handling [2]. Many researchers have been carried out work on the altered kinds of natural fibers such as jute, flax, coir, bamboo, and sisal and the possibilities of utilization as lightweight materials are studied [3-6]. Unfortunately, the performance of natural fiber as a reinforcement in polymer composites is insufficient and not similar even with other synthetic fibers due to lack of interfacial bonding strength between fiber and polymer. The Problem of poor interfacial strength between fiber and matrix is attributable to existence of superfluous non cellulosic content in the fiber exterior part. The removal of this extra lignin through surface modification process enhances the surface roughness and increase the bonding strength between fiber and polymer [7]. The use of surface modified fiber as reinforcement which gives significantly improves the mechanical strength of composites [8-9]. This investigation is objectives to increase the mechanical strengths of Bermuda Grass-polyester composites by means of NaOH treatment process parameter namely NaOH alkali solution concentration and fiber soaking time. The optimal process parameters were selected for maximum tensile strength using Swarm intelligence.

1. Experimental Procedure

1.1 Materials and Methods
In the present study, the Bermuda grass fiber used as reinforcement which is available in the local places of sathyamangalam. The used fibers was extracted by means of simple water retting process and it was treated with NaOH aqueous solution with the fiber treatment parameters namely; soaking time and solution concentration as shown in the Table.1.

| Parameters | Solution Concentration % | Soaking Time (Hrs) |
|------------|--------------------------|--------------------|
| Level1     | 2                        | 24                 |
| Level2     | 4                        | 48                 |
| Level3     | 6                        | 72                 |
| Level4     | 8                        | 96                 |
| Level5     | 10                       | 120                |

During the fabrication, the fibers keep in the random orientation in the resin system containing of isopathalic polyester resin, cobalt actuate as acted accelerator and MEKP as acted catalyst in the ratio of 1:0.015:0.015. The compression molding machine was used manufacture the composite plate in the dimension of 300 × 300 × 3 mm³ and pressed at a force of 0.5 kN. After 1 hour, released the pressure and fabricated composite plate was recover from mold and the plates were permitted to cure at room temperature for 24 hours. The composite specimens were cut to ASTM -D638 standards and were tested for its tensile properties. The five tensile samples were tested for every plate and stated the average value for the statically significant result.

2. Mathematical modeling and Optimization.

Using RSM, the experimental data obtained from tensile testing of Bermuda Grass-polyester composite, the nonlinear regression equation was formed. The mathematical equation formed by RSM, was optimized using non heuristic Particle Swarm Optimization (PSO) Technique. The parameters assigned during optimization of tensile strength using PSO parameters are given (Table.2).

| Parameters used in PSO |
|------------------------|
| No of particles        | 100          |
| Penalty                | 300          |
| Multiplication parameter | 1.2        |
| No. of cycles          | 5            |
| No of iterations       | 100          |

3. Result and Discussion.

3.1 Effect of NaOH alkali treatment parameters on the tensile strength of Composites

Figure.1 shows the association between the alkali treatment parameters and tensile properties in MPa. The maximum tensile property was obtained in all the levels of the 72 hours soaking time. After 72 hours the strength of composites were dwindled, because of higher elimination of lignin, pectin, wax and ash etc., material from the fiber may weaken the fiber. The same kind of situation was happened in the solution concentration after 6 %. More solution concentration may damages the fiber by excess removal of non-cellulosic content and less concentration may remove the less amount of non-cellulosic contents available in the fiber which could not sufficient to develop the enough interfacial strength. A less value of the tensile property of 5 MPa was attained in 24 hours and 2% of solution concentration, and a superior range of tensile property of 19 MPa was obtained in 72 hours and 6 % of solution concentration.
3.2 Mathematical Modeling Using RSM.

The regression equation of alkali treated bermuda grass fiber composites after tensile tested was identified. The response ($t_s$) and the input parameters (alkali process parameters) were obtained from the coefficients resulting from the Design experiment 8.0.4 software. Table 3 shows the mathematical equation for tensile strength model.

The equation was identified mathematically significant or not using coefficient of correlation ($R^2$). The coefficient of determination ($R^2$) value shows high range (0.88) which indicate the correctness and accuracy of predicting of the regression equation.

Table 3. The nonlinear regression of tensile properties

| Response | Mathematical Equation          | $R^2$ Value |
|----------|--------------------------------|-------------|
| $t_s$    | $-8.77500 + 4.88379 f_1 + \frac{1.63442E-003 f_2}{f_1^2}$ | 0.24682$f_2 - 4.79167E-004 f_1 f_2 - 0.39536 f_1^2$ | 0.88 |

3.3 Optimization using PSO algorithms

The mathematical equation formed by Response Surface methodology technique, was optimized using PSO Technique. PSO is used to find the solution in the n-dimensional solution space. The each iteration observes the fitness value them and near particles also. The PSO is suitable for the where the solution in global maxima and local maxima. It is a simple method to find the mimic of flocks bird and it find the food searching process. They involved to find thir food in a simple and easiest method. It has been observed and converts as coding to find the better alkali treatment process for the better mechanical properties. The algorithm of PSO has been given in Figure 2.
For each particle
    Initialize particle
End

Do
For each particle
    Calculate fitness value
    If the fitness value is better than the best fitness value (gBest) in history
        set current value as the new gBest
End

Choose the particle with the best fitness value of all the particles as the gBest
For each particle
    Calculate particle velocity according equation (a)
    Update particle position according equation (b)
End
While maximum iterations or minimum error criteria is not attained

**Figure 2.** The working of PSO algorithm

PSO was established by James Kennedy and Russell Eberhart in the year of 1995. It is related to evolution-inspired problem solving methods such as genetic algorithms. The PSO algorithm accurately predicted the maximum value of tensile strength. This could be inferred from the Table 4 shown below.

| Parameters                  | Value          |
|-----------------------------|----------------|
| Solution Concentration (%)  | 6.04           |
| Soaking Time (Hrs)          | 73             |
| Tensile Strength (MPa)      | 19.005         |
|                             | (PSO-Prediction) |
|                             | 19             |
|                             | (Experimental value) |

The PSO plot obtained for the tensile property model of treated Bermuda grass fiber - polymer composites is shown in the Figure 3.

**Figure 3.** PSO plots for Tensile strength model.
4. Conclusion

The tensile properties of treated Bermuda grass fiber-polyester composites were evaluated as per ASTM D638 standard in this investigation. The surface modification process of Bermuda grass fiber in 6% aqueous solution for 72 h gave an 26.3% improvement in tensile strength. Hence it can be proved that NaOH surface modification process can successfully improve the mechanical strengths of Bermuda grass fiber-polymer composites. The mathematical equation for predicting tensile strength over different environments was formulated using RSM technique. The extreme value of tensile strength for arrangement of process parameters were obtained using PSO algorithm. The PSO algorithm accurately anticipated the maximum value of tensile strength.

References

1. Wallenberger, F. T., Weston, N.: Natural Fibers, Plastics and Composites Source Book from C.H.I.P.S. Texas, (2004).
2. U.U. Modibbo, B.A. Aliyu, I. I. Nkafamiya and A. J. Manji, The effect of moisture imbibition on cellulosic bast fibres as industrial raw materials, Int J Phy Sci 2007; 2 (7):163-168.
3. Satyanarayana, K. G., Sukumaran, K., Mukherjee, P. S., Pavithran, C., Pillai, S. G. K.: Natural Fiber–Polymer Composites, J Ceme. and Conc. Compos. 12 (2), 136 (1990).
4. Mansur, M. A., Aziz, M. A.: Study of Bamboo-Mesh Reinforced Cement Composites, Int.Ceme. Compos. and Lightweight Conc, 5(3), 171 (1983).
5. Gowda, T. M., Naidu, A. C. B., Chhaya, R.: Some Mechanical Properties of Untreated JuteFabric-Reinforced Polymer Composites, J. Compos. Part A: App. Sci. and Manuf. 30(3), 284 (1999).
6. Mishra S, Mohanty AK, Drzal LT, Misra M, Parija S, Nayak SK, Tripathy, SS (2003) Studies on mechanical performance of biofiber/glass reinforced polyester hybrid composites Compos. Sci. Technol. 63:1377–1385.
7. Harish S, Peter Michael D, Bensely A, Mohan Lal D, Rajadurai A (2009) Mechanical property evaluation of natural fiber-coir composite. Materials Characterization 60:44-49.
8. Monteiro SN, Terrones LAH, D’almeida JRM(2008) Mechanical performance of coir fiber/polyester composites Polymer Testing 27:591–595.
9. Mishra S, Mohanty AK, Drzal LT, Misra M, Parija S, Nayak SK, Tripathy, SS (2003) Studies on mechanical performance of biofiber/glass reinforced polyester hybrid composites Compos. Sci. Technol. 63:1377–1385.