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# Forecasting the Finest Firmness of Biocomposites using Response Surface Design Methodology

A. Parre, B. Karthikeyan, A. Balaji, P. Sudhagar, R. Udhayasankar

***Abstract: Natural fibers are considered likely to be used in polymer composite materials as reinforcing agents because of their main advantages such as fine strength and rigidity, low cost, environmentally friendly, degradable and renewable material. A study was conducted to assess the impact of properties of bicomposite made from cardanol resin banana fibers. The banana fiber extracted from the banana stem was treated with alkali to enhance the interfacial linkage around fiber and cardanol resin. Biocomposite was manufactured using formaldehyde mixed with cardanol oil to form cardanol resin mixed with banana fiber using compression moulding Techniques with different process factors such as fiber weight (5%, 10%, 15%, 20%, and 25%) different fiber length (5, 10, 15, 20, and 25 in mm) and alkali treatment (varying in 1%, 3%, 5%, 7% and 9%. The developed banana fiber reinforced composite were then characterized by impact testing showing strong significance and association in DOE using 15.2% fiber weight response surface methodology with 15.3 mm fiber length and 4.7% alkaline treated. Thus we examined the effect of the above factors on impact and suggested the best combinations of factors for composite processing.***

***Keywords: Natural fiber, Biocomposite, Cardanol resin, Response surface design.***

## I. INTRODUCTION

At present a conscious attempt is shown to keep the environment free from pollution and the necessity towards sustainable development that has increased attentiveness in the use of natural fibre to replace synthetic fibers as reinforcements in polymer composites [1, 2]. As a result replacement of the present use of synthetic substances likes polymer and glass fiber by biofiber and resins. This will lead to a situation less concerns for weight and energy [3]. Composite can be defined as a substance made up of more than one constituents or polymer together with another types of components. Biocomposite components are composites in which minimum one of the component obtained should be from natural resources [4].

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* Correspondence Author
**A. Parre***, Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Tamil Nadu, India.
**B. Karthikeyan,** Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Tamil Nadu, India.
**A. Balaji,** Department of Mechanical Engineering, A.V.C College of Engineering, Mayiladuthurai, Tamil Nadu, India.
**P.Sudhagar,** Department of Chemical Engineering, Faculty of Engineering and Technology, Annamalai University, Tamil Nadu, India.
**R. Udhayasankar,** Department of Mechanical Engineering, Faculty of Engineering and Technology, Annamalai University, Tamil Nadu, India.



Fiber reinforced polymers (FRS) are the base materials widely used where strong structures are needed for example aero crafts of all types, including space stations, spacecraft besides ships and off shore drilling platforms [5].

Such composites often have very complex reasons for the addition of fibers; for example, improvements in creeping, wear, fracture strength, thermal stability, etc. may be sought [6]. Over the last few decades, polymer composites have been taking the place of many traditional metals / materials in different implementations. The benefits of new structural materials are those of enormous strength and rigidity weakening qualities [7].

So far phenolic resin is produced keeping cardanol as a base material and synthesized with formaldehyde, an electrophilic compound [8,9]. Cardanol polymerization by formaldehyde will form cardanol formaldehyde (CF) as a natural's resin. To reduce threat of environmental pollution can be achieved by using natural materials of low density in thermostat which promotes sustainable progress of the transport sector and there is a considerable increase in the purchaser market benefitting the industries. A great deal of attention is given for the development of various industrial functions due to the availability of natural fiber materials and low cost in regenerating them. Air craft and automotive production industries are mainly benefitted by different types of natural fibers for making different interior components [10, 11].

The natural fiber composites (NFCs) have both good and bad aspects. Unique impact durability and low density regenerability of fiber are the positive aspects while the negative aspects include resistance to moisture, ultraviolet light high cost and low output [12, 13]. Whereas banana fiber is a waste product of banana production, it is therefore possible to obtain these fibers for industrial purposes without any additional cost [14]. In addition to natural fiber, the use of organic particles to enhance the mechanical performance of polymer composites has grown in recent years [15, 16]. One study has been reported on husk fiber [17] and another study on Coconut shell [18]. New variety of composites has been implemented in material science and engineering. Balaji et al also discussed the role of biocomposites in this follow up [19].

The use of Response surface optimization method in composites were suggested the morphological research on untreated and NaOH–treated fibres by Scanning Electron Microscopic (SEM) discloses the contaminations on the unprocessed naturally found fiber on the exterior and the eradication of the similar processed fibers [20]. TGA test was periodically conducted with due care taking into consideration of available thermal stability acquired from the unprocessed and especially NaOH processed fiber [21].

The surface reponse method is a technique that applies a statistical approach to maximizing the experimental properties of natural fibers.

The goal of our work is therefore to define the parameter weight percentage of biofiber loading, fiber length and alkali treatment percentage condition for improved impact properties of biocomposite using the surface response methodology.

Purchased banana fiber from Sri Achu in Erode, Tamil Nadu, India. Sodium hydroxide (NaOH) was brought from Indian Scientific Solution (Mayiladuthari, /TamilNadu, India).

Dry banana leaf fibers were individually immersed in 1,3,5,7 and 9 per cent NaOH (Relative to banana fiber weight per cent) at normal room temperature for 24 hours [21]. The banana fibers were then dried for two days under sunlight and kept in a hot air over at 90°C- 100°C for 24 hours to remove any moisture content [24, 25]. CNSL oil produced using a standardized procedure [17].Cardanol isolated from bioorganic CNSL and formaldehyde (HCHO) with the help of a simple catalyst, HOH by a structured process of polycondensation [26].

During the above mentioned process, the ground work has been specifically done by hand layup method. This method has been performed to prove pressure using compression moulding. The impact properties obtained from the experimental investigation were used to develop the regression model between manufacturing parameters and mechanical properties.

Response surface methodology is the technique used in this investigation to construct an empirical model between the output response (impact strength) and independent variables (fiber weight percent, fiber length mm, fiber alkali-treated percent)

The model thus developed has been optimized to maximize the impact properties of banana fiber reinforced polymer composites. Biocomposites have been prepared according to three factors and five levels represented in Table 1 using the surface response design.

**Table 1 – Actual and coded variable selected for the response surface design.**

| **Factors / Levels** | | -1.633 | -1 | 0 | +1 | +1.633 |
|---|---|---|---|---|---|---|
| **Weight Percentage (%)** | **A** | 5 | 10 | 15 | 20 | 25 |
| **Length(mm)** | **B** | 5 | 10 | 15 | 20 | 25 |
| **NaOH treatment (%)** | **C** | 1 | 3 | 5 | 7 | 9 |

The purpose of impact testing is to measure the ability of the object to withstand high speed loading. The test measures the energy of impact or energy absorbed prior to fracture. The Izod impact testing machine was used to perform an impact test in accordance with ASTM D 256.

**Fig.1(a). Sample before impact test**

**Fig.1(b). Sample after impact test**

## II. RESULTS AND DISCUSSION

Tested specimens available from the above process are perfectly proved their impact evaluation. Each and every sample shall be tested five times and the mean value shall be calculated. The sample models created with respect to 20 are described below in the Table 3.

A comparison of the impact strength of various mixture of banana fiber emphasized polymer composites are shown in the table 2. It can be seen from Table 2 that the fiber weight 15%, fiber length 15 mm and 5% fiber alkali treatment bio composites achieve a better impact load of 2.60 Joules [27] (Table3). Maximum impact strength was achieved under optimum setting with a fiber weight of 15.2%, extension of fiber length with 15.3 mm and NaOH treated fiber of 4.6%. One of the finest biocomposite samples before impact experiments shown in Fig.1a and Fig. 1b reveals a sample after impact as it reflects an impact power of 2.63 Joules.

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**Table 2. Experimental and predicted impact strengths of biocomposites**

| Run Order | Fiber Weight (%) | Fiber Length (mm) | Fiber Treated NaOH (%) | Impact ( J ) |
|---|---|---|---|---|
| 1 | 20 | 10 | 3 | 1.80 |
| 2 | 15 | 15 | 5 | 2.60 |
| 3 | 20 | 20 | 7 | 1.80 |
| 4 | 15 | 15 | 5 | 2.60 |
| 5 | 10 | 20 | 3 | 2.20 |
| 6 | 10 | 10 | 7 | 1.20 |
| 7 | 15 | 15 | 1 | 2.02 |
| 8 | 15 | 25 | 5 | 2.10 |
| 9 | 25 | 15 | 5 | 1.84 |
| 10 | 5 | 15 | 5 | 1.50 |
| 11 | 15 | 15 | 9 | 1.60 |
| 12 | 15 | 5 | 5 | 1.40 |
| 13 | 15 | 15 | 5 | 2.50 |
| 14 | 15 | 15 | 5 | 2.50 |
| 15 | 10 | 10 | 3 | 1.60 |
| 16 | 15 | 15 | 5 | 2.52 |
| 17 | 15 | 15 | 5 | 2.52 |
| 18 | 20 | 10 | 7 | 1.40 |
| 19 | 20 | 20 | 3 | 1.70 |
| 20 | 10 | 20 | 7 | 1.40 |

### 3.1. Optimization using RSM results:

Response surface methodology (RSM) is an analytical modelling technique that is useful in establishing, enhancing and optimizing the mechanism that is used to test the association between a collection of controlled experimental variables and the results observed [28]. Single response optimization of process parameters using MINITAB17 software has been carried out in the present work. Fig. 1c displays the surface response optimiser plotted from the experimental results.

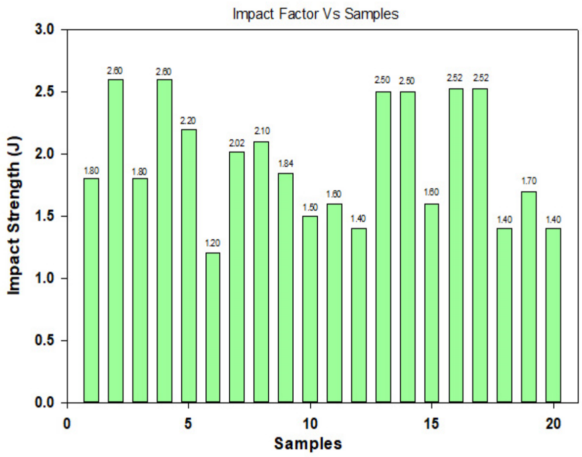


**Fig.1(c). Impact strength of biocomposites on RSM**

### 3.2 Verification of optimum conditions

Maximum impact strength was attained under optimum settings with a fiber weight of 15.2 percent, extension of fiber length with 15.3 mm and NaOH treated fiber of 4.6 percent. The measured impact intensity was 2.63 J, similar to its experimental value of 2.60 J. Fig. 1 (d) represents the image of the composite sample produced under enhanced conditions.

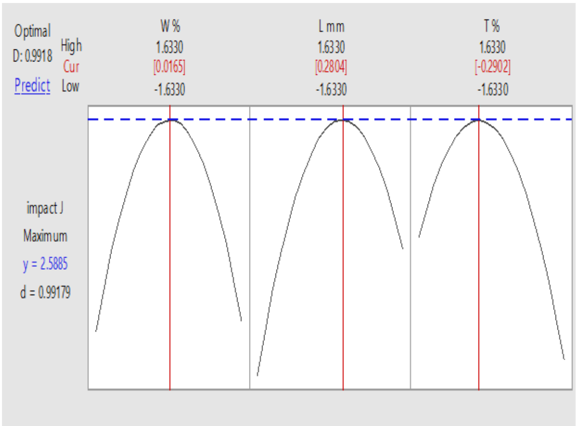


**Fig.1 (d). Response optimizer of biocomposite material in weight, length, treated banana fiber respectively.**

**Table 3. Conformation test on impact strength of Biocomposite:**

| S.No | Mechanical properties | Fiber Weight (%) | Fiber Length (mm) | Fiber Treated NaOH (%) | Impact Values (J) | Error (% ) |
|---|---|---|---|---|---|---|
| 1 | Impact strength of experimental value | 15 | 15 | 5 | 2.60 | 0.3 |
| 2 | Impact strength of predicted value | 15.2 | 15.3 | 4.6 | 2.63 | |

Table 3 displays the error value of the experimental impact strength and the impact strength of the expected values as 0.3 percent, which Specifies that all of the predicted values are similar to the experimental setup. The findings showed a good agreement between the experimental effect power and the expected values.

In one study, it was concluded that the NaOH treated bagasses fiber cardanol composites showed an increasing trend with an increase in fiber content. Thus the increase in impact strength indicates the fiber contribution. Higher impact force demonstrates the ability of the composites to absorb energy. This is due to a strong interfacial bond between the fiber and the matrix [29]. In another case, it has also influenced the nature of the fiber and the polymer [30].

## III. CONCLUSION

Using RSM through experimental design enabled the determination of optimum processing conditions for biocomposite impact strength. The result of fiber loading, fiber length, and alkaline thermoset treated components on banana fiber reinforced thermosetting the central composite concept, was evaluated. In this analysis a model of interaction was used to understand and match 3 variables with 5 rates. The full impact strength was reached with optimum fiber weight condition of 15.2% 15.3 mm fiber length and 4.6% NaOH fiber treated. The predicted impact strength was 2.63 J, Near to the derived value of 2.60 J. As a result there was a strong association between the experimental impact strength and the predicted values.

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## AUTHORS PROFILE

**Er. A. Parre** M.E,MBA,(Ph.D) Instructor special grade in the Department of Mechanical Engineering, Annamalai University, Tamilnadu, India since 2003. He is having sixteen years of Lab teaching and five years of research experience. He secured his B.E., degree in 2001, MBA (Human Resource Management) in 2006, M.E., (Thermal Engineering) in 2010, from Annamalai University, Tamil Nadu, India. He is currently working in the area of Biocomposite and Materials as a part of his Ph.D work and presented two papers in International conferences with one paper published in Elsevier.

**Dr. B. Karthikeyan** is working as Professor of Mechanical Engineering in the Annamalai University, Tamilnadu, India. He is a faculty in Mechanical Engineering with twenty seven years of teaching and research experience. He holds Doctoral degree from Annamalai University and published more than fifty publications in refereed journals and conferences. He is currently working in areas of Composites, Biocomposites and Energy.

**Dr. A. Balaji** received his B.E., and M.E., degree from Annamalai University, Annamalai Nagar, India in 2002 & 2005. He got his Ph. D. from Annamalai University in 2018. He currently works as Associate Professor in Department of Mechanical Engineering at A. V. C. College of Engineering, Mayiladuthurai, India. He has published 24 papers in conferences and refereed journals. His research areas of interest are Bio & polymer Composites, Renewable Energy and IC Engine. Act as a reviewer in various peer review journal. He is a life member in IIPE and ISTE.

**Dr. Sudhakar. P** Associate Professor of Chemical Engineering. Graduated BE Chemical in 2001, M.Tech Food Processing Technology in 2007,Ph.D (Chemical) in 2013, since 2002 working in Department of Chemical Engineering, Annamalai University (seventeen and half years). So for published 6 international journals, Attended more than 20 conferences. In 19th to 20th September 2019 Trincomalee campus, Eastern University, Srilanka 4th Annual research conference " Sustainability through Transformation" my paper " Statistical screenings of medium components for the production of Chitinase using agro industrial residues" was selected as the best presenter of the conference. In many conferences acted as chair person in Technical sessions.

**Dr. R. Udhayasankar** obtained his Bachelor's degree in Mechanical (Manufacturing) from Annamalai university in 2006. Then he obtained his Master's degree in manufacturing engineering in 2011 and received PhD in Mechanical Engineering in Annamalai University in 2019. His areas of academic research include polymer biocomposites. He has more than 12 years of experience in teaching different subjects of mechanical and manufacturing engineering discipline. He has published /presented a large number of technical papers. Currently, he is a Assistant professor at the Faculty of mechanical Engineering, Annamalai University.