# INVESTIGATION OF MECHANICAL PROPERTIES ON JUTE FIBER-EPOXY REINFORCED COMPOSITES USING TAGUCHI METHOD

**P.GOPINATH[1] A.MOHANRAJ[2] P.SURESH[3]**

[1,2]Assistant Professor, Department of Mechanical Engineering, KSR Institute for Engineering and Technology, Tiruchengode. Email: gopinath.palani@gmail.com
[3] Professor, Department of Mechanical Engineering, Muthayammal Engineering College, Rasipuram. Email:suresh.me2004@gmail.com.

**Abstract**

Natural fibers are low cost, light weight and it seems that environmentally superior to the synthetic fibers in composites. In this present investigation focus on mechanical properties of natural jute fiber composites. Jute fiber composites are used as natural fiber reinforcement and epoxy resin as matrix. In order to get better interfacial bonding between fiber and matrix by the extracted jute fibers from jute husk are chemically treated. The prepared composites are randomly orientated fibers with different proportions of fibers and matrix ratio. The impact and hardness tests are performed and the results are reported. The results showed that the fiber volume fraction and composite post curing time increases with the mechanical properties of the composite increased. In addition Taguchi analysis is performed for optimization of single response problem.

**Keywords*:*** Natural jute fibers, Impact test, Hardness test, Taguchi Method.

## 1. INTRODUCTION

The development of natural fiber composites concentration was increased to the fast growth and used as reinforcement. Natural composite fibers are an alternate source to synthetic fibers as reinforcement for polymeric materials for the manufacturer of renewable and environmentally friendly composites. The waste plastics have caused unbearable stress to environment in recent years. Environmental knowledge, new rules and legislations were forcing industries to search for new materials which are more environmentally welcoming. Natural plant fibers from agricultural crops were renewable materials which had potential for creating green products and replacing synthetic materials which were currently being used such as glass fiber, carbon fiber and plastic fibers. The combinations of bio-fiber and bio-polymer could be the products of fully biodegradable composite materials [1]. Among others, natural fibers (e.g., flax, jute or sisal) reinforced materials has important meaning for reduction of density in automobile components owing to its high stiffness and strength. The several attempts were conducted by the researchers to utilize natural fibers in the production of composite materials. They have been found that the natural fiber-reinforced composites have better electrical resistance, chemical resistance, good thermal and acoustic insulating properties the increasing attention in introducing degradable, renewable, and inexpensive reinforcement materials which have been environment friendly. The low cost, less weight and density makes the natural fibers an attractive alternative. Among all the natural fiber-reinforcing materials, jute is the most useful, inexpensive and commercially available fibers. In the literature it has been documented that the jute fibers can be used as reinforcement in thermoplastics e.g., polyethylene, polyvinyl chloride and polypropylene and thermo sets like unsaturated polyester and epoxy resin [2]. Presence of OH groups in the structure of jute fibers make them susceptible toward moisture absorption from the surroundings. This hydrophilic nature lowers the compatibility and wetting behavior with the hydrophilic polymer matrix [3]. Jute fiber is renewable, versatile, nonabrasive, biodegradable, and compatible [4]. In order to develop composite made from natural fibers with enhanced strength, stiffness, durability and reliability, it is necessary to study the mechanical behavior of natural fiber composites. The mechanical properties of a natural fiber reinforced composite depend on many parameters, such as fiber strength, modulus, fiber length, orientation, and fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber where by maximum utilization of the fiber strength in the composite can be achieved [5-12]. Most research reviewed indicated the effect of alkali treatment in improving fiber strength, fiber matrix adhesion and the performance of the natural fiber composites. The present work highlighting on the effect of alkali treatment on mechanical behavior of jute fibers reinforced epoxy composites. Finally, the effects of fiber volume fraction and composite curing time on mechanical properties of jute fibers reinforced epoxy composites are studied.

## 2. MATERIALS AND METHODS

### 2.1 MATERIALS

The composites were produced using chemically treated and untreated jute fiber and polypropylene pellets. The treated and untreated jute fibers were cut into various lengths of 1, 2 and 4 mm. For all lengths of fibers, composites were developed with 5, 10 and 15% (by volume) of jute.

### 2.2 METHODS

#### 2.2.1 Fiber Extraction

Selected handmade jute fibers were used as the composites. Dried jute husk was soaked in deionizer water for about five days. The soaking process loosens the fibers and can be extracted out easily. Finally, the fibers were washed again with deionizer water and dried at room temperature for about 15 days. The dried fibers are designated as untreated fibers.

#### 2.2.2 Alkali Treatment

First, the jute fibers were treated in a solution of 10% Potassium Hydroxide, where the total volume of solution. The fibers were kept in this alkaline solution for 36 hours at a temperature of 30°C; it was then thoroughly washed in running water then neutralized with a 2% acetic acid solution. Lastly, it was again washed in running water to remove the last traces of acid sticking to it, so that the pH of the fibers is approximately seven neutral. Then, they were dried at room temperature for 48 hours to get alkali treated fibers.

### 2.2.3 Preparation of Composites

Fiber configuration and volume fraction are two important factors that influence the properties of the composite. In this work, the randomly distributed fibers are reinforced with epoxy resin in two different volume proportions (50 vol. %, and 60 vol. %) to prepare the composites. First, the mould is polished and then a mould-releasing agent polyvinyl alcohol applied on the surface is used to facilitate easy removal of the composite from the mold after curing. The low temperature curing epoxy resin LY556 and corresponding hardener (HY951) are mixed in a ratio of 10:1 by volume as recommended. The mixing is done thoroughly before the mixture filled into the mould of 300 x 300 x 50 mm size and pressed in a hydraulic press at the room temperature and a pressure of 0.5MPa for 30 minutes is applied before it is removed from the mould. Then, this cast is post cured in the laboratory at standard atmosphere for different hours to study the effect of post curing time on mechanical properties.

### 2.2.4 Characterization

The prepared composite boards were post cured for 360 hours, 720 hours and 1080 hours at standard laboratory atmosphere prior to preparing specimens and performing mechanical tests. The appropriate ASTM standards were followed while preparing the specimens for test. At least five replicate specimens were tested and the results were presented as an average of tested specimens. The tests were conducted at a laboratory atmosphere of 27ºC and 46% relative humidity. Impact tests on specimens were performed by using both Charpy and Izod methods as per ASTM D 256. According to ASTM D 785 standard for composites, the specimens were prepared for Rockwell-B hardness test. The specimen size is of 25mm diameter and a length of 20mm. The hardness properties of the composites along and across the fibers are carried out.

## 3. RESULTS AND DISCUSSION

The investigation of mechanical properties of composites is one of the most important techniques in studying the behavior of composite materials. Mechanical properties of fiber-reinforced composites depend on the nature of matrix material, distribution and orientation of the reinforcing fibers, the nature of the fiber-matrix interfaces in inter phase region. A small change in the physical nature of the fiber for a given matrix may result in important changes in the overall mechanical properties of composites. It is well known fact that, different degrees of reinforcement effects are achieved by the addition of hydrophilic fibers to different polymers. This may be due to the different adhesion strength between matrix and fibers.

### 3.1 Mechanical properties

### 3.1.1 Impact properties

Impact resistance is the ability of a material to resist breaking under a shock loading or the ability to resist the fracture under stress applied at high speed. Impact behavior is one of the most widely specified mechanical properties of the engineering materials. Both Izod and Charpy methods perform impact tests on jute fibers reinforced with epoxy composite specimens as per

ASTM-D256-90. The variations of impact strength with respect to fiber volume fraction and composite curing time as shown in Figures 1 and 2 for Charpy and Izod method of impact test respectively. These Figures indicate that the impact strength of composites increases with curing time at a greater degree when compared to fiber volume in the composite. The important aspect regarding impact strength of the jute composite is that the composite curing time increases the alkali treated composites becomes more brittle than the untreated fibers.

**(BEFORE GRAPH INSERT TABLE CONSIST OF READINGS IN THE GRAPH – APPLY TO ALL GRAPH)**

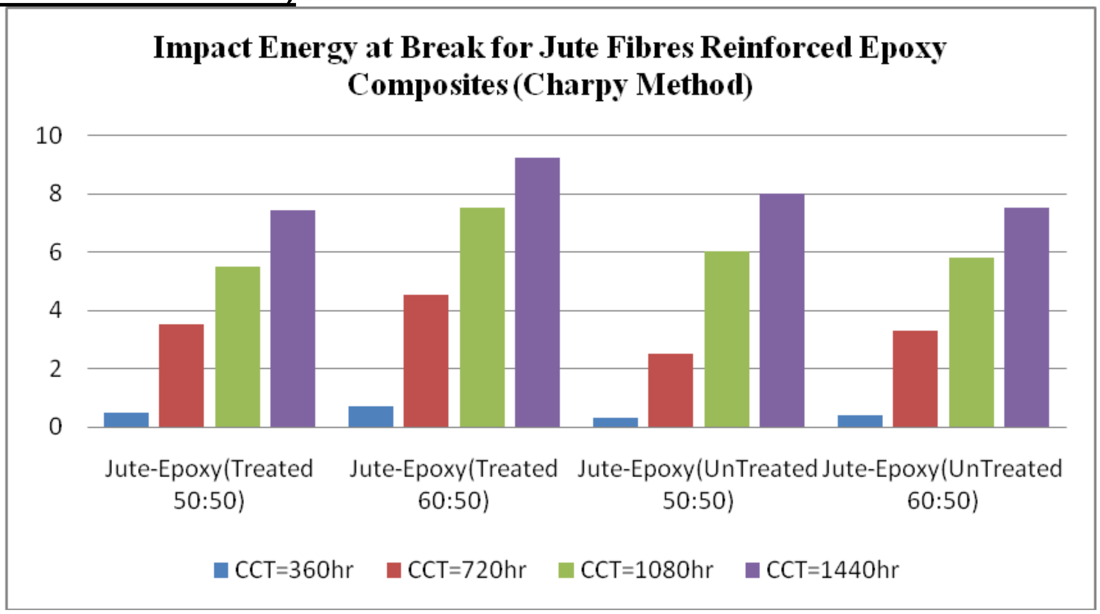


Figure 1 Shows impact energy of composites in charpy impact test

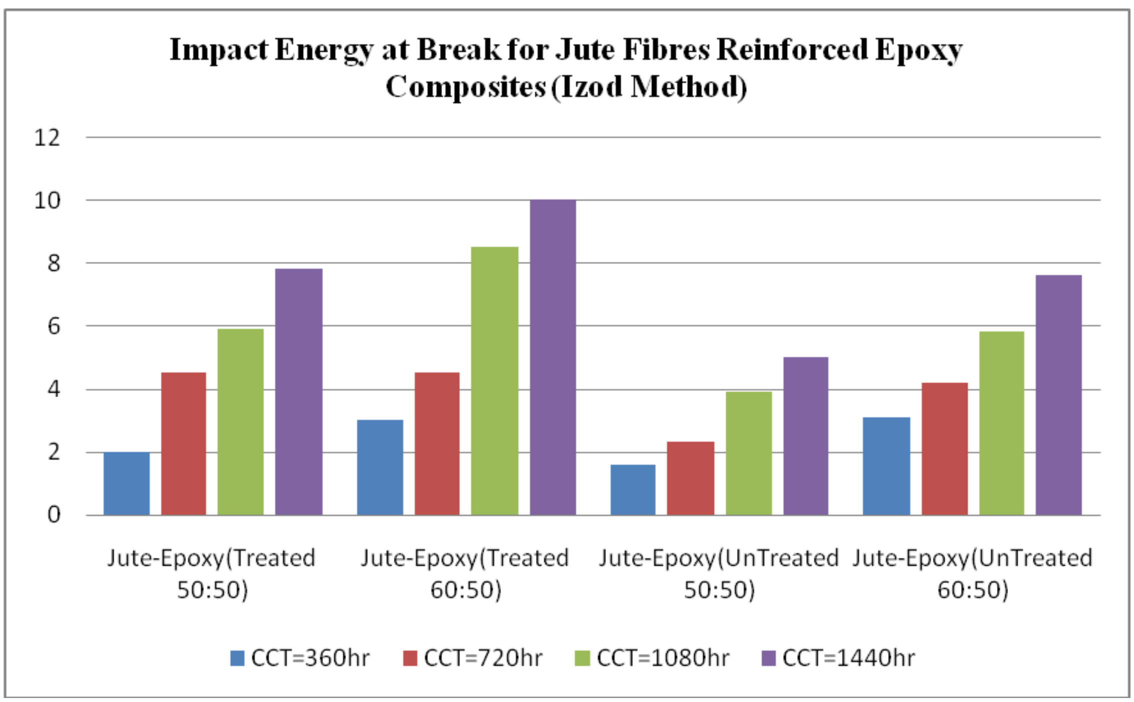


Figure 2 Shows impact energy of composites in Izod impact test

### 3.1.2 Hardness properties

According to ASTM D 785 standards for composites the specimens were prepared for Rockwell-B hardness test. The diameter of the specimen is 25mm diameter and a length of 20mm. Fiber configuration and volume fraction are two important factors that affect the properties of the composite. In this test, the configuration is limited to unidirectional and continuous fibers equal to the length of the specimen. The hardness of the composites is studied by applying indentation load normal to fibers diameter and normal to fiber length. The influence of fiber loading and post curing time on Rockwell hardness is illustrated in Figure 3 and Figure 4. The hardness of the composite is increases with increase of the module of composites because hardness is a function of the relative fiber volume and modulus.

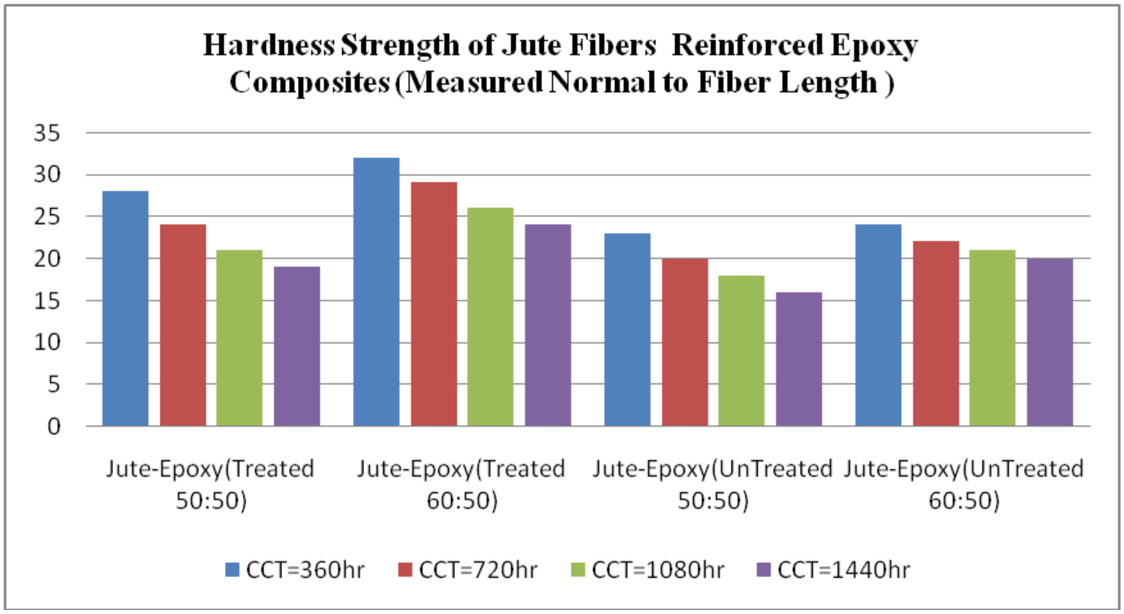


Figure 3 shows the hardness strength of composites (Measured normal to fiber length)

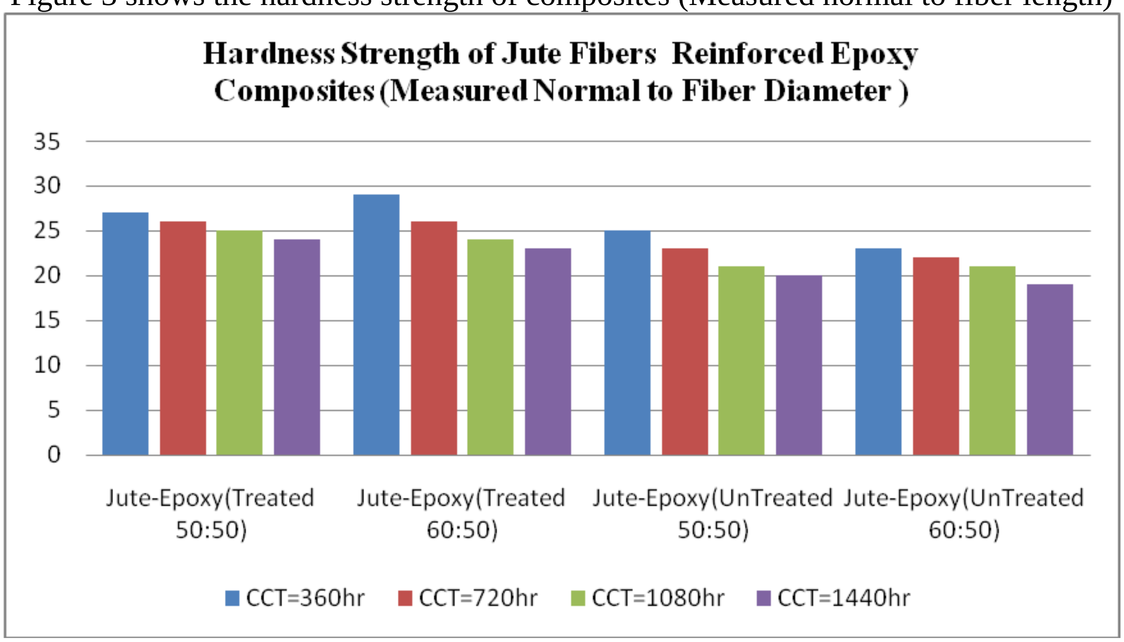


Figure 4 shows the hardness strength of composites (Measured normal to fiber diameter)

### 3.2 Taguchi Analysis for Jute Fibres Reinforced Epoxy Composites

Taguchi method is applied for solving single response optimization problem with objective of maximization impact energy (IE) and hardness of the jute fiber reinforcement composite using larger the better category. The factor and levels are given in Table1. The experimental results and S/N ratio for jute fiber reinforcement composite are shown in Table 2. The Taguchi analysis for impact energy (Charpy Test), impact energy (Izod test) and hardness of the fiber (measured normal to length and diameter) is given Table 3. Taguchi analysis for impact energy of charpy test (IE-C) is given Table 3, it clearly shows that the delta value for CCT is 24.90 and treatment is 3.90. It can be seen that the CCT is strongest effect on IE-C. Optimal setting parameter for maximization of IE-C is treatment set as Jute-Epoxy (Treated 60:50) and CCT set to as 1440hr.

Table 1 Factor and Levels

| Parameter | Level 1 | Level 2 | Level 3 | Level 4 |
|---|---|---|---|---|
| Treatment (A) | Jute-Epoxy(Treated 50:50) | Jute-Epoxy(Treated 60:50) | Jute-Epoxy(Untreated 50:50) | Jute-Epoxy(Untreated 60:50) |
| CCT (B) (hr) | 360 | 720 | 1080 | 1440 |

Table 2 Experimental Details and S/N ration for all response

| S.No. | A | B | IE-C | SNRA1 | IE-I | SNRA2 | H-NL | SNRA3 | H-ND | SNRA4 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 0.5 | -6.021 | 2 | 6.021 | 28 | 28.943 | 27 | 28.627 |
| 2 | 1 | 2 | 3.5 | 10.881 | 4.5 | 13.064 | 24 | 27.604 | 26 | 28.300 |
| 3 | 1 | 3 | 5.5 | 14.807 | 5.9 | 15.417 | 21 | 26.444 | 25 | 27.959 |
| 4 | 1 | 4 | 7.4 | 17.385 | 7.8 | 17.842 | 19 | 25.575 | 24 | 27.604 |
| 5 | 2 | 1 | 0.7 | -3.098 | 3 | 9.542 | 32 | 30.103 | 29 | 29.248 |
| 6 | 2 | 2 | 4.5 | 13.064 | 4.5 | 13.064 | 29 | 29.248 | 26 | 28.300 |
| 7 | 2 | 3 | 7.5 | 17.501 | 8.5 | 18.588 | 26 | 28.300 | 24 | 27.604 |
| 8 | 2 | 4 | 9.2 | 19.276 | 10 | 20.000 | 24 | 27.604 | 23 | 27.235 |
| 9 | 3 | 1 | 0.3 | -10.458 | 1.6 | 4.082 | 23 | 27.235 | 25 | 27.959 |
| 10 | 3 | 2 | 2.5 | 7.959 | 2.3 | 7.235 | 20 | 26.021 | 23 | 27.235 |
| 11 | 3 | 3 | 6 | 15.563 | 3.9 | 11.821 | 18 | 25.106 | 21 | 26.444 |
| 12 | 3 | 4 | 8 | 18.062 | 5 | 13.979 | 16 | 24.082 | 20 | 26.021 |
| 13 | 4 | 1 | 0.4 | -7.959 | 3.1 | 9.827 | 24 | 27.604 | 23 | 27.235 |
| 14 | 4 | 2 | 3.3 | 10.370 | 4.2 | 12.465 | 22 | 26.849 | 22 | 26.849 |
| 15 | 4 | 3 | 5.8 | 15.269 | 5.8 | 15.269 | 21 | 26.444 | 21 | 26.444 |
| 16 | 4 | 4 | 7.5 | 17.501 | 7.6 | 17.616 | 20 | 26.021 | 19 | 25.575 |

Taguchi analysis for impact energy of Izod test (IE-I) is given Table 3, it clearly shows that the delta value for CCT is 9.99 and treatment is 6.09. It can be seen that the CCT is strongest effect on IE-I. Optimal setting parameter for maximization of IE-I is treatment set as Jute-Epoxy (Treated 60:50) and CCT set to as 1440hr. Taguchi analysis for hardness strength of composites (Measured normal to fiber length) (H-NL) is given Table 3; it clearly shows that the delta value for treatment is 3.20 and CCT is 2.65. It can be seen that the treatment is strongest effect on H-NL. Optimal setting parameter for maximization of H-NL is treatment set as Jute-Epoxy (Treated 60:50) and CCT set to as 360hr. Taguchi analysis for hardness strength of composites (Measured normal to fiber diameter) (H-ND) is given Table 3; it clearly shows that the delta value for CCT is 1.66 and treatment is 1.60. It can be seen that the CCT is strongest effect on H-ND. Optimal setting parameter for maximization of H-ND is treatment set as Jute-Epoxy (Treated 50:50) and CCT set to as 360hr.

Table 3 Taguchi analysis for all the response

| Level | IE-C | | IE-I | | H-NL | | H-ND | |
|---|---|---|---|---|---|---|---|---|
| | A | B | A | B | A | B | A | B |
| 1 | 9.263 | -6.884 | 13.086 | 7.368 | 27.14 | **28.47** | **28.12** | **28.27** |
| 2 | **11.686** | 10.569 | **15.299** | 11.457 | **28.81** | 27.43 | 28.10 | 27.67 |
| 3 | 7.782 | 15.785 | 9.279 | 15.274 | 25.61 | 26.57 | 26.91 | 27.11 |
| 4 | 8.795 | **18.056** | 13.794 | **17.359** | 26.73 | 25.82 | 26.53 | 26.61 |
| Delta | 3.904 | 24.940 | 6.019 | 9.991 | 3.20 | 2.65 | 1.60 | 1.66 |
| Rank | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 |

## 4. CONCLUSION

In this present investigation focus on mechanical properties of natural jute fiber composites and resulted in the following major conclusions.

- The development of fiber reinforced composites properties through fiber surface alteration. The mechanical properties of chemically treated jute fibers composites are better results than the natural untreated fibers.
- The strength of the jute fibers composites was increased with increase in volume fraction of fiber in the composite and post composite curing time. This is a very rare phenomenon which is not observed in many of the natural fiber composites.
- Hence, based on the availability, cheaper and good strength of jute fiber composites investigated in the present research work. The composite can certainly be considered as a very promising material to fabrication of lightweight materials used in automobile body building, office furniture, packaging industry, partition panels, etc. compared to conventional wood based plywood or particle boards.
- Optimal setting parameter for maximization of IE-C and IE-I is treatment set as Jute-Epoxy (Treated 60:50) and CCT set to as 1440hr.

- Optimal setting parameter for maximization of H-NL is treatment set as Jute-Epoxy (Treated 60:50) and CCT set to as 360hr. Optimal setting parameter for maximization of H-ND is treatment set as Jute-Epoxy (Treated 50:50) and CCT set to as 360hr.

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