Mechanical Properties of Epoxy Resin Matrix Composites Reinforced with Jute Fiber, Coconut Coir and Human Hair

Mrinal Kanti Manik, Radheshyam H. Gajghat, Anooj Joseph

Abstract: ***Presently scientist and engineers are looking for the new generation of materials that are easily biodegradable as well as maintain sustainability to protect our environment. Concept of smart materials and recycling of the waste materials are the key considerations at the face of material scientist. Nowadays natural fiber composites are preferred over conventional synthetic fiber composites in many industrial applications. In this study jute fiber, human hair and coconut coir reinforced composites bonded with epoxy resin were prepared using hand lay-up technique to compare their mechanical properties. For this purpose, an open type wooden mould was used. This study reveal that the jute fiber reinforced composite exhibit better toughness, tensile and shear strength than human hair and coconut coir composites. Also it shows that human hair composite has better hardness property than jute fiber and coconut coir composites. Overall jute fiber and human hair composites show far better mechanical properties than coconut coir composite.***

Keywords: ***Jute fiber, Human hair, Coconut coir, Natural fibers, Epoxy resin, Composites.***

I. INTRODUCTION

Composite is a product made up of two or more different types of materials that are combined together to form something totally different than that of the original constituents. Structure of composite material is shown in figure 1 consist of outer cover generally called as matrix, mostly it protect the inner strengthening part of the composite called as fiber. Natural composites exist in both animals and plants. Wood is one of the best examples of natural composite – it is made from long cellulose fibers and much weaker matrix substance called lignin. Cellulose is also found in cotton, but without the lignin matrix, which cannot be bound together for strengthening. The bone in the human body is also a good example of natural composite.

Composites can be natural or synthetic. In the above example, wood is a natural composite whereas plywood is made of sawdust and ply, a man-made composite that combines natural and synthetic materials. Figure 2 shows an example of preparation of man-made composite.

Revised Manuscript Received on October 15, 2019

Dr. Mrinal Kanti Manik, Professor, Department of Mechanical Engineering, Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India

Radheshyam H. Gajghat*, Associate Professor, Department of Mechanical Engineering, Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India

Anooj Joseph, PG Student, Department of Mechanical Engineering, Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India

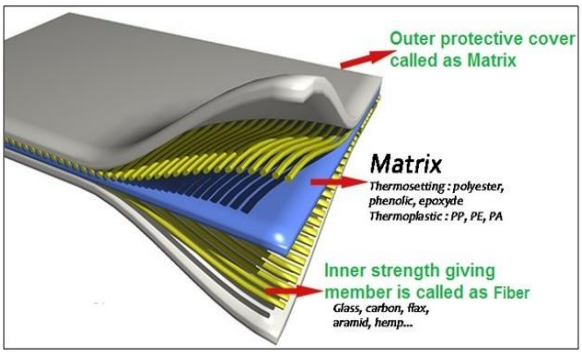

Figure 1 Structure of composite material

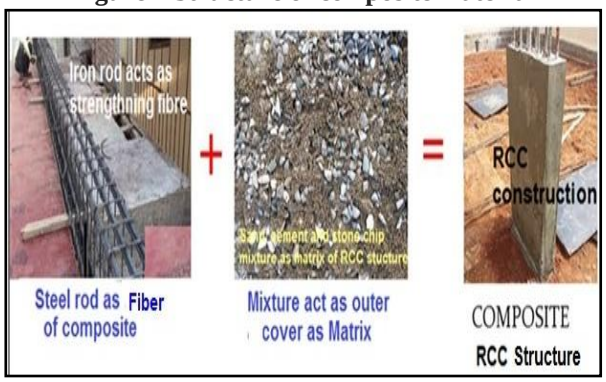

Figure 2 Preparation of man-made composite

In last few years, due to an environmental awareness the attention has been given to use the natural fiber composites in many industrial applications. Ecological balance and global warming have created a substantial interest in using natural materials to manufacture green products and reduce carbon dioxide emissions by all possible ways [1]. The environmental protection regulation act strictly focuses to find out environment friendly composite materials. At present it was observed that plant fibers are very eye-catching for composite materials for the following characteristic such as biodegradability, availability in abundance, renewability, high specific strength, low cost, and many more. However, there are few weaknesses such as incompatibility with some polymer matrix, the tendency to form aggregates during processing, and poor resistance to moisture absorption which reduce considerably the mechanical properties of the natural fibers reinforced composite materials [2]. Among all the natural fibers, jute fiber shows its good mechanical properties compared with other natural fibers, such as sisal, coir, and ramie [2]. Several authors have studied the jute fiber composites from different aspects, for example, mechanical properties [3], physical properties [4],

the effect of fiber treatments on mechanical properties [5], and dynamic mechanical properties [6].

Although natural fibers possess comparatively good mechanical properties, their poor wet capacity, inbuilt variability, and poor adhesion with many polymer matrices lead to composites whose mechanical properties are low as compared to synthetic fiber composites. However these problems can be solved by a proper combination of reinforcements [7] or by physical and chemical treatments of the fibers [8].

The manufacturing processes of various natural composites are very unique for different fibers. Hand lay-up technique is the oldest and common technique for manufacturing fibers reinforced composites. This is due to the good mechanical properties particularly the fatigue properties which can be obtained by this method [9].

In this research the used jute bags were recycled by mincing them and mixed with short jute slivers to produce jute mats. These jute mats were produced by applying slightly compressive load on short jute fibers to be packed together in the form of mat and then needle punched. The other natural fibers used are coconut coir and human hair which are cheap and easily available in the local market.

According to the review of the literature, there no research was reported about the fabrication of human hair reinforced composites and only the few reported the work with coconut coir composites by the use of hand lay-up method. In this study all these three different types of natural degradable fibers are used for making composites. The various mechanical properties of these composites are found out and compared with each other. This work will help to increase the use of these composites in future domestic and industrial applications.

II. MATERIAL PREPARATION AND TESTING

Nowadays, researchers are working in the field of materials that provides sustainability and environmental protection. Most emphasize is given to look for environmental friendly, biodegradable and sustainable natural fibers that can replace synthetic fiber composites. Here the authors look forward to find out the mechanical behavior of an epoxy resin with coconut coir, jute fiber and human hair composites preparing by using hand lay-up technique.

A. Preparation of Composites

Initially three different natural fibers, such as jute fiber, human hair and coconut coir were collected from local area and these fibers were made fine by manual segregation. Fibers were arranged in the form of layers so that these layers can be placed one by one with the layers of resin. All three types of fibers were arranged and kept separately for making their own layered composites. Here, three different types of natural fibers such as coconut coir, human hair and jute fiber are shown in figure 3.

Figure 3 Coconut coir, human hair and jute fiber

Figure 4 shows how these fibers were cleaned and aligned in the form of layers to make the composites. The weight percentage of fiber to resin was maintained to 7:3. The weighted resin was applied over the fiber putting the fiber layer by layer.

Figure 4 Cleaning and aligning of jute fiber

After applying resin over one layer of fiber a soft roller was repeatedly rolled to make surface even for next layer, in this way repeated layers of composite was prepared. After the preparation of composite into the mold a dead weight of 2.5 kg was placed over it to remove trapped air/gases and to get a uniform solid structure. The detail of application of resin layer by layer along with natural fiber is shown in figure 5.

Figure 5 Preparation of composites by using hand lay-up technique

Figure 6 shows a flow chart showing the steps of preparation of natural fiber composites.

The composites of three different natural fibers were prepared and shown in figure 7. All these three composites were prepared maintaining fiber to resin weight ratio of 7:3 so that the mechanical properties of these composites can be compared with each other. Prepared composites of these three materials were weighted and their weight was found same for all of these materials as 77 ± 0.3 gram. Samples for different tests such as Izod and Charpy impact tests, Rockwell hardness test, Tensile and Shear strength test were prepared as per the standards followed in material science. All the test samples were taken from the prepared composites as shown in figure 8. Each and every test was out as per the standard procedure prescribed in the material testing laboratory.

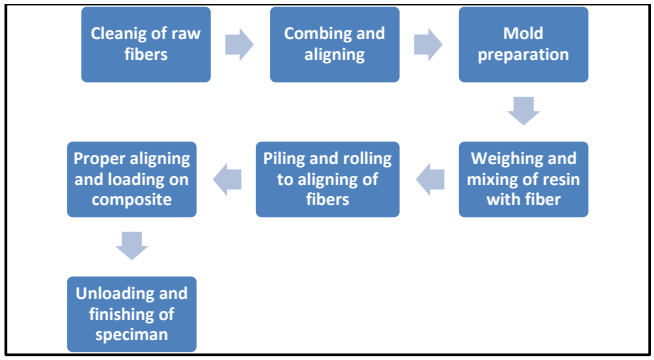

Figure 6 Flow chart shows the steps of preparation for natural composites

Figure 7 Composites made from coconut coir, human hair and jute fiber with epoxy resin

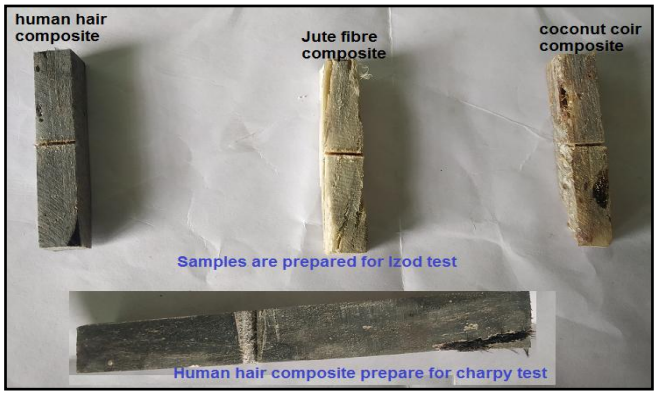

Figure 8 Test samples for Izod and Charpy test

B. Toughness Test

The samples for Izod and Charpy tests were prepared from the natural fiber composites as per above procedure and the size of the samples were taken as **75 x 10 x 10** for Izod test and **125 x 10 x 10** for Charpy test. Also a cut mark at the defined distance was made to perform the experiment as per material testing standards. Charpy and Izod test procedure and details is shown in figure 9 (a, b & c). Before conducting the Izod and Charpy test the machine was operated repeatedly and the error in the initial reading was noted down. There after the sample was positioned as per procedure and the test was carried out. The reading of the test result was noted down. Just after the Izod test, the set up of the impact test machine was changed to conduct the Charpy test. Set up with knocking hammer was also altered to conduct the test as per norms and again the error was found out to govern the accuracy of the result.

Table 1 Hardness and Toughness Test results

Composites	Rockwell Hardness No.	Charpy No. (Jule)	Izod No. (Jule)
Coconut coir	25	0.5	0.2
Jute fiber	40	3	2
Human hair	43	2	1

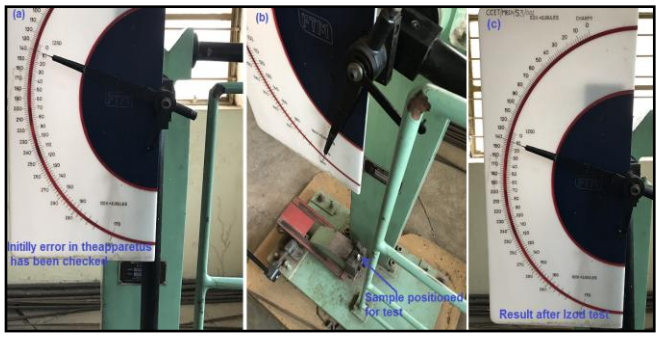

Figure 9 (a) Error in Izod reading (b) The sample for Izod test is positioned and (c) Reading in the dial chart after test

C. Shear Strength Test

All three samples of coconut coir, human hair and jute fiber composites were made to conduct shear test on Universal Testing Machine. The apparatus was arranged in such way that double shear could be happened on the sample under test. The gauge diameter was measured with the help of vernier caliper and based on the test result shear stresses were calculated for all the samples of different fiber composites. The detail of test procedure is shown in figure 10 (a, b & c).

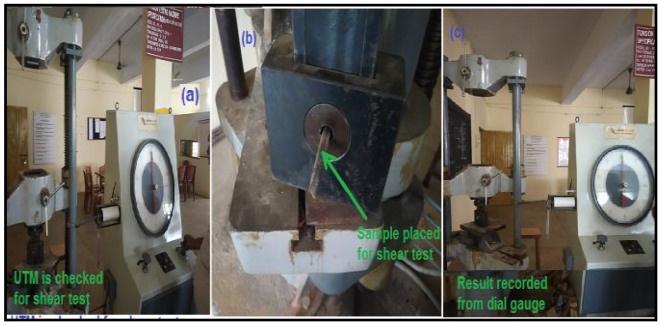

Figure 10 (a) Checks the machine error for shear force, (b) The sample for shear test was positioned and (c) Reading of shear force in the dial chart after test

All the test results are tabulated in table 1 and 2 after conducting all the tests. The gauge diameter was specified to find out the tensile as well as shear stress for the different fiber composites.

Table 2 Tensile and Shear Test results

Composites	Gauge Dia. (mm)	Tensile Stress (MPa)	Gauge Dia. (mm)	Shear Stress (MPa)
Coconut coir	11.8	129	7.8	83
Jute fiber	11.8	419	7.8	239
Human hair	11.8	406	7.8	219

D. Tensile Strength Test

The tensile test for all three composites of different fibers was performed with the help of UTM in material testing laboratory. Samples as shown in figure 11 (a) were initially prepared to study the tensile test. Samples were positioned by a specially designed mounting in between the upper and lower cross bar of UTM as shown in the figure 11 (b).

Figure 11 (a) Three samples for tensile test (b) The sample is positioned for tensile test

E. Hardness Test

Hardness of these three samples was found out on Rockwell hardness test apparatus with the load of 60N. Figure 12 (a, b & c) shows the hardness testing of three different fiber composites on Rockwell hardness test apparatus. The results were recorded from the dial gauge as shown below.

Figure 12 Rockwell hardness test for (a) human hair (b) jute fiber and (c) coconut coir composites

III. RESULT AND DISCUSSION

Result of the Rockwell hardness test is plotted in figure 13 and the test result show that Rockwell hardness of coconut coir, jute fiber and human hair composites are 25, 40 and 43 respectively. Hardness of coconut coir composite is lower than jute and human hair composites whereas hardness of jute fiber composite lies between coconut coir and human hair composites.

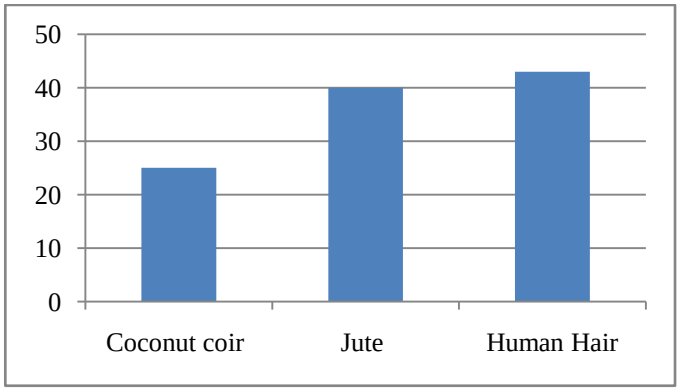

Figure 13 Rockwell Hardness Number of three different composites

To find toughness/energy absorbing property of composites, both Izod and Charpy test was carried out by preparing specimen from all three different fiber composites and the test result were plotted in the figure 14 and 15 respectively. Averages of five different tests were tabulated in table 1 for Izod and Charpy test respectively.

The result of both Izod and Charpy tests visibly differentiate the energy absorbing capacity of all three composites. Jute fiber composite prominently placed at the top and coconut coir composite placed at the bottom of the energy absorbing capacity. Test results confirm that Izod numbers for coconut coir, human hair and jute fiber composites are 0.2, 1 and 2 Joule respectively. Similarly in case of Charpy test, it was found as 0.5, 2 and 3 Joule respectively.

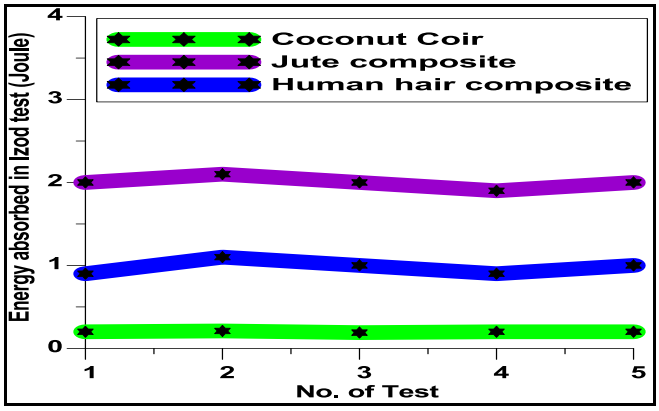

Figure 14 Energy absorbed in Izod test

Result based on the tensile test is shown in figure 16 and the result represents that tensile strength of coconut coir composite is very low as compared to jute fiber and human hair composites. A very little difference is observed between the tensile strength of jute fiber and human hair composites. In the tensile test the needle restricted at 129, 419 and 406 MPa for coconut coir, jute fiber and human hair composites respectively. It indicates the stress bearing capacity of coconut coir composite is very less as compared to other two composites.

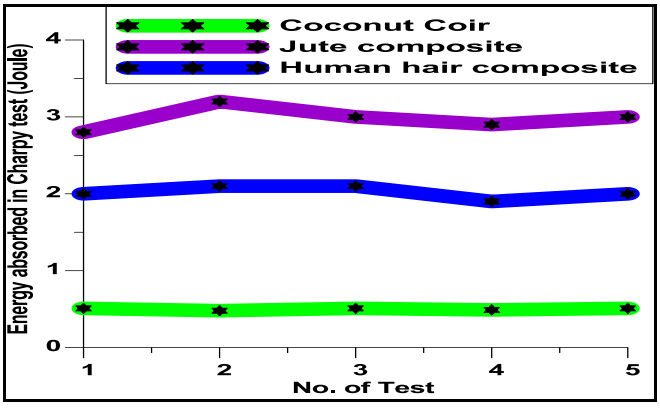

Figure 15 Energy absorbed in Charpy test

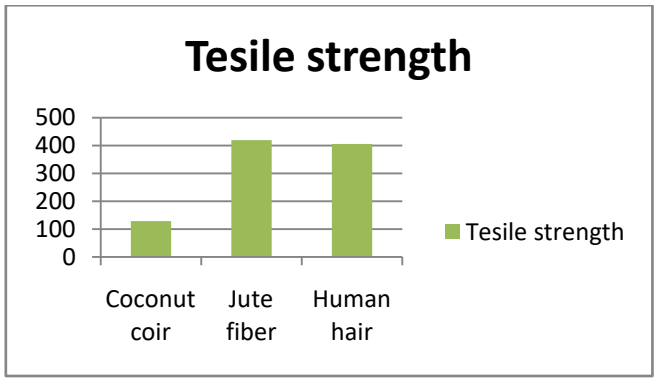

Figure 16 Tensile Test of three different composites

Result based on the shear test is showing in figure 17 and the result represent that the shear strength of coconut coir is also remarkably less as compared to jute and human hair composites. There is no distinguishable variation seen between the shear stress result of jute fiber and human hair composites. The readings of shear test are 83, 231 and 219 MPa for coconut coir, jute fiber and human hair composites respectively. It indicates that coconut coir composite will fail very early with respect to other two composites in shear test.

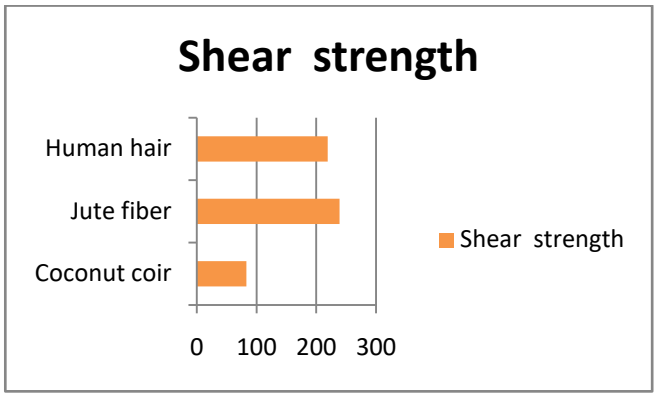

Figure 17 Shear Test of three different composites

IV. CONCLUSIONS

Natural fiber composites show significant potential for automotive industry because of instantaneous demand for light weight to strength ratio as well as environmental friendly materials. Presently natural fiber composites are mostly used for interior parts such as dashboards, door panels, seat cushions, parcel shelves and backrests whereas its exterior applications are very limited. In the present study it is found that:

- Jute fiber composite is 60% and human hair composite is 72 % harder than coconut coir composite respectively. It indicates that hardness of coconut coir composite is less than other two composites.
- In Izod test jute fiber composite shows 900 % and human hair composite shows 400 % more toughness than coconut coir composite whereas in Charpy test jute fiber composite shows 500 % and human hair composite shows 300 % more toughness than coconut coir composite.
- The result of tensile test shows that jute fiber composite is 225% and human hair composite is 215% stronger than coconut coir composite. The shearing strength of jute fiber composite is 178% and human hair composite is 164% stronger than coconut coir composite. It indicates that load bearing capacity of coconut coir composite is very less as compared to other two composites.
- The tests were conducted with same length and gauge diameter for all three specimens therefore the tensile force and shear force will be proportionate to tensile stress and shear stress respectively.
- After overall considerations of the results of the tests it can be concluded that jute fiber composite exhibit better and coconut coir composite exhibit very poor mechanical properties. Human hair composite shows mechanical properties very close to jute fiber composite.

REFERENCES

1. Pervaiz, M. and Sain, M. M., "Carbon storage potential in natural fiber composites," Resources, Conservation and Recycling, vol. 39, no. 4, pp. 325–340, 2003.
2. Mohanty, A. K., Misra, M., and Drazal, L. T., "Natural Fibers, Biopolymers, and Biocomposites," Taylor & Francis, New York, NY, USA, 2005.

3. Roe, P. J. and Ansell, M. P. , "Jute-reinforced polyester composites," Journal of Materials Science, vol. 20, no. 11, pp. 4015–4020, 1985.
4. Acha, B. A., Marcovich, N. E., and Reboredo, M. M., "Physical and mechanical characterization of jute fabric composites," Journal of Applied Polymer Science, vol. 98, no. 2, pp. 639–650, 2005.
5. Razera, I. A. T. and Frollini, E., "Composites based on jute fibers and phenolic matrices: properties of fibers and composites," Journal of Applied Polymer Science, vol. 91, no. 2, pp. 1077–1085, 2004.
6. Saha, A. K., Das, S., Bhatta, D., and Mitra, B. C., "Study of jute fiber reinforced polyester composites by dynamic mechanical analysis," Journal of Applied Polymer Science, vol. 71, no. 9, pp. 1505–1513, 1999.
7. Idicula, M., Sreekumar, P. A., Joseph, K., and Thomas, S., "Natural fiber hybrid composites-a comparison between compression molding and resin transfer molding," Polymer Composites, vol. 30, no. 10, pp. 1417–1425, 2009.
8. Ray, D., Sarkar, B. K., Rana, A. K., and Bose, N. R., "Mechanical properties of vinylester resin matrix composites reinforced with alkali-treated jute fibers," Composites Part A, vol. 32, no. 1, pp. 119–127, 2001.
9. Brøndsted, P., Andersen, S. I., and Lilholt, H., "Fatigue performance of glass/polyester laminates and the monitoring of material degradation," Mechanics of Composite Materials, vol. 32, no. 1, pp. 21–29, 1996.

AUTHORS PROFILE

Dr. Mrinal Kanti Manik is a Professor at Department of Mechanical Engineering,, Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India. He has completed his Graduation as AMIE in Mechanical Engineering from The Institution of Engineers (India), Post Graduation in Production Engineering from Motilal Nehru National Institute of Technology (MNNIT), Allahabad and PhD in Mechanical Engineering from Indian Institute of Engineering Science & Technology, Shibpur, West Bengal. He has published seven research papers in national/international journals and presented several research papers in national/international conferences.

Radheshyam H. Gajghat is an Associate Professor at Department of Mechanical Engineering,, Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India. He has completed his Graduation in Production Engineering from RTMNU, Nagpur, Post Graduation in Production Engineering from Motilal Nehru National Institute of Technology (MNNIT), Allahabad and PhD (Submitted) in Mechanical Engineering from RTMNU, Nagpur. He has published eight research papers in national/international journals and presented several research papers in national/international conferences.

Anooj Joseph is a PG Student at Department of Mechanical Engineering,, Christian College of Engineering & Technology, Bhilai, Chhattisgarh, India. He has completed his Graduation in Mechanical Engineering from CSVTU, Bhilai.