Finite Element Analysis of Ply Orientation Effect on Mechanical Properties of Hybrid Composite Material

Mahesh Gund*, R T Vyavahare

Department of Mechanical Engineering, SKN Sinhgad College of Engineering, Korti- Pandharpur, PAHSU, Solapur, India.

*Corresponding author
doi: https://doi.org/10.21467/proceedings.118.27

ABSTRACT

In recent years, composite material is used as an alternative material for materials like metal, wood, etc. due to low in weight, strength to weight ratio and stiffness properties. Natural fibers like coir fiber, palm fiber, jute fiber, banana plant fiber, etc have low cost, easy availability and less harmful to human body. Also, carbon fiber having various properties such as high strength to weight ratio, rigidity, good tensile strength, fatigue resistance, fire resistance/not flammable, high thermal conductivity. This research work aims to find out the mechanical properties of Carbon fiber, Coir fiber and Epoxy composite material with different ply orientations angles by using FEA software Ansys APDL R15.0.

Keywords: Carbon fiber, Coir fiber, Epoxy, ANSYS APDL R15.0, Mechanical properties.

1 Introduction

To highlight the researches done in composite laminates, new fibers and resins and to create future applications for composites. Eco-friendly resins will replace recycled plastics and bio-based polymers with composites. This research work was done to perform the analysis on CFRP laminate with in-plane loading conditions. In this research, the mathematical calculation of determining the failure criteria of the laminate with ply orientation of $90^0/0^0/0^0/-45^0/+45^0$wasdone by writing stress program on MATLAB and further analysis was performed using ANSYS. After obtaining both the results the design was validated [1].

Analysis of composite specimen performed using ANSYS static structural workbench. Analysis was performed on 4 different materials which include conventional structural steel and 3 different composite materials. E glass/ Epoxy, High strength Carbon Epoxy (230 GPA) and High Modulus Carbon Epoxy (395GPA). Results were compared and conclude High strength carbon was the optimum material [2].

The optimization of most commonly discussed natural fiber-reinforced composites such as Banana fiber, Jute fiber, Kenaf fiber, Hemp fiber and Pineapple Leaf fiber (PALF) based on fiber orientation has been used. Finite element models of each fiber reinforced epoxy composite were prepared at constant fiber volume percent of 30% with fiber orientation angles of 0^0, $+22.5^0/-22.5^0$, $45^0/-45^0$, $+67.5^0/-67.5^0$ and 90^0 measured from the horizontal axis. The models were loaded for different standard loading conditions, i.e., tensile, flexural, and hardness tests. From the results, it was observed that for tensile and flexural tests all the fibers showed minimum stress at the orientation of 0^0 and 90^0. [3].

A finite element study of specimens was conducted by blending fibers. The arrangements were chosen using sequence and combination. After designing the specimen, many types of FEM analysis were done on 'ANSYS' Mechanical APDL by applying a point load on specimens. Through the current study, hybrid composites were analyzed under the same loading conditions and their deflection results were compared. It could step to sustainable development by making a hybrid composite. And a good-quality composite could be designed for the manufacturing of a great strength material [4].

Proceedings DOI: 10.21467/proceedings.118; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-947843-6-4

2 Materials and Methods

2.1 Properties of Epoxy

Epoxy is known for its higher bonding capabilities. Epoxy resins have a better adhesive property as compare to polyester and vinyl ester resins, also epoxy has a good two important mechanical properties are tensile strength and stiffness. Epoxy was more resistant to wearing, cracking and peeling, and corrosion or damage from chemical or environmental degradation.

2.2 Properties of Coir fiber

Coir fiber or Natural fiber having industrial attraction due to its advantageous properties as low density, low in cost, having specific mechanical properties, very strong and light in weight, it has water-proof as well as resistant to damage by salt water, also having dynamic properties, etc. as compared to synthetic fiber.

2.3 Properties of Carbon fiber

The Carbon fiber having various properties such as High Strength to weight ratio, rigidity, good tensile strength, corrosion resistance, electrical conductivity, fatigue resistance, fire resistance/not flammable, high thermal conductivity in some forms, low coefficient of thermal expansion

3 FEA Analysis

ANSYS was engineering simulation software based on the finite element method and was capable of performing static (stress) analysis, thermal analysis, modal analysis, frequency response analysis, and transient simulation and also coupled field analysis. The ANSYS multi-physics can couple various physical domains such as structural, thermal and electromagnetic. For the present study, simulation was done for tensile and compressive testing under different loading conditions; the case static analysis was carried out. Element type and material properties in both cases were the same. The finite element analysis has been successfully made to investigate the tensile and compressive strength of Carbon/coir fiber and epoxy Composite. In this work, properties of Carbon/coir fiber and epoxy system have been used and commercially available FE package ANSYS APDL 15.0 has been used for conducting static analysis. The element chosen was SHELL 181 which was compatible with polymer matrix composite structures. The total thickness of the specimen was maintained at 3 mm throughout the analysis.

3.1 Procedure of modelling in ANSYS for tensile testing

There were major and sub important steps in the ANSYS model,

- Pre-processing
- Solution stage
- Post-processing.

Requirement specification

Firstly, it was required to give preference for what type of analysis you want to do, here we were analyzing for rectangular cross-section so given here structural part.

Pre-processing

Now next step was the pre-processor, where the pre-processor menu was used to inputs the entire requirement thing for analysis such as element type, real constraints, material properties, modelling, mes hing, and loads. Element menu contains defined element type and degree of freedom defined where we've to offer the element structure type like BEAM, SOLID, SHELL, and therefore the degree of freedom, here in this analysis selected part was SHELL show menu contained part. After this, the next step was to define the real constants set, which was contained the material number, fiber orientation angle, and the thickness of each layer. The next step was to define material properties, with the help of the material model menu in the ANSYS. For material model behaviour considered material as orthotropic and for this given all the nine inputs which were required (young modulus, modulus of rigidity and Poisson ratio) in XY, YZ, and XZ direction respectively. The geometry shape of the structure, in this analysis we considered the shape of the shell was tensile specimen dimension cross-section. After the completion of this stage now meshing menu was introduced to mesh the problem, in our problem we considered the element divisionwas60. The next step was to define the boundary condition with the help of the defined load menu, here in this analysis we defined the different boundary conditions for different problems and the dimensions considered for tensile testing as per ASTM D3039 were 250 x 25 x 3 mm.

Tensile Testing

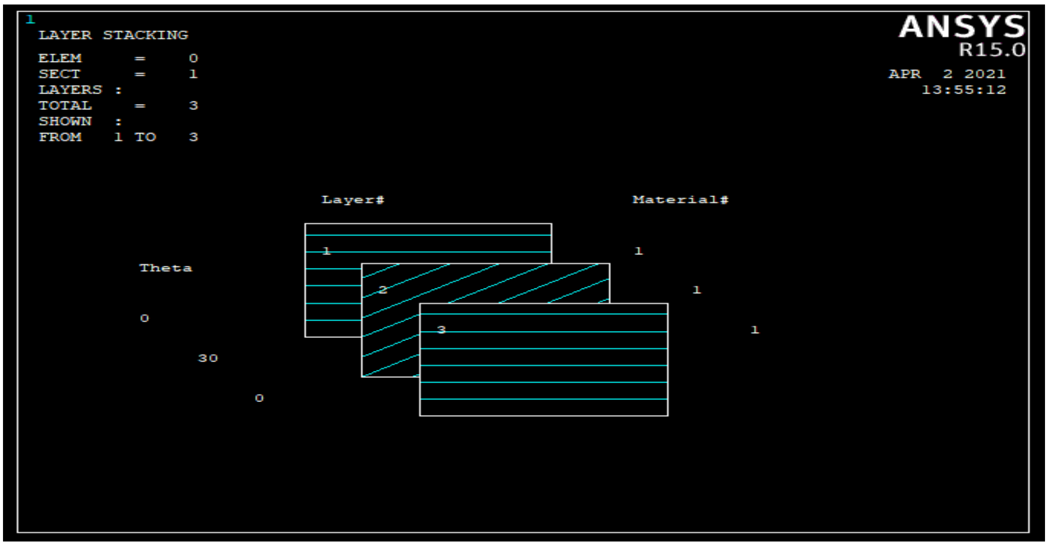


Fig 3.1 Ply Orientation

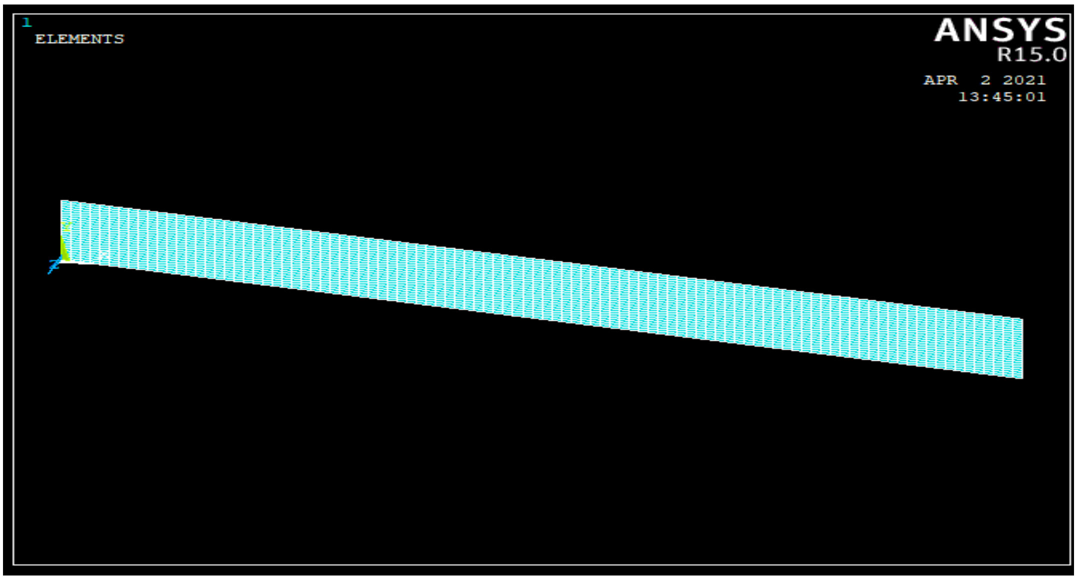


Fig 3.2 Meshing

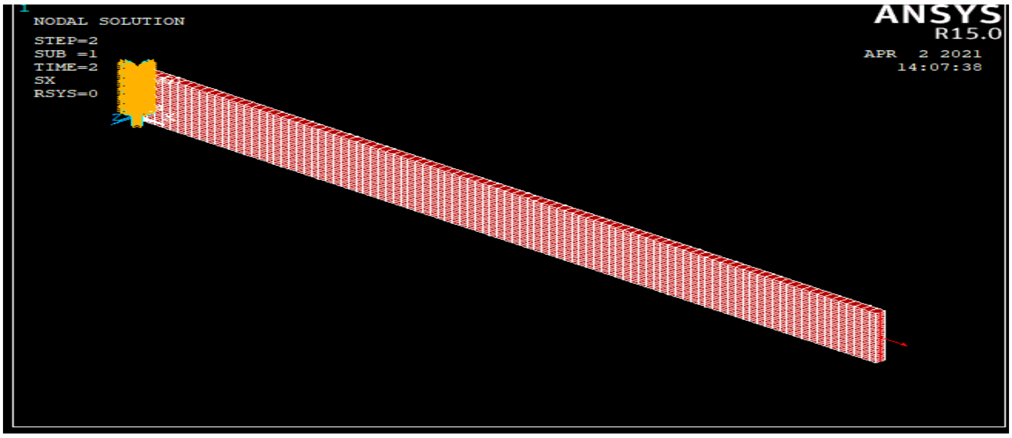


Fig 3.3 Applied Load

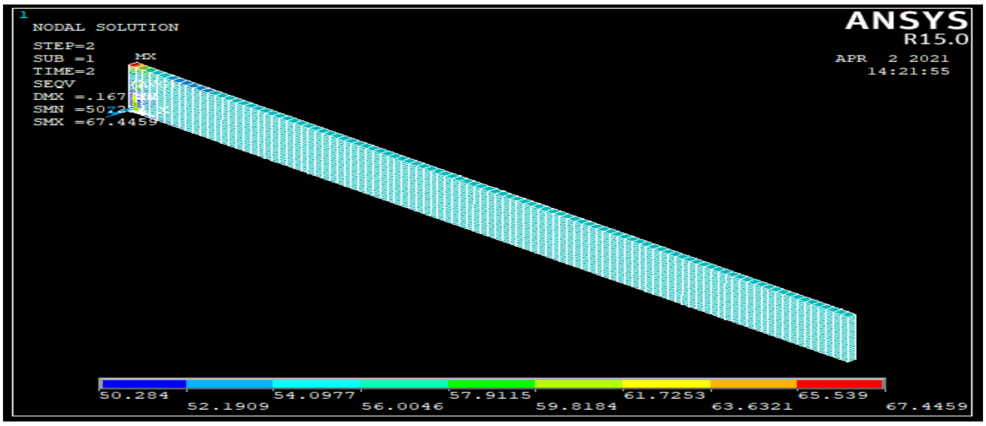


Fig 3.4 Maximum Stress

Compressive Testing

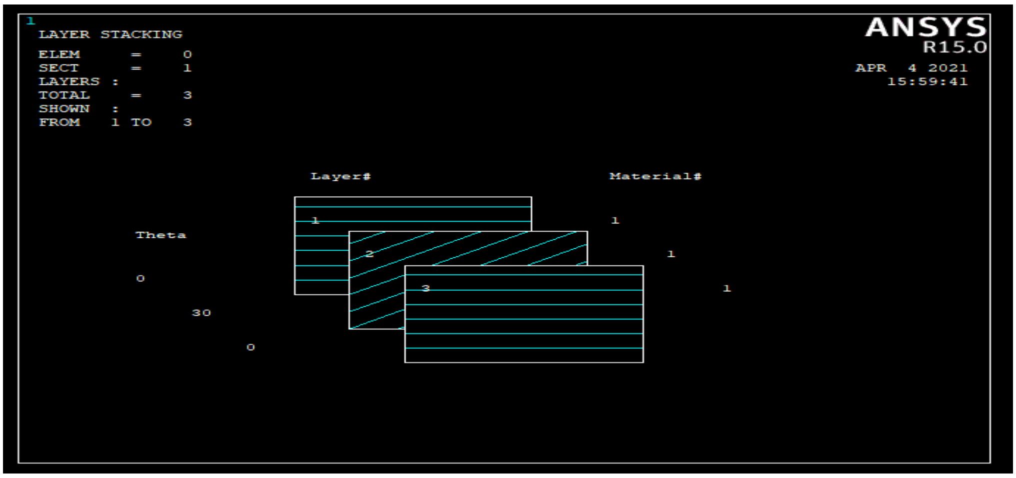


Fig 3.5 Ply Orientation

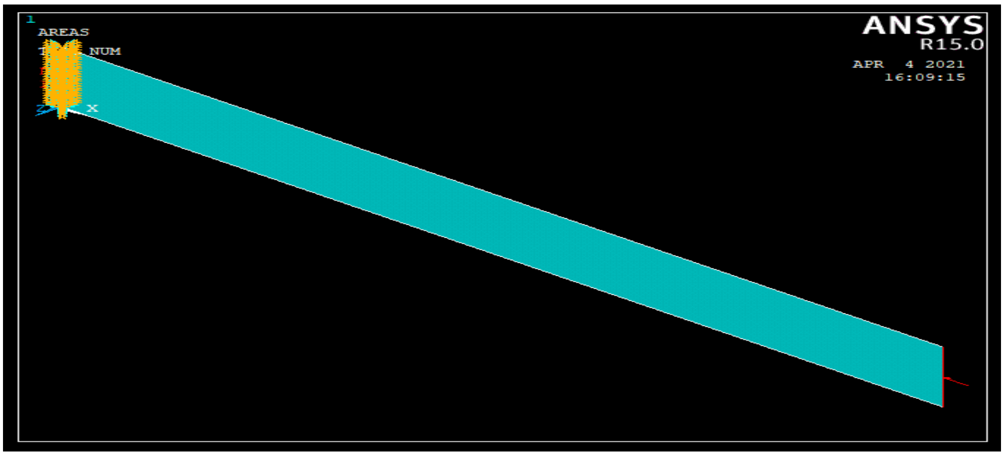


Fig 3.6 Applied Load

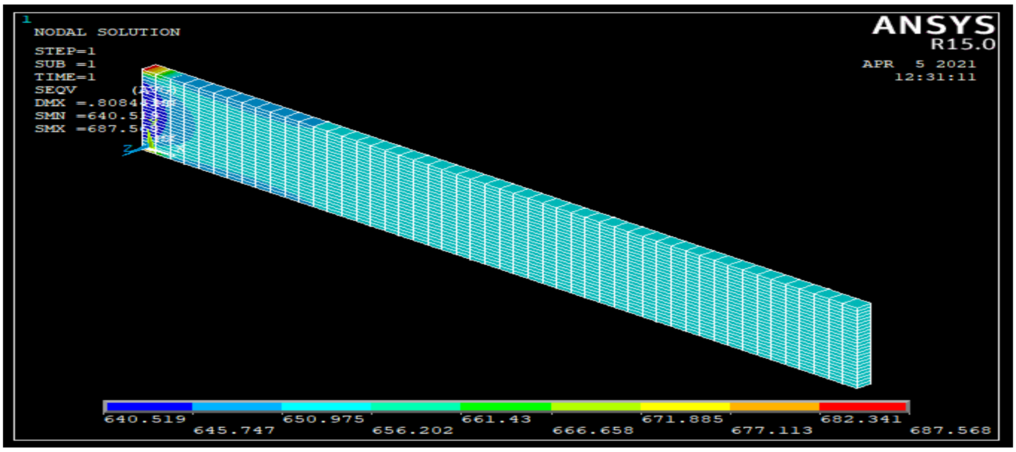
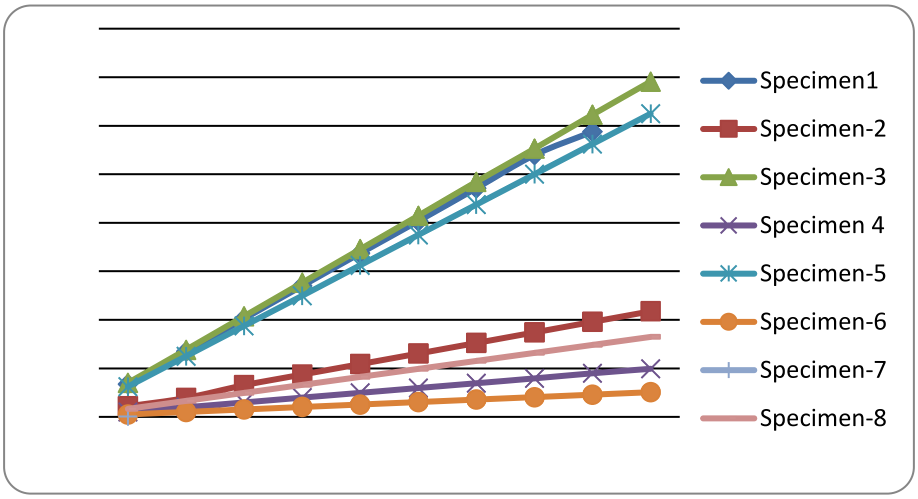


Fig 3.7 Maximum Stress

4 Results and Discussion

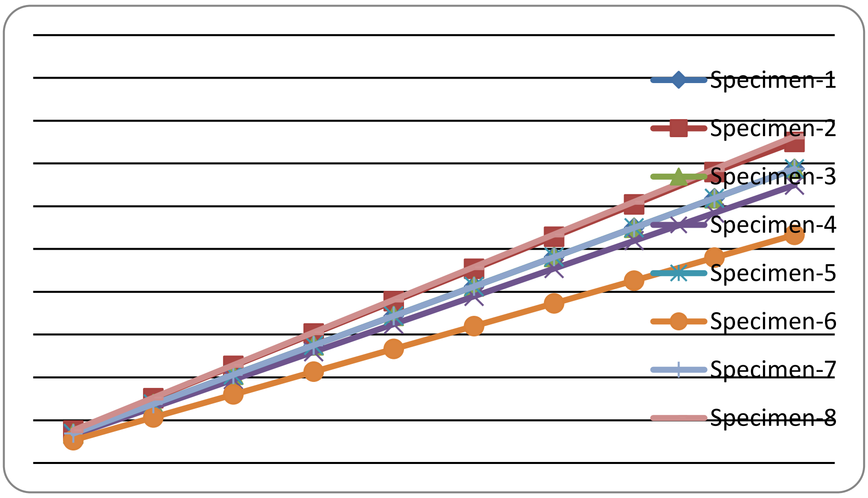
4.1 Tensile Test Results

Load (N)	Specimen-1 0^0-30^0-0^0	Specimen-2 30^0-0^0-30^0	Specimen-3 0^0-60^0-60^0	Specimen-4 60^0-0^0-60^0	Specimen-5 0^0-90^0-0^0	Specimen-6 90^0-0^0-90^0	Specimen-7 0^0-45^0-0^0	Specimen-8 45^0-0^0-45^0
100	67.75	21.75	69.94	9.91	62.48	5.09	71.74	16.48
200	134.481	38.96	138.18	19.82	124.97	10.187	143.48	32.96
300	202.338	65.26	207.28	29.74	187.45	15.28	215.22	49.44
400	269.784	87.2	276.37	39.69	249.52	20.37	286.96	65.92
500	337.13	108.77	345.47	49.57	312.42	25.46	358.7	82.4
600	403.44	130.5	414.56	59.48	374.92	30.55	430.44	98.88
700	471.19	152.25	484.5	69.34	437.4	35.64	502.18	115.36
800	539.56	174.04	552.75	79.31	499.88	40.73	573.92	131.84
900	587.71	195.79	622.69	89.82	562.32	45.82	645.66	148.32
1000	607.31	217.55	690.94	99.14	624.85	50.93	717.412	164.81



4.2 Compressive Test Results

Load (N)	Specimen-1 0^0-30^0-0^0	Specimen-2 30^0-0^0-30^0	Specimen-3 0^0-60^0-60^0	Specimen-4 60^0-0^0-60^0	Specimen-5 0^0-90^0-0^0	Specimen-6 90^0-0^0-90^0	Specimen-7 0^0-45^0-0^0	Specimen-8 45^0-0^0-45^0
100	68.75	75.58	68.75	64.94	68.75	53.31	68.75	76.324
200	137.5	151.16	137.5	129.88	137.5	106.62	137.5	152.64
300	206.25	226.74	206.25	194.83	206.25	159.93	206.25	228.97
400	275	302.32	275	259.66	275	213.24	275	305.29
500	343.75	377.9	343.75	324.6	343.75	266.55	343.75	381.62
600	412.5	453.48	412.5	389.54	412.5	319.86	412.5	457.94
700	481.25	529.06	481.25	454.48	481.25	373.17	481.25	534.26
800	550	604.64	550	519.42	550	426.48	550	610.59
900	618.75	680.22	618.75	584.36	618.75	479.8	618.75	686.92
1000	687.5	750.287	687.5	649.43	687.5	533.16	687.5	763.25



5 Conclusions

In this research work noted mechanical properties for various ply orientations with the help of ANSYS APDL 15.0 software and high tensile strength ply orientation was selected for composite. Following conclusions are obtained.

Proceedings DOI: 10.21467/proceedings.118
ISBN: 978-81-947843-6-4

Series: AIJR Proceedings
ISSN: 2582-3922

1. The mechanical properties i.e. tensile strength in ANSYS APDL R15.0 Maximum at ply orientation angle 0^0-45^0-$0^0$is 717.412 Mpa and minimum at ply orientation angle 90^0-0^0-$90^0$is 50.93 Mpa.
2. The mechanical properties i.e. compressive strength in ANSYS APDL R 15.0 maximum at ply orientation angle 45^0-0^0-45^0 is 763.25 Mpa and minimum at ply orientation angle 90^0-0^0-90^0 is 533.16 Mpa.

References

[1] N.B.V. Lakshmi Kumari, Dr.AfrozMehar, Mohammed Abdulrahman, SheetalTatineni, EllendulaVenkateshwaraShashank, Jonathan Ted Muthyala "Performance Analysis of Ply Orientation in Composite Laminates", Materials Today: Proceedings 5 (2018) 5984–5992.

[2] PNE Naveen & R. Bhaskar Reddy "An Analysis Of Composite Drive Shaft Using ANSYS ACP " International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN (P): 2249-6890; ISSN (E): 2249-8001 Vol. 8, Issue 5, Oct 2018, 117-124 © TJPRC Pvt. Ltd.

[3] RohitGhosh, SushovanGhosh, ShirishGhimire, Dr. RabindraNath Barman "Static Analysis Of Multi-Leaf Spring Using ANSYS WORKBENCH 16.0", International Journal of Mechanical Engineering and Technology (IJMET)Volume 7, Issue 5, September–October 2016, pp.241–249, Article ID: IJMET_07_05_025.

[4]UpendraSharan Gupta, AmitDharkar, MohitDhamarikar, ArpitChoudhary, DipanshuWasnik, PankajChouhan, Sudhir Tiwari, Rajeev Namdeo, "Study on the effects of fiber orientation on the mechanical properties of natural fiber reinforced epoxy composite by finite element method", Materials Today: Proceedings.

5] Shivanshu Dixit, S.S.Padhee, "Finite Element Analysis of Fiber Reinforced Hybrid Composites", Materials Today: Proceedings 18 (2019) 3340–3347ICMPC-2019.

[6] S. Harish, D. Peter Michael, A. Bensely, D. Mohan Lal, A. Rajadurai "Mechanical property evaluation of natural fiber coir composite", Elsevier Materials Characterization 60 (2009) 44–49.

[7] Fang Liu, Shiqiang Deng, Jianing Zhang "Mechanical Properties of Epoxy and Its Carbon Fiber Composites Modified by Nanoparticles", Hindawi Journal of Nanomaterials Volume 2017, Article ID 8146248.

[8] Adewale George Adeniyi, Damilola Victoria Onifade, Joshua O. Ighalo, Akorede Samson Adeoye "A review of coir fiber reinforced polymer composites" Composites Part B 176 (2019) 1073051359-8368/© 2019 Elsevier.

[9] M. Z. Rahman, B. R. Mace, and K. Jayaraman, "Vibration Damping of Natural Fiber-Reinforced Composite Materials", Conference: ECCM17 - 17th European Conference on Composite Materials. June 2016

[10]J.S.Mahajan, L.S.Dhamande "Design of Passive Composite Isolation System for Machine Foundation", IJAERD, Volume 04 Issue 05, page no 1111-1114, 2017.

[11] P N E Naveen, M Yasaswi"Experimental Analysis of Coir-Fiber Reinforced Polymer Composite Materials" IJMERR, Volume 2, No. 1, January 2013.

[12] ShunjieYin, NassifRayess "Characterization of Polymer-Metal Foam Hybrids for Use in Vibration Dampening and Isolation", Elsevier8th International Conference on Porous Metals and Metallic Foams, MetfoamProcedia Materials Science 4, 2014, page no. 311 – 316.