Nat. Volatiles & Essent. Oils, 2021; 8(4): 2809-2820

Effect of Foam and Epoxy on Aluminium Honeycomb structure for an Automobile Applications

[1]Dr. Sridhar B S, [2]Dr. Shashikala A R

[1]*Assistant Professor, Mechanical engineering department/ MS Ramaiah Institute of Technology, Bangalore, 560054.India*

[2]*Associate Professor, Department of Chemistry, Presidency University, Bangalore 560064.India*

Abstract

With the world involved in an advancing global warming, we have started to be concerned about the environment and how we could take care of it since just few decades ago. Nowadays the strategy has changed into reduce consumptions and pollution. The governments and institutions are now setting aims of decrease the emissions during the next decades. In the automotive industry, the requirements of reduction of weight and fuel consumption have become an essential study without losing any mechanical strength. This is done by improving old technologies and developing new ones. One of these growing new technologies is in the field of materials engineering. Coming from aerospace and aeronautic industries, now the composite materials are being introduced to the automotive sector. One such attempt is made by reducing the weight of wheel spoke. Spoke is one of the some rods that are rotating from the center of the wheel that connects the hub. Spoke is an important automobile part which bears a major load. This work is unique in such a way that spokes are made using epoxy based composite materials along with the honeycomb material filled with liquid foam which is sandwiched between the fibers. In general spokes are made using either steel or aluminum material. But from this work it is highlighted that the sandwich based composite materials can also be used as the spokes material.

Key words: *Composite material, Natural fibers, Epoxy, Honeycomb material, Foam.*

1. Introduction

In Automobile parts one of the major important part is a wheel spoke because of all of the automobile parts are carried by spokes. Heavy load carrying vehicles will have high strength and good fatigue property spoke. Overdesigning a wheel by adding material increases the wheel mass and rotational inertia which negatively affects the vehicle's performance and efficiency. This has led to substantial development efforts to reduce the wheel weight and rotational inertia while simultaneously maintaining or increasing the material strength. All these aspects has led to develop a spoke made of a composite material, which is improved in that it has a higher fatigue strength and impact strength. This work highlights the production and testing of various mechanical properties of foam filled honeycomb sandwiched, epoxy based composite material spokes. Honeycomb material is used inorder to improve the life and also to improve the ductility of the composite spokes. Polyurethane foam is used to fill the honeycomb core inorder to add strength and also to improve the stiffness of the honeycomb material. Thus composite embedded spokes can be used in various automobile applications which in turn reduces the weight of an automobile which leads to the minimal fuel consumptions.

2. Materials and Fabrication

The raw materials that are used in this work and also the fabrication process that is been carried out is been elaborated in this section. Materials used are:

- Natural fiber(Jute, Banana)
- Honeycomb material(Paper and aluminum)
- Polyurethane foam(50Kg/m^3 and 60 Kg/m^3)
- Epoxy
- Hardener

2.1. Materials

In some engineering field of applications, composites are still been widely used. It is still used in finite manner just because of its issues in durability and also difficulty in determining its accomplishment during its period of assistance. Hence inorder to overcome this drawback honeycomb material is sandwiched between the natural fibers inorder to improve the life of the composite material and also to enhance the ductility of the composite. Polyurethane foam is been filled in the core of the honeycomb material so that stiffness gets added to the material. The resin used in this work is epoxy resin which exhibits poor thermal and also poor mechanical properties. Inorder to improve these properties this resin is subjected to rehabilitate reaction. When this occurs the linear chain of this resin gets changed to 3D cross linked chain and this is achieved by adding the hardener which is the curing agent in the ratio of 1:10.

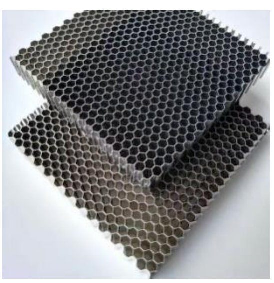



Fig.1 Aluminum honeycomb **Fig.2 Paper honeycomb** **Fig.3 Jute and Banana fiber** **Fig.4 Polyurethane foam**

2.2 Fabrication Process

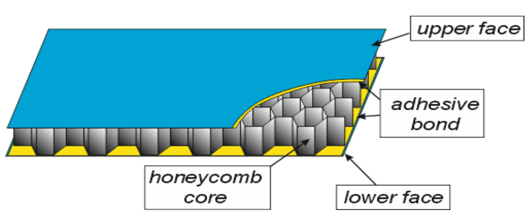


Fig.5 Honeycomb Sandwich Composite

The methodology used in this work is handlayup method. Since the part produced is not under requirement of getting joined to any other parts, handlayup is the appropriate method that is incorporated in this work. Binding agent along with hardener is mixed thoroughly in the ratio of 10:1.The foam is filled in the honeycomb core and kept for drying for about 1hour.Once it becomes stable then the further work is carried out. A layer of fiber is spread and epoxy is made to spread gently over the fiber mat. Foam filled honeycomb material is then placed over the fiber mat. After perfect adhesion another layer of fiber is placed over the honeycomb material with the aid of binder. Then with the aid of vacuum pressing process the excess epoxy material is removed and the composite material is cured.Fig.5 shows the honeycomb sandwich composite material constituents.



Fig.6 Spreading of Honeycomb Material Fig.7 Mixing of polyol and isocyanate Fig.8 Pouring of Polyurethane Foam to Mould in the mould



Fig.9 Paper Core Material Fig.10 Aluminum Core Material Fig.11 Sandwich Composite with Core Material

Fig.6, 7, 8 shows the various stages of the fabrication processes.Fig.9 and Fig.10 indicates the finished core products.Fig.11 shows the final sandwich composite specimens embedded with jute and banana fibers. Hence prepared specimens are named based on the materials used in it. J and B indicates the name of the fiber used that is Jute and Banana fiber. P and A indicates the material of the honeycomb used that is paper and aluminum respectively. 1 and 2 represents the density of the foam used that is 50 and 60 Kg/m^3.Table 1 shows the detailed description of the specimens.

Table 1: Specifications of the Specimens

Sl. No	Specimen Name	Fiber used	Honeycomb Material	Density of the Foam(Kg/m^3)
1	JP1	Jute	Paper	50
2	JP2	Jute	Paper	60
3	JA1	Jute	Aluminum	50
4	JA2	Jute	Aluminum	60
5	BP1	Banana	Paper	50
6	BP2	Banana	Paper	60
7	BA1	Banana	Aluminum	50
8	BA2	Banana	Aluminum	60

3. Experimental Procedure

3.1 Tensile Strength

As per the ASTM D3039 standard, the specimens are made for the tensile test. Tensile, compression, bending tests are conducted as per the standards. Tensile test was carried out in TUE-C-400 UTM machine. Specimen was machined as per the standard dimension i.e. 150mm length,20mm thick and 30mm width. UTM test arrangement for tensile test is as shown in Fig.12.

Fig. 12 UTM Test arrangement for tensile test

3.2 Compressive Strength

ASTM C365 standard was used to conduct compression test and the dimensions are 150mm length, 20mm thickness and 30mm width. Compression test was carried out in TUE-C-400 UTM machine.

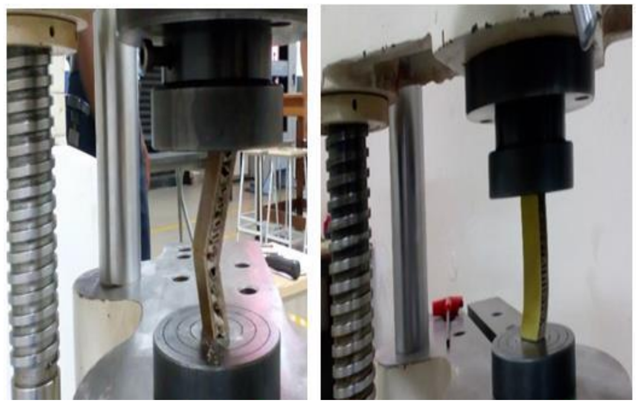


Fig. 13 UTM Test arrangement for compressive test

3.3 Fatigue Strength

Fatigue strength of a material is defined as ability of any material to withheld the highest stress which is applied during given number of cycles without breaking. Fatigue tests were carried out in the hydraulic fatigue testing machine with frequency of 5Hz.Load was applied as sine wave. Load was applied with the aid of 30mm cylindrical material. The dimensions of the specimen used here is 200*50*20mm as per the ASTM C394 standard.

3.4 Impact Strength

Ability of the material to withstand the predetermined load which is applied suddenly on it is termed as impact strength of that material. Specimen was made as per the ASTM D7766 standard and impact strength was tabulated by carrying out Charpy test with 5Joule of impact energy. Specimen size is as same as that of the tensile strength specimen dimensions.

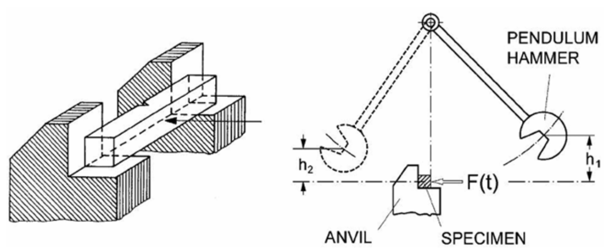


Fig.14 Schematic of the Impact test arrangement

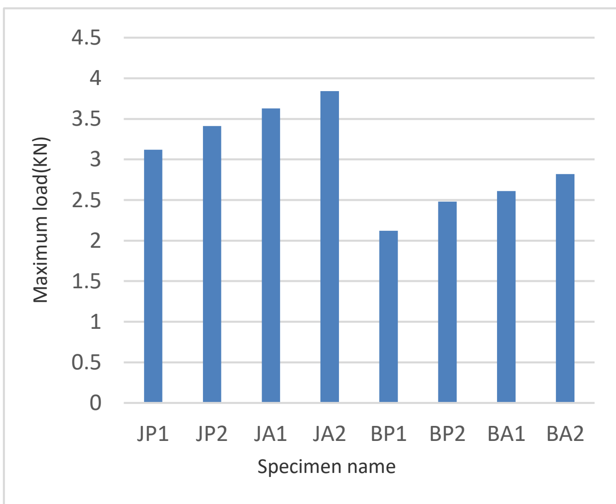
4. Results and Discussions

4.1. Tensile Strength

The tensile strength of the various specimens is as shown in Table 2.It is been observed from the table that the jute reinforced, aluminum honeycombed core with polyurethane foam of density 60Kg/m^3(JA2) is having a dominated tensile strength when compared other specimens. It has been observed that the average tensile strength of the specimen JA2 is 7.12MPa and its peak load capacity is 3.841KN.

Table 2: Average Tensile Strength

Specimen Name	**Average Tensile Strength(Mpa)**
JP1	5.212
JP2	5.916
JA1	6.163
JA2	7.12
BP1	3.522
BP2	3.981
BA1	4.4234
BA2	4.7164



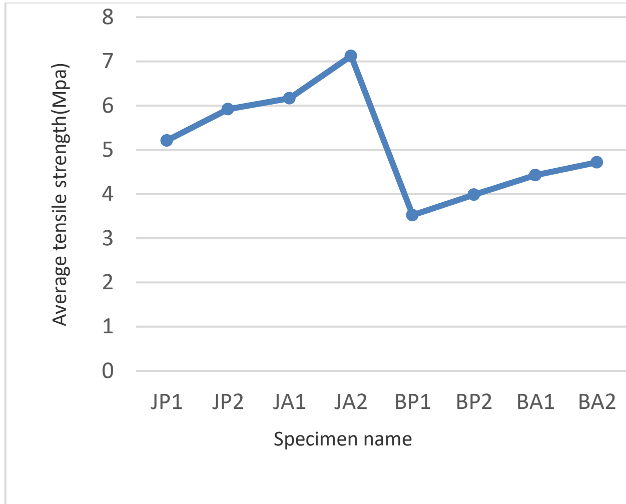


Fig.15 Comparison of Maximum Tensile Load Fig.16 Comparison of Average Tensile Strength

The average tensile strength of various sandwich composites is tabulated as shown in the Fig.16.We found that the specimen JA2 exhibited a better tensile strength when compared to other specimens. The poor tensile strength was observed in the BP1 specimen. Fig.15 indicates the maximum load that a specimen can bear. It is clear from the graph that JA2 specimen could withstand more load when compared to that of the other specimens.

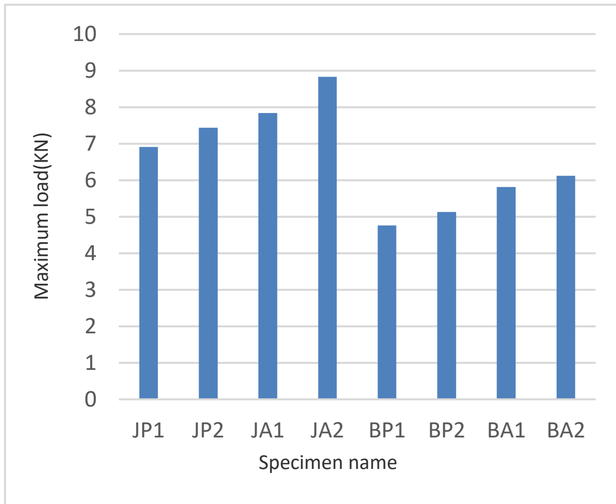
4.2. Compression Strength

Table 3 shows the average compressive strength of the sandwich composite materials. It is been observed that the sandwich composite with aluminium core material exhibited better compressive strength which is filled with foam of density 60Kg/m^3 and reinforced using jute fiber(JA2).It was also observed that aluminium core embedded composite material exhibited better compressive strength when compared to that of the paper embedded core material.

Table 3: Average compressive strength

Specimen name	Average compressive strength(MPa)
JP1	14.912
JP2	13.485
JA1	16.124
JA2	17.386
BP1	11.851
BP2	12.113

BA1	12.861
BA2	13.485



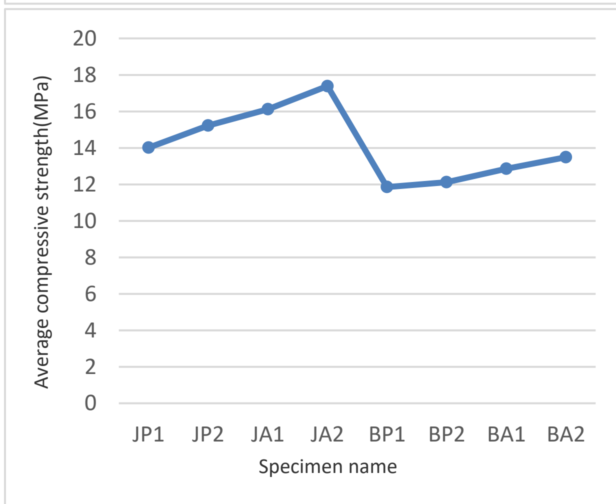


Fig 17 Comparison of Maximum compressive load
Fig.18 Comparison of average compressive strength

The Fig.17 shows the comparison of peak compressive load that a specimen can bear. Maximum load bearing capacity was found in the specimen JA2 i.e. 8.826KN. Fig.18 is an evidence that JA2 specimen exhibits the better compressive strength i.e. 17.386 and specimen BP1 exhibits lowest compressive strength of all the other specimens i.e. 11.851MPa.

4.3. Fatigue Strength

Fig.19 shows the peak stress vs the number of cycles. It is clear from the graph that specimen

BP1 exhibits the less peak stress when compared to that of the other specimens. In the banana reinforced sandwich composites the specimen BA2 exhibited the better flexural strength for the given number of cycles. In jute reinforced sandwich composites the aluminium core sandwiched composite with foam density of 60Kg/m^3 exhibited better peak stress. It was also observed that jute reinforced composites exhibited better fatigue strength than that of the banana reinforced composites. It was proven that as the loading ratio(r) increases the reduction in fatigue strength also increased.

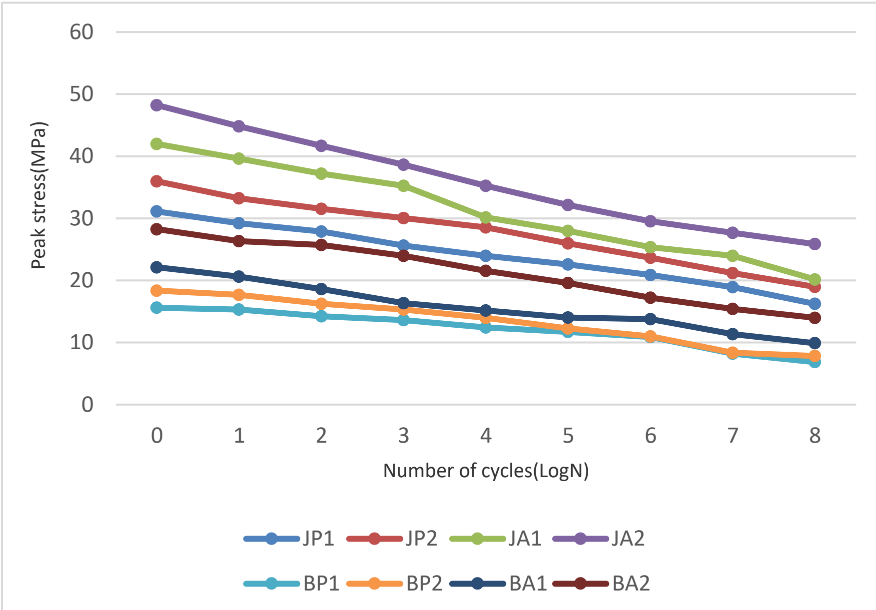


Fig.19 Peak stress Vs Number of cycle for failure

4.4. Impact Strength

The impact energy is distributed along the width of the specimen. Aluminum core filled with 60Kg/m^3 density of foam and sandwiched between jute fibers could absorb more impact energy as compared to other specimens.Fig.20 shows the comparison of average impact strength of the various sandwich specimens. It is clear from the graph that JA2 specimen i.e. the specimen with aluminium honeycomb core filled with greater density foam sandwiched between the jute fibers exhibit good impact strength when compared to other sandwich specimens. Moreover, it is observed that banana reinforced sandwich composites is having less impact strength as of compared with the jute reinforced sandwich composites. The maximum impact strength observed was 19.83Kg/m^2 in the specimen JA2 and the minimum impact strength observed was 12.16 Kg/m^2 in the specimen BP1.

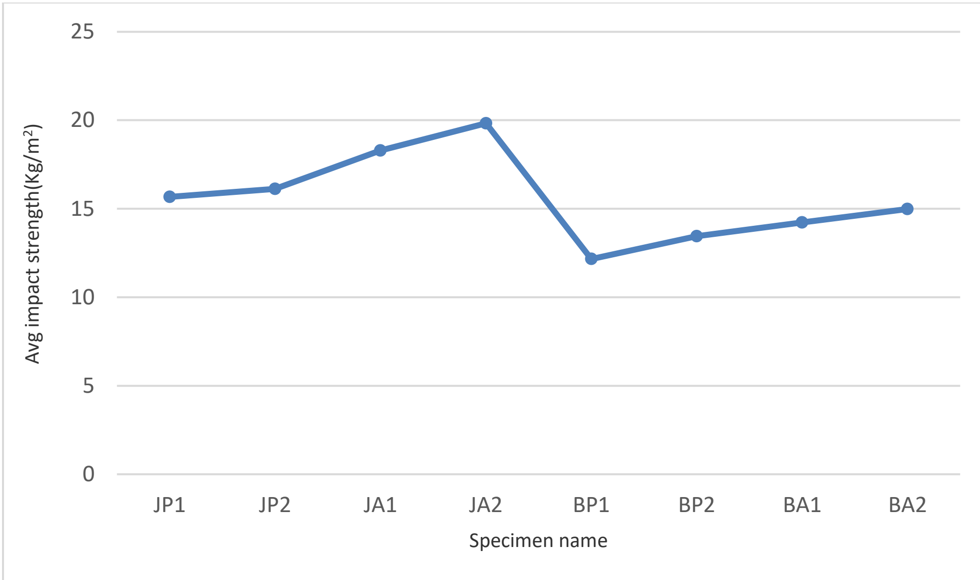


Fig.20 Comparison of Average Impact Strength

Conclusion

The comparison of the mechanical properties of sandwich composites embedded using paper and aluminium honeycomb material with different foam densities filled in it was done. Two types of fibers namely jute and banana fibers were used in the work and the following conclusions are indicated based on the results obtained.

- Composites are made by sandwiching 2 different honeycomb materials which are filled with polyurethane foam of 2 different densities. Thus prepared core material was sandwiched between 2 layers of natural fibers namely Jute and banana fibers. Typical hand lay-up method was used for the fabrication process.
- From tensile test, it is concluded that the specimen embedded with jute fiber showcased better tensile strength when compared to that of the banana fiber embedded composites. Specifically aluminium honeycomb material with foam density 60Kg/m^3 (JA2) required maximum load for breaking.
- Compressive test proved that jute embedded sandwich composites had better compressive strength than banana embedded sandwich composite material. It is also seen that with the increase in the foam density there was slight increase in the compressive strength of the material.
- Fatigue test is an evidence that the aluminium core sandwich composites is having greater ability to withstand the cyclic load that is been applied on the material. Paper honeycomb material filled with 50Kg/m^3 density foam which is sandwiched
- is having better impact energy absorption capacity without breakage. It was observed that jute embedded between banana fibers (BP1) was having least ability to withstand the cyclic load.
- Impact test again proves that the specimen JA2 paper honeycomb filled with 50 and 60Kg/m^3 of foam also had very good impact strength then compared to that of the banana embedded sandwich composites with paper and aluminium core materials filled with different foam densities.

References

Maries Indicula, Abderrahim Boudenne. Thermopyhsical properties of natural fiber reinforced polyester Composites. Composites science and technology, 66, (2006), 2719- 2725

Verma, D., Gope, P. C., Shandilya, A., Gupta, A., &Maheshwari, M. K. (2013). Coir Fiber Reinforcement and Application in Polymer Composites: A Review, Journal of Material & Environment Science, 4, pp. 263-276.

Materials Science and Engineering, Fifth Edition, William F Smith, Javad Hashemi, Ravi Prakash Page no-13

Prakash Reddy, B., Satish, S., & ThomasRenald, C.J. (2007). Investigation on Tensile and Flexural Properties of Coir Fiber Reinforced Isophthalic Polyester Composites .Composites Part B: Engineering, 42(6), pp.1648-1656.

Hashin, Z., 1983. Analysis of composite materials—a survey. Journal of Applied Mechanics, 50(3), pp.481-505.

Sridhar B S, Raji George Titled - Tilted: " Study and Analysis of the Mechanical Properties of Carbon/Epoxy Composites used for Automobile Wheel Application ISSN: 2278-0181, Volume 8, Issue 14, page 100- 103 during September 2020.

Ramakrishna, S., Mayer, J., Wintermantel, E. and Leong, K.W., 2001. Biomedical applications of polymer-composite materials: a review. Composites science and technology, 61(9), pp.1189-1224.

Watt, J.P., Davies, G.F. and O'Connell, R.J., 1976. The elastic properties of composite materials. Reviews of Geophysics, 14(4), pp.541-563.

A. G. Mamalis, K. N. Spentzas, N. G. Pantelelis, D. E. Manolakos, and M. B. Ioannidis, "A new hybrid concept for sandwich structures," Composite Structures, vol. 83, no. 4, pp. 335–340, 2008.

ASTM D638–14, Standard Test Method for Tensile Properties of Plastics, 2014, (American
Society for Testing and Materials, Philadelphia)

Sridhar B S, Raji George Titled" Synthesis of Silicon Carbide Based Composite Material" for Industrial Applications Vol.2, No.9, September 2014 E-ISSN: 2321-9637

ASTM, "Standard test method for flatwise compressive properties of sandwich cores," ASTM Standard C 365-03, American Society for Testing Materials, 2005.

H. Ning, G. M. Janowski, U. K. Vaidya, and G. Husman, "Thermoplastic sandwich structure design and manufacturing for the body panel of mass transit vehicle," Composite Structures, vol. 80, no. 1, pp. 82–91, 2007.

F. C. Campbell, Manufacturing Processes for Advanced Composites, Elsevier, London, UK, 2004.

Bitzer T., 1997, "Honeycomb technology. Materials, design, manufacturing, applications and testing", Springer-Science+Buisness Media, B.V

Sridhar B S, Raji George Titled: "Mechanical Characterization Of Polyurethane Foam And Hybrid Natural Fibre Based Sandwich Composite PalArch's Journal of Archaeology of Egypt/ Egyptology 17 (9) (2020) , page 5588-5604 during December 2020.

CMH-17-6, 2013, Composite Materials Handbook, Volume 6 – Structural Sandwich Composites.

D.H. Chen. Bending deformation of Honeycomb consisting of regular hexagonal cells, Elsevier, August 2010.

Al-Shammari, Mohsin Abdullah, and Muhannad Al-Waily. "Analytical investigation of buckling behavior of honeycombs sandwich combined plate structure." *International Journal of Mechanical and Production Engineering Research and Development* 8.4 (2018): 771-786.

Marythraza, M., et al. "Vibration analysis of honeycomb sandwich panel in spacecraft structure." *International Journal of Mechanical and Production Engineering Research and Development* 8.3 (2018): 849-860.

Mohanavel, V., et al. "A review on mechanical and tribological behaviour of aluminium based metal matrix composites." *Int. J. Mech. Prod. Eng. Res. Devel* (2018): 473-478.

Ugla, A., Dhuha J. Kamil, and Hassan J Khaudair. "Interpretable Recommender System With Heterogeneous Information: A Geometric Deep Learning Perspective." *International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)* 10.3 (2020): 2411-2430.

Al-Zubaidi, Diyaa HJ, Muhannad Al-Waily, and Emad Q. Hussein. "Analytical heat generation investigation for forced vibration beam with different crack characterizations influence." *International Journal of Energy and Environment* 10.1 (2019): 33-48.