Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 4 (2024)

Performance Analysis on Hybrid Composites Leaf spring with Natural fibers Reinforcement.

Unmesh Pawar [1]*, Dr. Sachin S.Chavan [2],

[1]*Research Scholar, Department of Mechanical Engineering, Bharati Vidyapeeth (Deemed to be University) College of Engineering, Pune*

[2]*Department of Mechanical Engineering, (Deemed to be University) College of Engineering, Pune*

Abstract.
Integration of natural fibers, such as jute, flax Sisal, etc, with glass fiber composites has gained attention in many engineering applications. Natural and Synthetic fibers are progressively being utilized as fortifications in different applications. The present work aims is to examine the impacts of natural fibers on some mechanical properties of the composites. This exploration was completed by strengthening the network with natural fibers and synthetic glass fiber. Natural fibers like jute, flax and, Sisal were delivered utilizing Vacuum assisted resin transfer molding. After manufacturing of composite material, mechanical properties like tensile and flexural strength were considered. It was discovered that the tensile and flexural strength of jute, flax and Sisal fiber has good strength because of the VARTM process. The examination indicated that the Jute- Glass fiber exhibited superior properties over the other prepared composites. The glass fiber leaf spring is manufactured and physically tested in the laboratory. From the experimental findings, it is observed that the presented leaf spring shows much-closed results over the traditional steel spring.

Keywords: *Natural fiber reinforced hybrid composites, glass, jute, flax, Sisal, fibers, Leaf spring, tensile strength, flexural strength, VARTM*

1. Introduction

Composite materials, plastics, and ceramics have been at the forefront of the growing materials race for the better part of the previous three decades. Both the volume and number of applications for composite materials have been continually growing, which has led to their continued success in acquiring new markets.[1]

These composite materials (remarkably aramid, carbon and glass fiber reinforced plastics) presently command the aviation, recreation, car, development and brandishing businesses. Glass fibers are the most generally used to strengthen plastics because of their minimal effort (contrasted with aramid and carbon) and genuinely great mechanical properties. Be that as it may, these fibers have genuine drawbacks.[1] Natural fibers are intense, flexible and show great mechanical quality. The composite from natural fibers is presented for business reason and turns into a decent option of glass- reinforced composites in numerous uses.[1,2]
Materials are considered hybrid composites if they are created by fusing at least two unique types of fibers in a regular grid. By hybridizing natural fiber- reinforced composites with high-quality manufactured fibers, it is possible to enhance the qualities of the natural fibre reinforced composites. One of the most important focuses of composites is the fact that they may, via the use of the hybridization concept, provide the structural architect with the flexibility to modify the material characteristics to the requirements. [3] The hybridization of natural fibers with synthetic fibers provides an intriguing solution for improving the mechanical performances of hybrid composites and their resistance to the accumulation of moisture. [4] The improved qualities of hybrid composites that result from incorporating glass into jute fibre composites are referred to as hybrid composites. The Natural fiber is being blended with glass fiber-reinforced polymers (GFRPs), which are finding increased use in a various applications. If glass fiber reinforced polymer composites are made using sisal jute fiber that has

been joined with GFRP, the qualities of the composite may be improved, and the material can be used as a replacement. [3] When compared to GFRP, the interlaminar shear quality and the interlaminar fracture durability of flax/glass fibre reinforced hybrid composites were shown to be superior. The intercalation of flax layers between the layers of basalt was shown to be beneficial for both flexural and interlaminar strength. [5] The use of composite materials reinforced with natural fibres like flax, hemp, kenaf, and jute is becoming more significant in the automotive industry, as well as in the aviation industry, in the bundling industry, and in other mechanical applications. A new and innovative hybrid Glass/Flax/Epoxy composite plate with a sandwich structure has been created. This plate can potentially to be used for extended bone break plate applications.[6] The hybridization of natural fibers with manufactured ones offers an intriguing answer for improving the mechanical exhibitions just as the dampness opposition of the hybrid composites.[4] Flax, jute and hemp in unadulterated pressure with suitable regard for fiber and gum plan and auxiliary geometry, natural fiber composites may demonstrate a practical option in contrast to conventional structural materials.[7] Due to high fiber volume and low void contents Vacuum Assisted Resin Transfer Moulding process gets beneficial than the hand layup process. It also increases the strength of composites by 7 to 8 % in total volume fraction.[11] Layth Mohammed, et al (2015 [12] As a result of the chemical treatment, the adhesion between the fiber surface and the polymer matrix was improved, which eventually leading to an improvement in the physic, mechanical, and thermochemical characteristics of the NFPCs. This can be seen in the publication that reviews the research. M.R. Bambach (2017) [13] It has been discovered via the use of experimental and analytical research on natural fiber composite plates and channel sections that have been exposed to pure compression. These plates and channel sections comprise of flax, jute, and hemp fibers. The buckling and post-buckling reactions are demonstrated to be stable, the final state is attained stably and predictably and failure occurs via a slow and ductile process. This is proved to be the case. Juan Pablo Vitale, et al (2017) [14] The mechanical characteristics and failure mechanisms of natural and synthetic fibre reinforced composite sandwich panels were explored here under three- point bending conditions. It may thus be deduced that. 1) The face-sheet debonding was considered a potential failure mechanism in the case of the "all - natural fiber" panel. This was because of the fact that the panel was made entirely of natural fibers. 2) The majority of the specimens had a failure type that was consistent with the map's forecast and that was core crushing. Only the core made of jute-reinforced polyester, which also had jute-reinforced skins, exhibited a shift in mode from core crushing to face yielding when the loading situation was altered. V. Mittal, et al (2016) [15] The author of this review study concludes that alkaline treatment is the method that is used the most often for improving the mechanical, thermal, and water absorption characteristics of natural fiber-based epoxy composites because it is both cost-effective and highly effective. Guilherme Piovezan Otto, et al (2017) [16] The impact of the additional fibers on composite parameters such as resilience, elastic modulus, and deformation under permanent compression were evaluated with the use of a simplex-centroid mixture design model. It has been discovered that a composite made of sisal fibers has significantly subpar qualities as a result of its non-homogeneous distribution over the polymer matrix. In addition, sugarcane and rice husk composites performed better and have the potential to be incorporated into industrial production, which has significant implications for the economy. S.V.Joshia et al (2004) (2004) [18] Studies that have been done in the past comparing the environmental life cycle performance of natural fiber composites with that of glass fiber reinforced composites have shown that natural fiber composites are more ecologically friendly for the particular applications in question. R.M.N. Paul Wambua et al (2003) [19] The specific properties of natural fiber composites, such as sisal, hemp, coir, kenaf, and jute, were found to be superior to those of synthetic fiber composites, according to the findings of an investigation into the mechanical properties of polypropylene composites reinforced with these natural fibers (e.g glass fibers.) Arib, et al. (2006) [21] The outcome of this study showed that Tensile modulus (687.02) and tensile strength (37.28 MPa) of the composites (PALF + polypropylene) with a volume fraction of 10.8 % increased extensively, compared with pure resin. As volume fraction increases flexural stress and flexural modulus of composites increase. The details discussion is presented in the following section. Ranjit Singh et. al [22] designed and fabricated an epoxy-based hip implant with enhanced physical and mechanical characteristics. The design was done using manual calculation and modeling software. The results show that the maximum stress acting on the neck of the hip

---

joint. H. Mithun et. al [23] have investigated the effect of bonded stepped and scarf repair methods on the tensile strength restored in the glass fiber epoxy composites.

2. **Experimental**.

2.1 Materials

In the present work the composites specimen i.e. Jute,sisal, flax, and glass fabrics are fabricated. The raw jute ,flax and Sisal fabrics are collected from Go Green Products Chennai, Tamil Nadu India. The epoxy resin (Biresin CR-82) and Hardner (CH-80) are provided by Axson Sika pvt.ltd. Germany. The Glass- fabric 7781 available in Nano composite lab BVUCOE Pune.

2.2. Preparation of composite specimen

Following are the steps of preparation of final composite samples which is according to ASTM standards.

2.2.1 *Preparation of Laminate*

This is the first step in composite preparation. In the present work, laminate samples of Sisal, Flax, and Glass are used effectively. All laminates were made by using Vacuum Assisted Resin Transfer Molding Process (VARTM) process as shown in the figure.1 (a).This method used in this study was employed due to its simplicity and availability of the items. Also, maintain high fiber volume and low void in the composite laminate. To begin, the vacuum pump must be activated so that the preform assembly may be purged of any remaining air. After ensuring there are no air leaks left in the system and bringing it back to equilibrium, the resin will be permitted to flow into the preform. The driving force for the resin to saturate the reinforcement and the compression force to compact the preform to the appropriate fiber volume fraction are provided by a pressure of 1 atm. in both cases, the reinforcement is impregnated with the resin. The resin can allowed to continue to gel fully while the suction is left on. After that, the component may be cured either at room temperature or by placing it in an oven. As a result of the low injection pressure of 1 atmosphere, it is common practice to add a resin distribution medium with high permeability into the vacuum bag lay-up to promote the flow of resin inside the preform. Figure 1 shows the appearance of the composites (b).

Fig: 1(a) VARTM setup

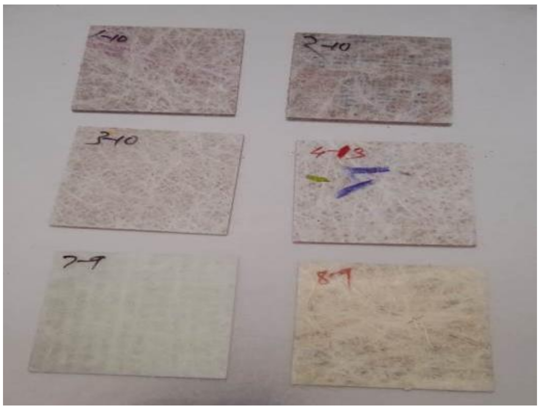


Fig. 1(b) Laminate Natural and Synthetic fiber composite.

2.2.2. *Cutting of coupons:*

After producing sheets of all natural fiber composites, cutting them to conform to ASTM: D638 requirements using Water Jet Machining (WJM), OMAX 60120 Jet Machining Center at Kakade Laser in Narhe, Pune, as illustrated in Figure 3, was the last step. It is used in the cutting of coupons by the ASTM requirements. The removal of material or machining is accomplished by applying the mechanical energy of water, expressed as a high pressure of around 3800 bar. The component suffers less wear and tear due to the procedure since it does not generate any heat.

2.3. Mechanical Properties of fabricated Composites

2.3.1. Tensile test

When conducting tensile testing, the specimen edges are completed with a file and polishing paper before the test. There are six distinct varieties of specimens that are made, each of which is a different combination of fabric and fiber, such as jute, flax, Sisal and glass with three and five layers of each (As listed in table 1). As may be seen in figures 4a and 4b, respectively (b) The ASTM D638 standard was adhered to regarding how the specimen was prepared, its dimensions, the gauge length, and the speeds. The test is carried out on a Universal Testing Machine (UTM), and the temperature of the environment is set at 35 degrees Celsius,) A tensile test specimen is loaded into the testing equipment, and the load is gradually increased until the specimen cracks. The elongation of the specimen is measured after being loaded, as a result of which the measurement was taken. The tests are carried out three times, and each time the average results are calculated for display purposes.

2.3.2. Flexural test

In accordance with the requirements of ASTM D790, the flexural test specimens are prepared in the manner seen in figures 2, and the 3-point flexure test, which is depicted in figure 3, is utilised for the testing. The deflection of the specimen is measured, and the tests are carried out with the average relative humidity set at fifty percent, and the temperature set at around thirty-five degrees Celsius. The flexural load as well as the displacements is both recorded from the testing equipment for each and every one of the test samples.

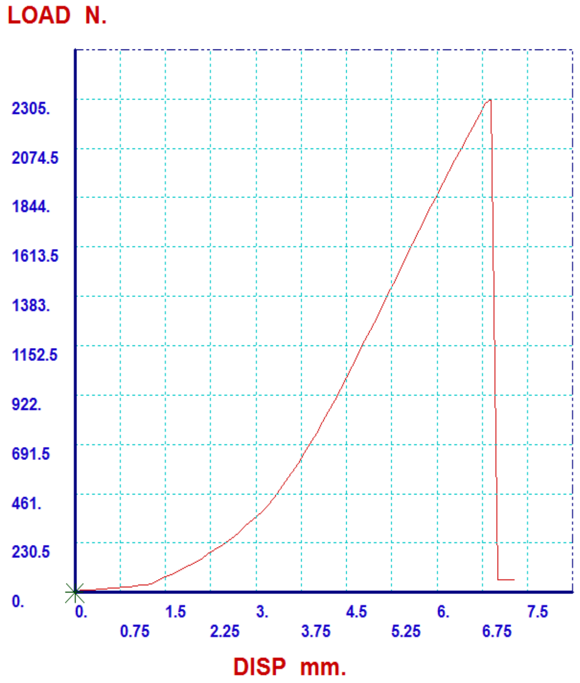
3. Results and discussion

In this investigation, a natural fiber composite mixed with glass fiber composite is manufactured. The effects of these types of fiber on the tensile and flexural characteristics of the material are analyzed and compared. Table 1 presents the findings obtained from conducting tensile and flexural tests on the samples of hybrid composite material.

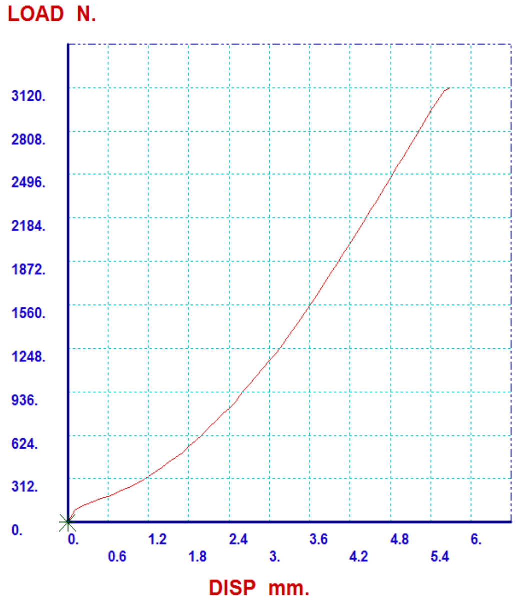
3.1 *Tensile properties*

A load–deformation curve is displayed after the composite samples have been put through the universal testing machine (UTM) and put through their paces. The typical graph obtained immediately from the machine for the tensile test for all synthetic and natural fiber hybrid composites, some of which are shown in figure 6a, is shown here.

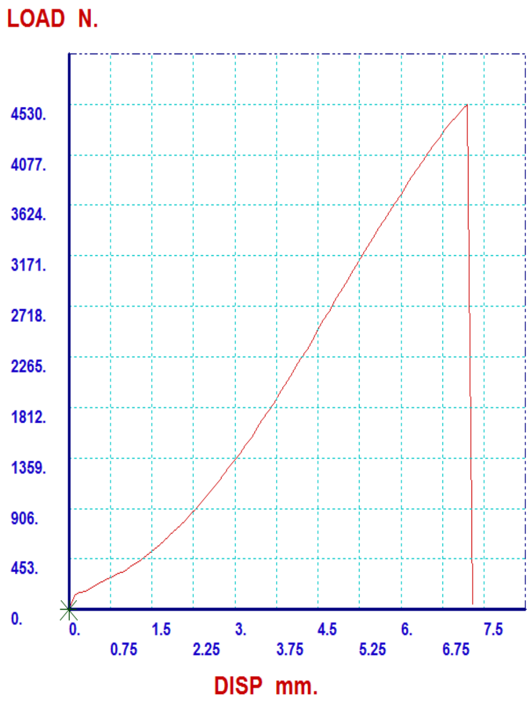
Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 45 No. 4 (2024)



Glass fiber composite



Jute fiber composite



Flax fiber composite

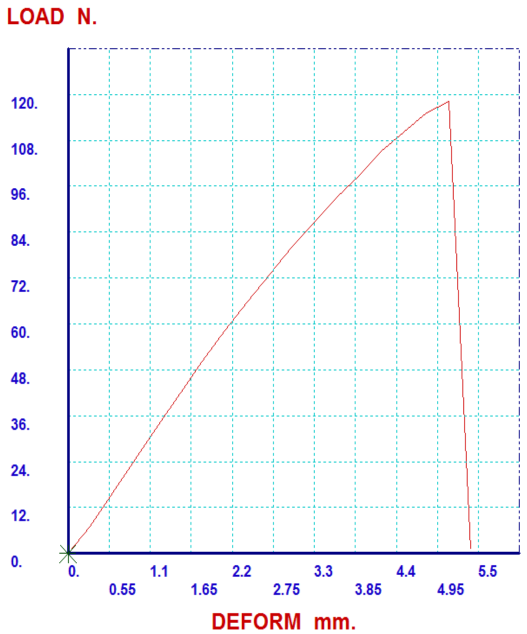
Figure 3. Load-deformation curve during tensile test for synthetic and natural fiber composite.

3.2 Flexural properties

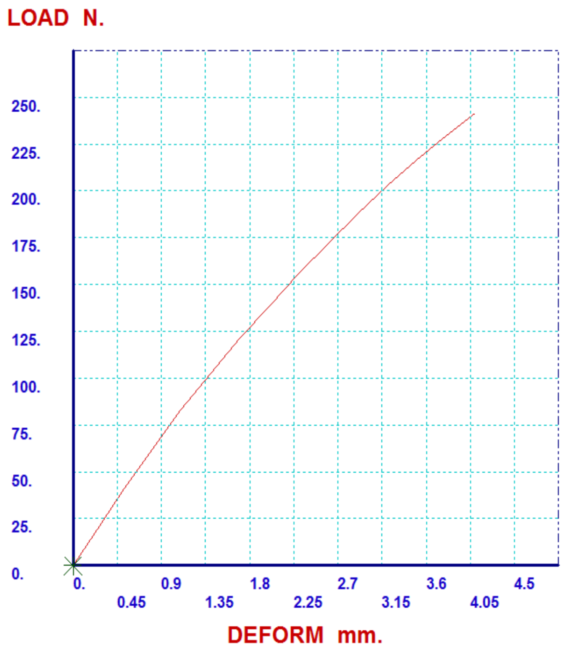
The flexural characteristics of the composite samples that were examined in the UTM, in addition to the typical load deformation curve that was obtained for all synthetic and natural fibre hybrids composite, part of which is depicted in Fig. 4, are discussed further.

The experiments were conducted using plan design of experiments. The experiment makes use of Taguchi's L18 (6^1 & 3^1) mix factorial design with run number 18. There are six variation in the composites and three variation in the load. The experiments were conducted as per the plan mentioned in table 2. The response variable i.e. flexural strengths of the various composite samples were measured w.r.t change in the input parameters and compiled in table 2.

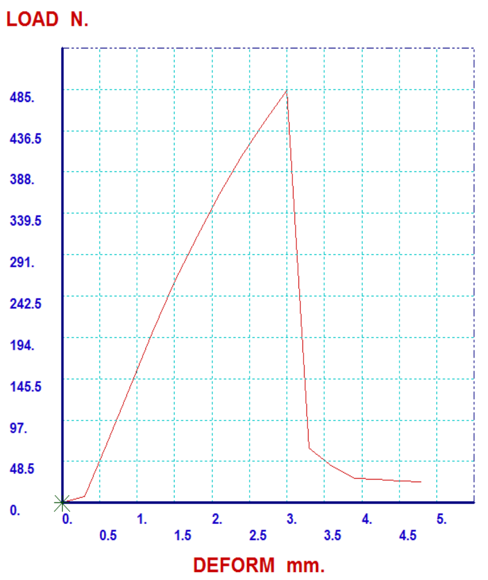
The load is varying from 100 to 200 N and corresponding strength and deformation is noted. Three samples replicates were taken to get the correct response. The average of three were taken and noted in the table 2 .



Glass fiber composite



Jute fiber composite



Flax fiber composite

Figure 4 Load-deformation curves during flexural test for synthetic and natural fiber composite.

Table 1.Tensile and flexural properties of different composite samples.

Sr. No.	Description	ID
1	Glass +Jute + Glass	GJG
2	Glass + Jute + Glass + Jute + Glass	GJGJG
3	Glass+Flax+Glass	GFG
4	Glass+Flax+Glass+ Flax +Glass	GFGFG
5	Glass+Glass+Glass+Glass+Glass	GGGGG
6	Glass+Sisal+Glass	GSG

Table 2. Performance of various composite w.r.t varying load

Exp No	Composite	Load	Tensile Strength (TS) MPa	Flexural Strength (FS)MPa
1	1	1	135.86	165.81
2	1	2	152.58	185.89
3	1	3	161.58	198.36

Load (N) (LD)	100	150	200
Level	1	2	3

4	2	1	155.68	172.65
5	2	2	166.87	176.59
6	2	3	159.32	177.36
7	3	1	144.69	165.69
8	3	2	156.70	168.96
9	3	3	148.32	162.25
10	4	1	148.32	169.26
11	4	2	147.29	169.73
12	4	3	154.69	168.52
13	5	1	136.25	147.63
14	5	2	141.46	152.09
15	5	3	137.63	148.57
16	6	1	142.58	162.65
17	6	2	143.32	163.52
18	6	3	145.32	161.36

Table 3. Analysis of variance (ANOVA) for response tensile strength (TS)

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Model	5	1788.83	357.767	0.67	0.065
Linear	2	80.49	40.243	0.07	0.028
Composite	1	38.06	38.062	0.07	0.095
Load	1	52.38	52.380	0.10	0.060
Square	2	65.75	32.874	0.06	0.041
Composite*Composite	1	65.17	65.168	0.12	0.34
Load*Load	1	0.58	0.580	0.00	0.974
2-Way Interaction	1	22.63	22.633	0.04	0.841
Composite*Load	1	22.63	22.633	0.04	0.841
Error	12	6447.61	537.301		
Total	17	8236.44			

Table 4. Analysis of variance (ANOVA) for response flexural strength (FS)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	4780.6	956.12	0.99	0.063
Linear	2	888.6	444.32	0.46	0.042

Composite	1	635.8	635.77	0.66	0.033
Load	1	158.9	158.90	0.16	0.092
Square	2	524.4	262.20	0.27	0.767
Composite*Composite	1	498.6	498.61	0.52	0.486
Load*Load	1	25.8	25.79	0.03	0.873
2-Way Interaction	1	64.2	64.21	0.07	0.801
Composite*Load	1	64.2	64.21	0.07	0.801
Error	12	11590.4	965.87		
Total	17	16371.0			

ANOVA is carried out to find out the impact of various loads and types of composure on the automatic belongings such as tensile strength and flexural strength. The ANOVA is tabulated in table 3 and table 4 respectively. From the analysis, it is observed that the type of composite is the most influencing parameter followed by the load. The composite with jute and glass shows the well-powered possessions as compared to the other. The impact of various composite and the load is shown in figure 5.

Regression Equation for the response 'TS' is given by Eqn 1.

$$TS = -22 + 3.4\,Composite + 17.9\,Load - 0.122\,Composite{*}Composite - 0.4\,Load{*}Load - 0.32\,Composite{*}Load \quad (1)$$

Regression Equation for the response 'FS' is given by Eqn. 2.

$$FS = 37 - 8.9\,Composite + 39\,Load + 0.338\,Composite{*}Composite - 2.5\,Load{*}Load - 0.54\,Composite{*}Load \quad (2)$$

From the experimentation, it was observed that the composite with jute and Glass (G-J-G) shows the higher value of tensile and flexural strength than the Glass and flax composite and pure glass fibres. This is due to the stiffness of glass fibre is lower than the other reinforced fibers. It has also low density. Jute fibres have a high strength and modulus bonded to a matrix with distinct interfaces between them.

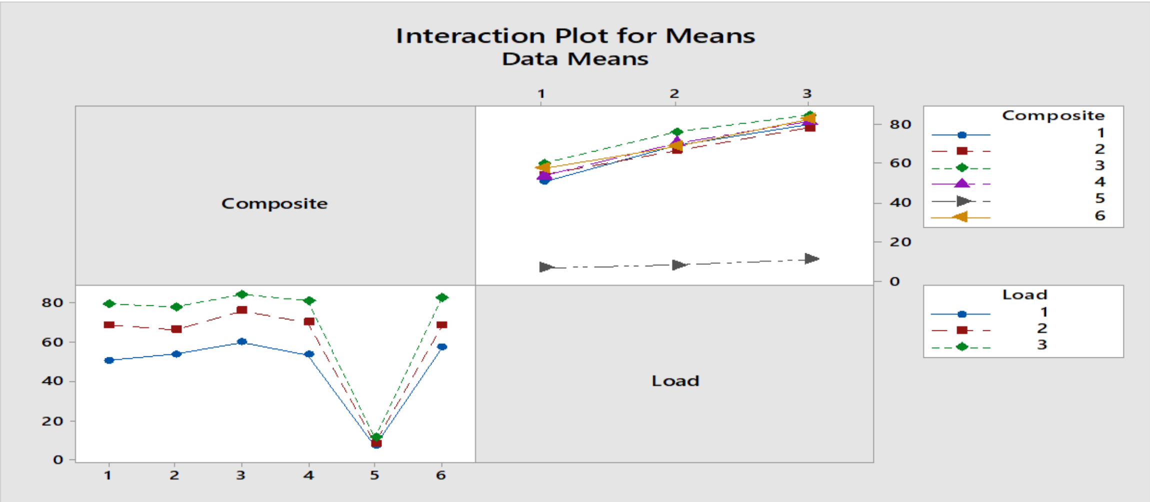


Fig. 5 Interaction plot for mechanical properties FS.

The best composite material (Jute and Glass composite) is used for the further analysis. The leaf spring is manufactured as per the standard dimensions and the performance is compared with the actual leaf spring. The deflection test will be carried out on **Jute glass** fiber composite leaf spring using UTM (Fig 6). The results obtained through the ANSYS analysis is as shown in figure 7(a) to 7 (f). During the analysis, the load is varying from 50 kg to 150 kg as per the recommendation.

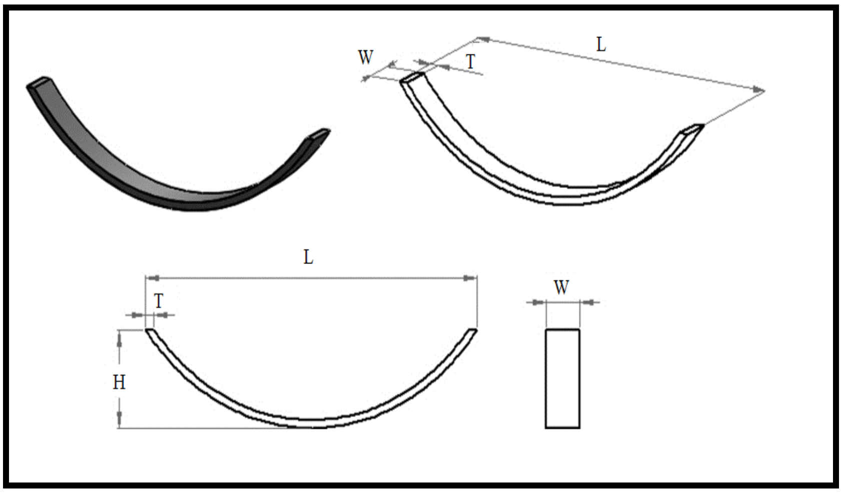
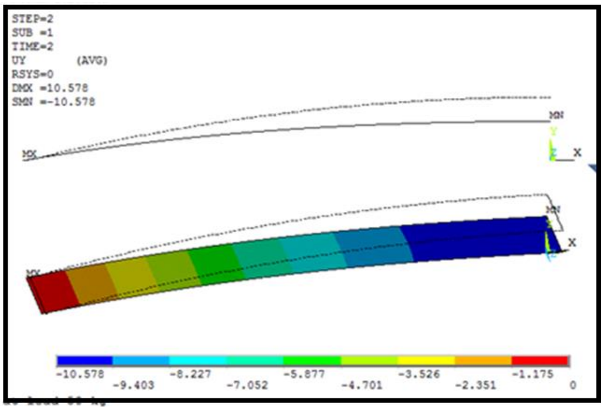


Fig 6- Geometry of the composite leaf spring.



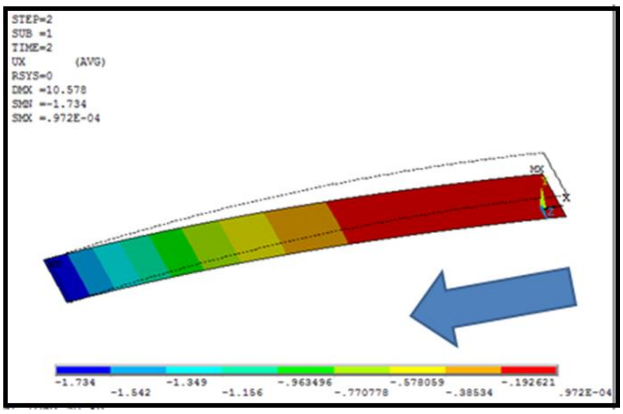
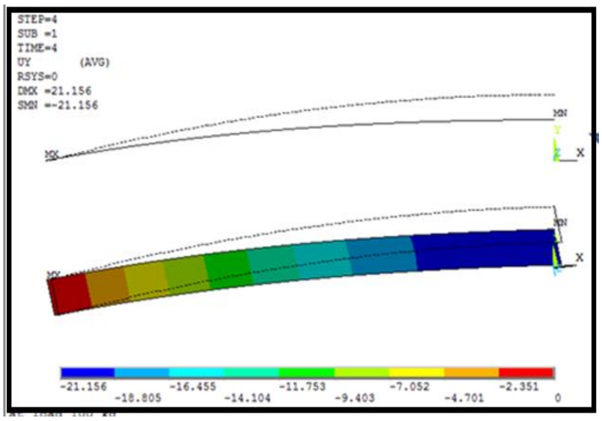


Fig 7 (a) : Vertical deflection @50 kg load **Fig 7 (b) : Horizontal deflection @50 kg load**



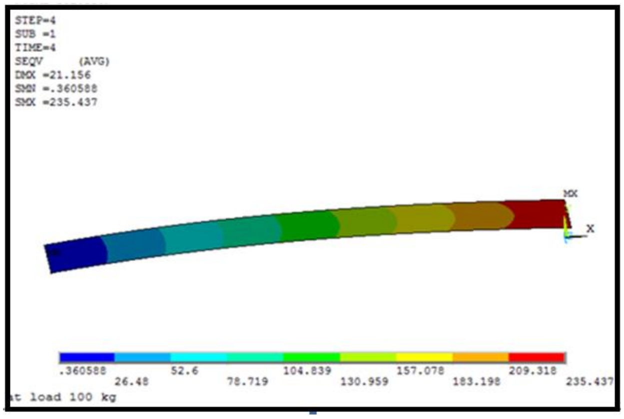
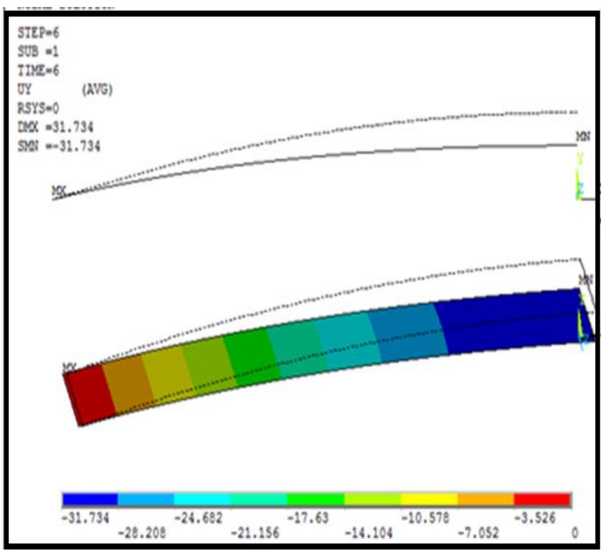


Fig 7 (c) : Vertical deflection @100 kg load **Fig 7 (d) : Horizontal deflection @100 kg load**



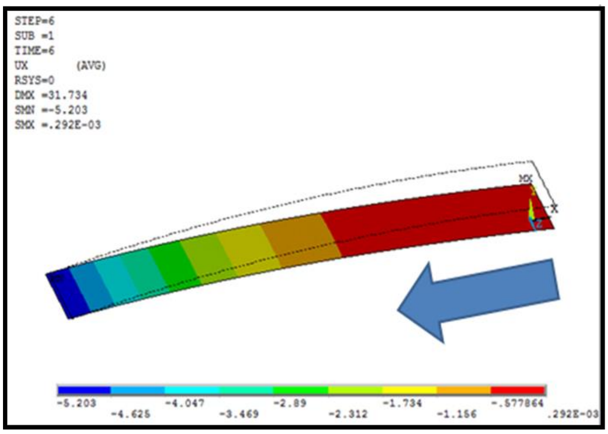


Fig 7 (e) : Vertical deflection @150 kg load **Fig 7 (f) : Horizontal deflection @150 kg load**

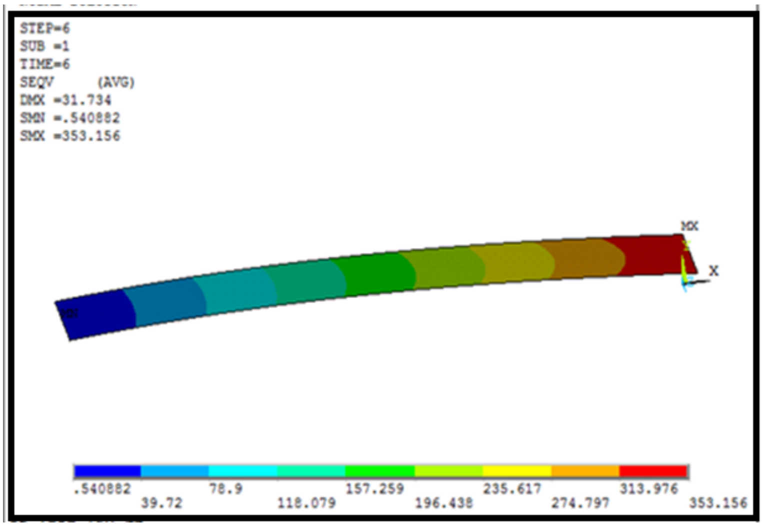


Fig 8: Von-Mises stress in the leaf spring @150Kg load.

The results obtained through software based analysis is shown in figure 7(a) to 7(f) and figure 8 and 9 respectively. The max deflection in the horizontal and vertical directions and von mises stress are determined by giving upto 150 kg vertical load in steps of 50 kg rise, at the center of leaf spring as recommended by the manufacturer of Maruti 800 car. This deflection & von mises stresses are found satisfactory.

Stress and deformation analysis of Composite Leaf Spring

Modulus of Elasticity= 231000 MPa

Poission ratio=0.3

Density = 1464.9kg/m3

Boundary conditions.

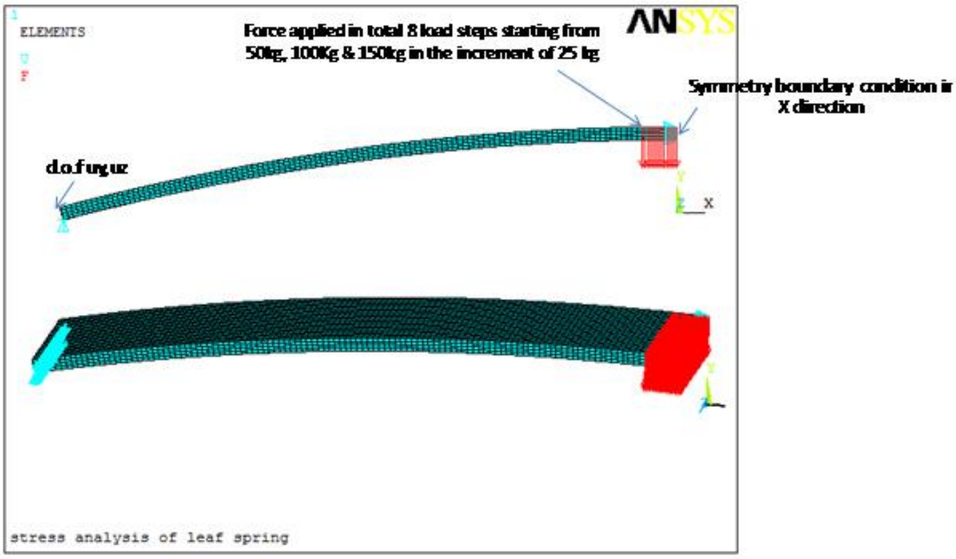


Fig 9: Von-Mises stress in the steel leaf spring under a number of different loads.

A comparison of the vertical deflection caused by pressure on a leaf spring made of Jute flax with one made of glass fibre composite material and one made of steel.

Table 5. Comparative performance analysis of steel and composite spring.

SN	Vertical Load By UTM In Kg	Vertical Deflection In Steel Leaf Spring In mm	Vertical Deflection in Jute glass fiber composite leaf spring In mm	%Difference In Deflection
1	50	10.5	9.62	8
2	100	21.15	19.23	9
3	150	31.7	28.84	9

4. Conclusion

In the present work, the results of the experimental examination into the mechanical characteristics of synthetic and natural fiber hybrid composites at the same fiber volume percent are as follows. The impact of various composites on mechanical properties is also examined. From the experimental findings, the following conclusions were drawn:

- Jute glass fiber composites show favorable mechanical properties amongst all composites tried in the present work.
- The synthetic and natural fiber hybrid composite produced by the VARTM process gives a chance of supplanting existing materials with higher strength, minimal effort elective that is earth benevolent.
- The performance analysis shows the effectiveness of jute glass fiber over the others.
- Taguchi and ANOVA help determine the impact of composites and load over the tensile strength and the flexural strength of a composite.

SN	Vertical Load By UTM In Kg	Vertical Deflection In Steel Leaf Spring In mm	Vertical Deflection in Jute glass fiber composite leaf	%Difference In Deflection

			spring In mm	
1	50	10.5	9.62	8
2	100	21.15	19.23	9
3	150	31.7	28.84	9

References

1. Paul Wambua, Jan Ivens, Ignaas Verpoest.2003, Natural fibres: can they replace glass in fibre reinforced plastics? Composites Science and Technology 63 (2003) 1259–1264
2. M. Asim, KhalinaAbdan, M. Jawaid, M. Nasir, Zahra Dashtizadeh,2015,Review Article. A Review on Pineapple Leaves Fibre and Its Composites. Hindawi Publishing Corporation International Journal of Polymer Science Volume 2015, Article ID 950567, 16 pages
3. M R Sanjay, B Yogesha.2017,Studies on Natural/Glass Fiber Reinforced Polymer Hybrid Composites: An Evolution.Materials Today: Proceedings 4 (2017) 2739–2747
4. El HadiSaidane, Daniel Scida, Mustapha Assarar, Rezak Ayad.2017,Damage mechanisms assessment of hybrid flax-glass fibre composites using acoustic emission.Composite Structures 174 (2017) 1–11
5. E.Nisini,C.Santulli, A. Liverani.2017,Mechanical and impact characterization of hybrid composite laminates with carbon, basalt and flax fibres.Composites Part B 127 (2017) 92 to 99
6. Saeed Manteghia, ZiaMahbooba, ZouheirFawazb, HabibaBougherara.2017,Investigation of the mechanical properties and failure modes of hybrid natural fiber composites for potential bone fracture fixation plates. journal of the mechanical behavior of biomedical materials 65 (2017) 306 – 316
7. M.R. Bambach.,2017,Compression strength of natural fibre composite plates and sections of flax, jute and hemp.ELSEVIER , Thin-Walled Structures [119] 103–113
8. SM Sapuan, Universiti Putra Malaysia, Serdang, Malaysia, KF Tamrin and Y Nukman, University of Malaya, Kuala Lumpur, Malaysia," Natural Fiber-Reinforced Composites: Types, Development, Manufacturing Process, and Measurement."(2017)
9. Mr. Akshay Kumar, Mr. V. J. Shinde and Mr. S. S. Chavan (2014). Design, Analysis, Manufacturing and Testing of Mono Composite Leaf Spring Using UD E -Glass Fiber/Epoxy, International Journal of Advanced Technology in Engineering and ScienceVol. 2, Issue 12, 112-121.
10. Lohitesh Jaga Kumar, Praveen D.N. Experimental and Finite Element Analysis of Sisal Fiber Reinforced Composite.IJRTER.ISSN 2455-1457.
11. Dr. Sachin S. Chavan**.** "Enhancement in Mechanical Properties by VARTM Process & Nylon Nano fibers in Advance Composite Materials" Paripex - Indian Journal ofResearch Vol. 3, Issue 5, June 2013, 112-114.
12. Layth Mohammed, M. N. M. Ansari,1 Grace Pua, Mohammad Jawaid, and M. Saiful Islam.2015, Review Article A Review on Natural Fiber Reinforced Polymer Composite and Its Applications. Hindawi Publishing Corporation International Journal of Polymer Science Volume 2015, Article ID 813568, 2
13. M.R. Bambach.,2017, Compression strength of natural fibre composite plates and sections of flax, jute and hemp. ELSEVIER , Thin-Walled Structures [119] 103–113
14. Juan Pablo Vitale a, Gaston Francucci a, Jian Xiong b, Ariel Stocchi a,2017, Failure mode maps of natural and synthetic fiber reinforced composite sandwich panels. ELSEVIER, Composites: Part A [94] 217–225
15. V. Mittal, R. Saini, S. Sinha.,2016, Natural fiber-mediated epoxy composites e A review. Composites Part B [99] 425 – 435
16. Guilherme Piovezan Otto, Murilo Pereira Mois , Gizilene Carvalho, Andrelson Wel.2017, Mechanical properties of a polyurethane hybrid composite with natural lignocellulosic fibers. ELSEVIER ,Composites Part B [110] 459- 465
17. Guang-Lin Zhao, Feng Gao, Kuo Li, Zhou Wang, Maryam Jahan.,2017, Using natural cotton fibers to synthesize carbon nanotubes and electromagnetic wave absorption properties. Materials Science and Engineering B 224 (2017) 61–68

18. S.V. Joshi, L.T. Drzal, A.K. Mohanty, S. Arora.2004, Are natural fiber composites environmentally superior to glass fiber reinforced composites? Composites: Part A 35 (2004) 371–376
19. Paul Wambua, Jan Ivens, Ignaas Verpoest.2003, Natural fibres: can they replace glass in fibre reinforced plastics? Composites Science and Technology 63 (2003) 1259–1264
20. Taweesak Piyatuchsananon, Akira Furuya,1 Baosheng Ren, and Koichi Goda.2015, Research Article Effect of Fiber Waviness on Tensile Strength of a Flax-Sliver-Reinforced Composite Material. Hindawi Publishing Corporation Advances in Materials Science and Engineering Volume 2015, Article ID 345398, 8
21. R.M.N. Arib S.M. Sapuan, M.M.H.M. Ahmad a,,2006, Mechanical properties of pineapple leaf fibre reinforced polypropylene composites. Materials and Design 27 (2006) 391–396
22. R.Singh, M. Narwariya, A. K. Sharma, P.S.Chauhan.2022, Design and fabrication of Epoxy-based hip implant 13(4) (2022) 346-359.
23. H.Mithun, M. Krishna, B. Shrikanth.2021, The effect of bonded stepped and scarf repair on impact damaged glass fibre reinforced polymer composite properties. 12(3) (2021) 234-245.