Evaluation of Thermal Properties of a Plastic Gears Composed of Sugar Bagasse Reinforced with Polyester/ Graphene Blends

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Abstract
Currently, bagasse sugarcane, a waste product of the sugar industry, is mainly burned as fuel in sugar mill boilers. The low cost, low density and acceptable mechanical properties of bagasse fibre make it an ideal candidate to be considered for value-added applications such as reinforcement in plastic composites. In this by varying the composition of bagasse sugarcane with graphene as the filler material five specimens are prepared. The Structural deformation, bending stress and strain of gears with different materials are analyzed through ANSYS software. The heat flow rate on the surface of the gear tooth is analyzed with the help of CFD software under dry and wet run condition. The performance of the gears under various speeds and torques are observed in this work.

Keywords: Sugarcane bagasse, Graphene, Ansys, CFD, Heat flow rate, tooths Surface.

1.Introduction

Now-a-days natural fibers such as banana, pineapple, and flax fiber composite materials are replacing the glass and carbon fibers owing to their easy availability and cost. Natural fibers may play an important role in developing biodegradable composites to resolve the current ecological and environmental problems. Natural fibers are lighter and cheaper, but they have low mechanical properties than glass fibers. By use of hybrid fibers may solve this issue. Most of the studies on natural fibers are concerned with single reinforcement. The addition of natural fibers to the glass fiber can make the composite hybrid which is comparatively cheaper and easy to use. Natural fibers are chosen as reinforcement because they can reduce the tool wear when processing, Respiratory irritation and serves as alternatives for artificial fiber composites in the increasing global energy crisis and ecological risks. A fiber reinforced polymer is a composite material consisting of a polymer matrix embedded with high strength fibers, such as glass, aramid and carbon. The major advantages of composite materials are that they have a high ratio of stiffness to weight and strength to weight. A principal advantage of composite materials lies in the ability of the designer to tailor the material properties to the application.

2.Literature Review

Barnasree, Kumar, and Bhowmik et. al. [1] were studied wood dust particle reinforced in epoxy based composite for analysis of mechanical behavior. The sundy wood dust particle used as reinforcement and LY 556 epoxy for resin. The six different percentage of filler particle used in study. Tensile and flexural test were carried out using UTM and sample size based on ASTM Standard. The different design parameters like as filler content and speed for loading with tensile and flexural strength using GRA were optimized. Optimization by GRA has the advantage of selecting best and worst options. GRG shows that test run number 13 is the best suited and test run number 3 is the least important. Epoxy composite with 10 filler contents (wt%) at corresponding speed of 1 mm/min shows best performance and on the other hand with 0 filler content (wt%) at the speed of 3 mm/min shows the worst performance.

Motaung and Anandjiwala et. al. [2] studied of behavior of sugar cane bagasse particle reinforced composite like as, thermal degradation and kinetics of the untreated, alkali treated and sulphuric acid treated sugar cane bagasse (SB). It had been estimated by non-isothermal thermogravimetric investigation under nitrogen atmosphere The alkali treated fabricated samples represent the maximum values of thermal degradation. FTIR and XRD established different functionalization with fiber surface and improved crystallinity. The NaOH treated sample exposed the maximum thermal stability with acid treated samples presented the lowest.

Dinesh and Jagdish et. al. [3] research focused on wear study of sisal fiber reinforced epoxy based composite materials. LY-556 and HY 951 used as resin and hardener respectively. 10%, 20%, and 30% sisal fiber used as reinforcement during fabrication of composite by had lay-up method. By increasing the percentage of the sisal fiber in fabrication work enhance the weight loss of the specimen of wear test. SFRECM can be used as substitute materials for human Orthopedic Implants.

Rout and sahoo et. al. [4] studied with analysis of erosion wear process of nonlinear problem with operating variables. The wear behavior of material depends on numerous constraints like as impact velocity, impingement angle, material, erodent size, etc. To obtain minimum rate of erosion, conduct experiments with the material having combination of these parameters. Waste granite powder was considering as filler in the jute fiber in reinforced epoxy composite. It was concluded, industrial waste like as granite powder can be utilized to produce low cost natural fiber reinforced composite. Also, chemical treatment of fiber and filler had enhanced erosion resistance of composite samples.

3.Design and Development of Gear

Table 1 Gear Geometry

S NO	GEAR	GEOMETRY
1	Type	Spur
2	Pressure angle	20^0
3	Module	2
4	Diameter of Pitch circle (mm)	34
5	Diameter of Tip circle (mm)	38
6	Diameter of Root circle (mm)	29
7	No. of teeth	17
8	Face width (mm)	6
9	Diameter of Hub (mm)	18
10	Diameter of Bore (mm)	12

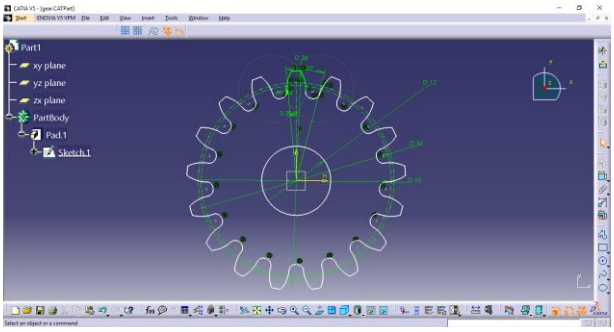

Figure 1 Sketch view of Composite spur gear

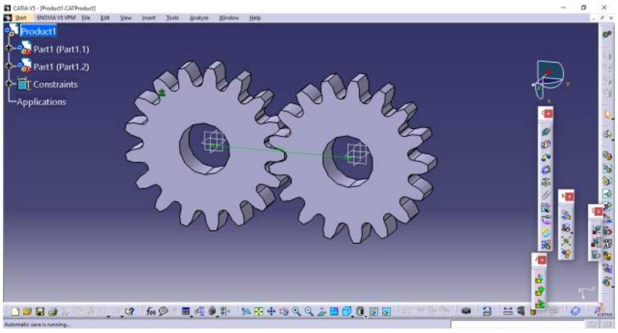

Figure 2 Gear pair assembly model in catia

Table 2 Material Specification

S.NO	SPECIMEN CODE	POLYESTER MATRIX	SUGAR BAGASSE FIBER	GRAPHENE FILLER
1	E	100% (Pure)	---	----
2	D	90%	10%	----
3	C	80%	15%	5%
4	B	70%	20%	10%
5	A	70%	10%	20%

Table 3 Material Properties

CODE	YOUNGS MODULUS	POISSION RATIO	YIELD STRESS	TANGENT MODULUS	DENSITY
	G.Pa		M.P	M.Pa	Kg/M3

			a		
E	3.5	0.4	16.9	1.6	800
D	2.63	0.32	12.73	1.2	868
C	2.78	0.3	13.46	1.27	880
B	2.38	0.26	11.5	1.08	1000
A	2.11	0.28	10.22	0.96	1030

3.1 Analysis of Designed Gear Using Ansys

Thin gearing is one of the most important components in a mechanical power transmission system, and in industrial rotating machinery. It is possible that thin gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of thin gear technology. A pair of gear teeth in action is generally subjected to two types of cyclic stresses: bending stresses inducing bending fatigue and contact stress causing contact fatigue. Both these types of stresses may not attain their maximum values at the same point of contact. However, combined action of both of them is the reason of failure of thin gear tooth leading to fracture at the root of a tooth under bending fatigue and surface failure, like pitting or flaking due to contact fatigue. In addition, there may be surface damage associated seizure of surfaces due to poor lubrication and overloading. The seizure of surfaces leading to welding is usually prevented by proper lubrication so that there is always a very thin film of lubricant between a pair of gear teeth in motion. However, the fracture failure at the root due to bending stress and pitting and flaking of the surfaces due to contact stress cannot be fully avoided. These types of failures can be minimized by careful analysis of the problem during the design stage and creating proper tooth surface profile with proper manufacturing methods. In spite of all the cares, these stresses are sometimes very high either due to overloading or wear of surfaces with use and need proper investigation to accurately predict them under stabilized working conditioned so that unforeseen failure of thin gear tooth can be minimized.

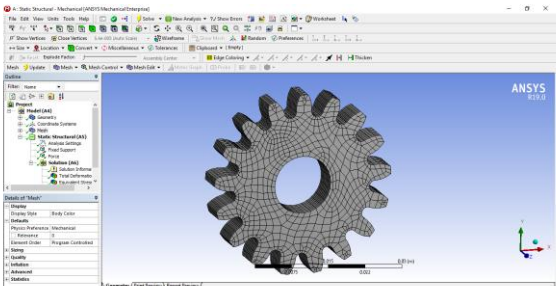

Figure 3 FE Model of a Spur Gear

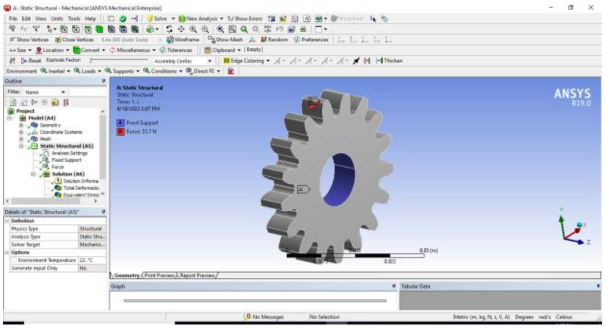

Figure 4 Boundary Conditions of a Spur Gear

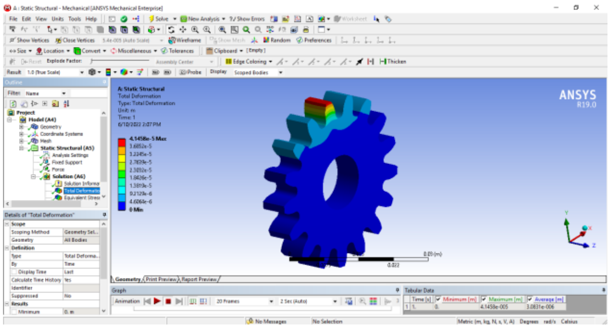

Figure 5 Deformation of a Test Specimen E

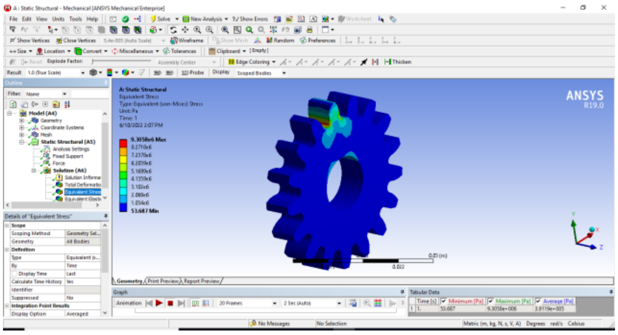

Figure 6 Stress of a Test Specimen E

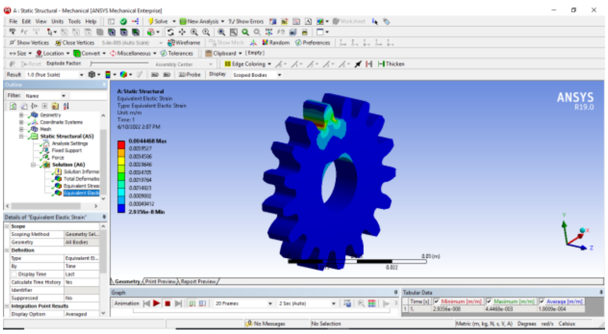

Figure 7 Strain of a Test Specimen E

3.2 Analysis of Designed Gear Using CFD

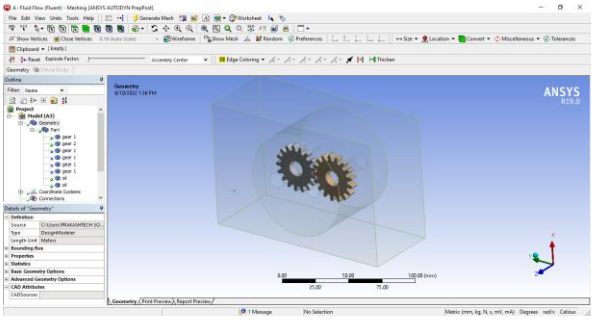

Figure 8 Meshing of a Gear under wetting Condition

Boundary conditions are used according to the need of the model. There is no inlet and outlet of boundary. The walls are separately specified with respective boundary conditions. No slip condition is considered for each wall. The gear1 is selected as rotate member with Z axis with 50 to 150 RPM. Another gear is taken as another direction with same speed. The details about all boundary conditions can be seen below.

Gas speeds: 50,75,100 and 150 Rpm

The number of iterations is set to 500 and the solution is calculated and various contours, vectors and plots are obtained.

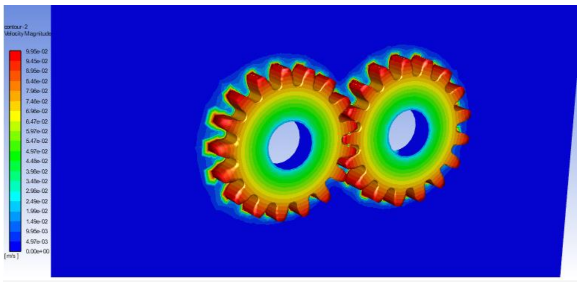

Figure 9 Velocity Distributions of Gears under Lubrication

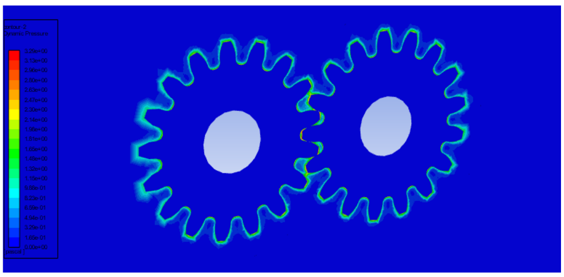

Figure 10 Dynamic Pressure Distributions of Gears under Lubrication

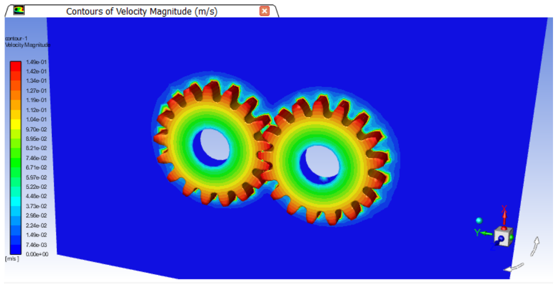

Figure 11 Velocity of Gear at 75 RPM

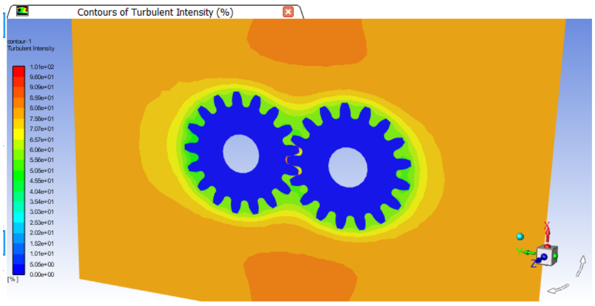

Figure 12 Turbulence of gears under Meshing

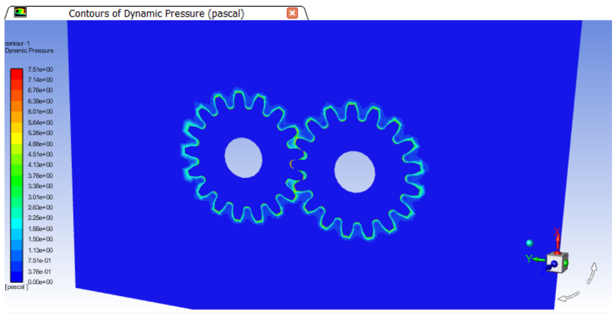

Figure 13 Dynamic Pressure Distribution of gears under lubrication at 75 RPM

4.Results and Discussions

In this work experimental work has done to find out the structural strength of specimens.
Objective of work is analyzing the tensile strength, flexural strength, impact and compressive strength of Sugar Bagasse fiber composite materials is utilized in this work to analyze the strength. the below table shows the ANSYS tensile testing results for composite material.

Table 4 Structural Analysis of Test Specimens

SPECIMEN	**E**	**D**	**C**	**B**	**A**
Deformation in mm	0.025	0.033	0.031	0.0367	0.0414

Stress in M.Pa	9.426	9.281	9.29	9.32	9.305
Strain in mm/mm	0.00271	0.00355	0.0033	0.0039	0.0044

Table 5 Structural Analysis of Test Specimens

SPECIMEN	**E**	**D**	**C**	**B**	**A**
factor of safety	1.79	1.37	1.44	1.23	1.09

Table 6 CFD Analysis of Test Specimens

RPM	**VELOCITY OF LUBRICANT IN M/SEC**	**DYNAMIC PRESSURE IN PA**
50	9.96E-02	3.29
75	1.49E-01	7.51
100	0.33	10.5
150	0.51	13.41

5.Conclusion

By varying the composition of bagasse sugarcane with graphene as the filler material five specimens are prepared. The Structural deformation, bending stress and strain of gears with different materials are analyzed through ANSYS software. The heat flow rate on the surface of the gear tooth is analyzed with the help of CFD software under dry and wet run condition. The performance of the gears under various speeds and torques are observed in this work. The stresses for all material are between 9M.Pa, the safety factor of the specimen A is high when compared to other specimens. The specimen A is used in geared material of a low load bearing applications. CFD analysis is performed on gear with 20W motor under SAE 50 lubricant to understand the heat flow rate on the flank of manufactured gears.

Acknowledgement
None

Conflicts of interest
The authors have no conflicts of interest to declare.

Author's Contribution Statement

P N E Naveen: Conceptualization, formal analysis, methodology, validation and writing draft. **Usha Rani:** Conceptualization, formal analysis, methodology, validation and writing draft. **Teja:** Conceptualization, formal analysis and methodology

References

[1] B Chanda, R Kumar, K Kumar and S Bhowmik. Optimisation of Mechanical Properties of Wood Dust-reinforced Epoxy Composite Using Grey Relational Analysis. © Springer India 2015

[2] T E Motaung, R D Anandjiwala. Effect of alkali and acid treatment on thermal degradation kinetics of sugar cane bagasse. Industrial Crops and Products 74 (2015) 472–477.

[3] K R Dinesh, S P Jagadish, A Thimmanagouda. Characterization and analysis of wear study on sisal fibre reinforcement epoxy composite materials used as orthopedic implant. International Journal of Advances in Engineering & Technology, Jan. 2014.

[4] L k rout, S S sahoo. Study on erosion wear performance of jute-epoxy composites filled with industrial wastes using Taguchi methodology. Proceedings of second IRF international conference, 30th november-2014, mysore, India, ISBN: 978-93-84209-69-8.

[5] A K Rout, S S Sahoo. Study on erosion wear performance of jute-epoxy composites filled with industrial wastes using taguchi methodology. Proceedings of Second IRF International Conference, 30-11-2014, Mysore, India, ISBN: 978-93- 84209-69-8.

[6] D J O Brien, W K Chin, L R Long, E D Wetzel.Polymer matrix, polymer ribbon-reinforced transparent composite materials. Composites: Part A 56 (2014) 161–171

[7]Qinglin Wu, Kai Chi, Yiqiang Wu, Sunyoung Lee. Mechanical, thermal expansion, and flammability properties of coextruded wood polymer composites with basalt fiber reinforced shells. Materials and Design 60 (2014) 334–342.

[8]Y Karaduman, M M A Sayeed, L Onal, A Rawal. Viscoelastic Properties of Surface Modified Jute Fiber/ Polypropylene Nonwoven Composites, Composites: Part B (2014).

[9]R Kumar, K Kumar, P Sahoo and S Bhowmik. Study of Mechanical Properties of Wood Dust Reinforced Epoxy Composite. Procedia Materials Science 6 (2014) 551 – 556.