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Comparative Analysis of Metallic and Hybrid Spur Gears

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ABSTRACT

In this thesis, comparative analysis is performed on a lathe machine tumbler gear mechanism using metallic gears and hybrid gear. The analysis is performed by taking metals Cast Iron, Aluminum alloy for metallic gears. For hybrid gear, the materials for teeth ring and hub are Cast Iron, Aluminum alloy and materials for hexagonal web and two outer parts is using Carbon Fiber composite material. 3D model of the gear mechanism is done in Pro/Engineer. Theoretical calculations are done to determine forces. Static structural, Modal and Random Vibration analysis are done on the metallic gears and hybrid gears and compared. Analysis is done in Ansys.

1. INTRODUCTION

Gears are the most useful and common means of transmitting motion and power in the today modern engineering field. They vary from tiny size used in watches to the large gears used in the lifting devices and speed reducers. Gears are the valuable mechanical element of mechanism such as rolling machinery, metal cutting machinery and automotive machinery.

There are different materials used as a gear material. Gear materials are used as per the type of application of power transmission and loading condition. All material are not providing similar properties during working condition due to their different structure and bonding nature. Materials are to be required to check under loading conditions to find their beneficial properties and remove unnecessary properties during the selection of material. When gears are in a loading condition, mainly two types of failure are produced in gear material like as bending failure due to low bending strength of material and pitting or contact failure due to lower strength of contact area of gear teeth.

LITERATURE REVIEW

The following papers were studied for this project:
In the paper by Sanjay K. Khavdu[1], main purpose of this study is to reduce weight of this gear mechanism by checking possibility of replacement of all metallic gears with composite hybrid gears in that gear mechanism. And a weight calculation is done using ANSYS workbench v11.

In the paper by Sanjay K. Khavdu[2], Gear is the special division of Mechanical Engineering concerned with the transmission of power and motion between the rotating shafts. In this study, a lathe machine tumbler gear mechanism used for threading purpose is taken and applied finite element analysis methodology on each metallic spur gears. Main purpose of this study is to compare FEA stresses of metallic spur gears with the AGMA standard stress. Modeling of gears is done in PRO-ENGINEERING and analysis is done using ANSYS workbench v11.

MODELING OF LATHE GEAR MECHANISM

The reference for modeling is taken from the journal "Comparative finite element analysis of metallic spur gear and hybrid spur gear" by Sanjay K. Khavdu, Prof. Kevin M. Vyas, IAEME: www.iaeme.com/IJMET.asp, Volume 6, Issue 4, April (2015), pp. 117-125

FORCE CALCULATIONS

Torque $T = (P \times 60) / 2\pi N$
Tangential force $F_t = 2000\ T / D_p$

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Normal force $F_n = F_t / \cos\alpha$

ORIGINAL METALLIC GEAR

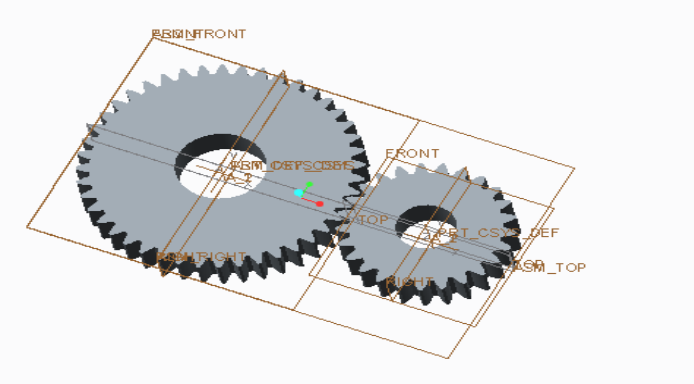


Fig 1-Assembly of Gear Pair

HYBRID GEAR

Figure shows the hybrid gear in which there are 5 components metallic teeth ring and metallic hub, hexagonal web and two outer composites as shown in figure.

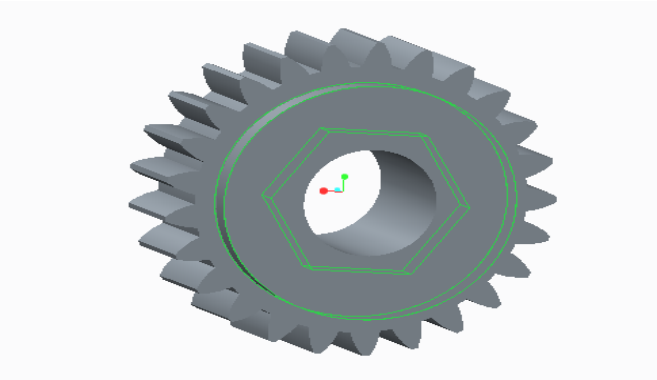


Fig 2 – Final Assembly of Hybrid Gear

ANALYSIS OF METALLIC AND HYBRID GEARS

The forces are taken from the theoretical calculations.

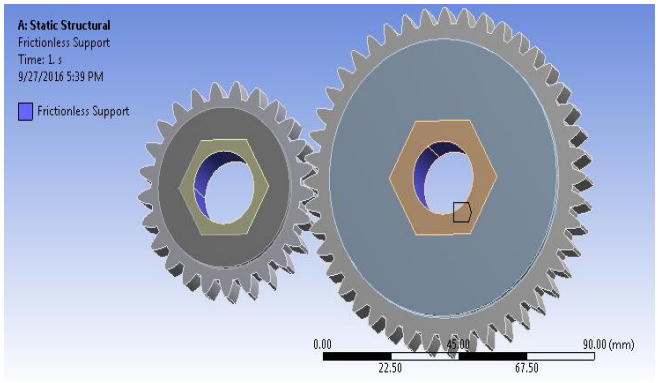
HYBRID GEAR

STRUCTURAL ANALYSIS

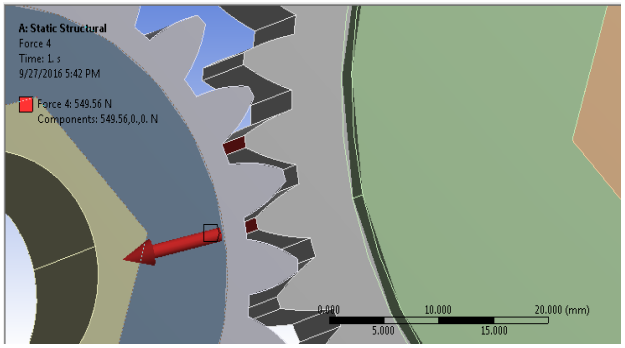
CAST IRON AND CARBON FIBER

Cast Iron for teeth ring, hub and Carbon Fiber for hexagonal web and two outer parts

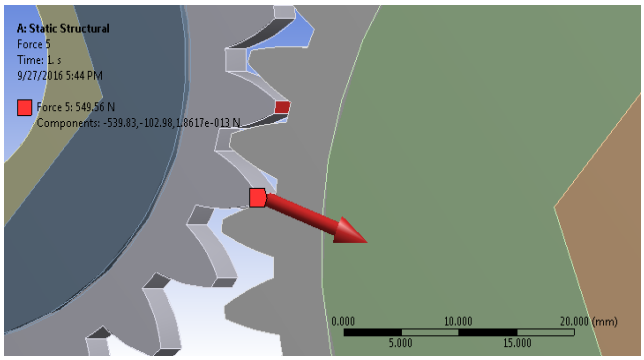
FRICTIONLESS SUPPORT



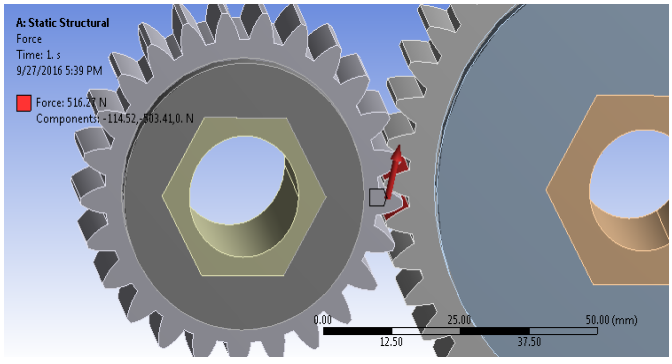
Normal force



Normal force



Tangential force



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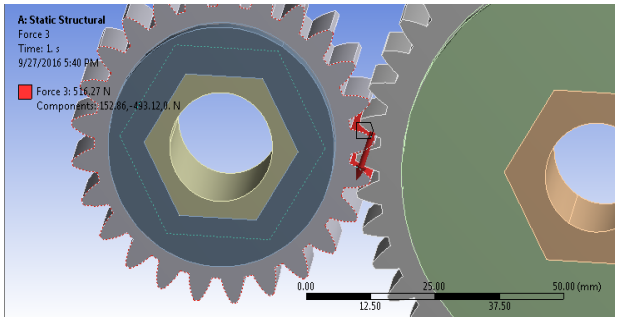
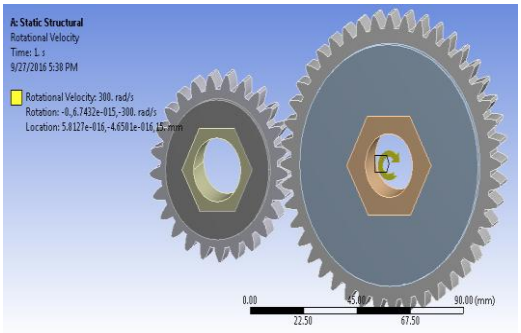
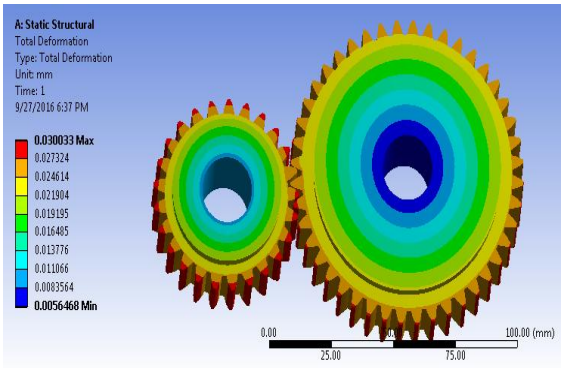
Tangential force



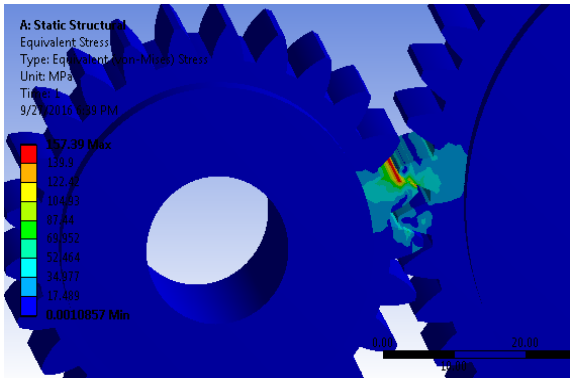
ROTATIONAL



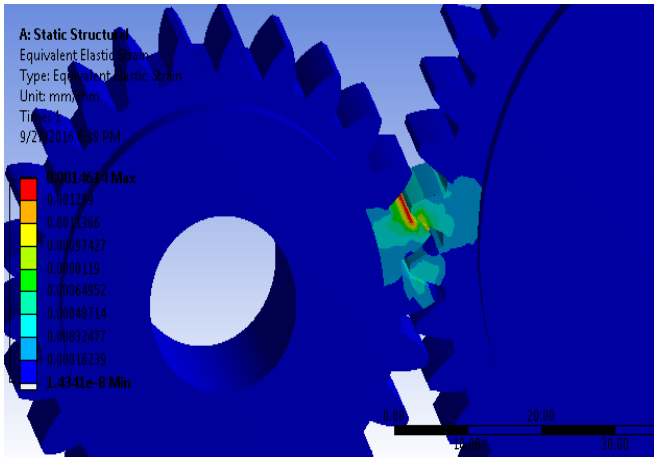
DEFORMATION



STRESS

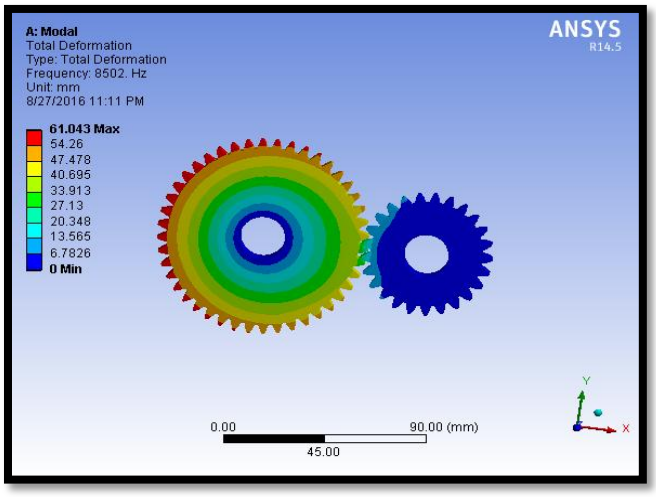


STRAIN

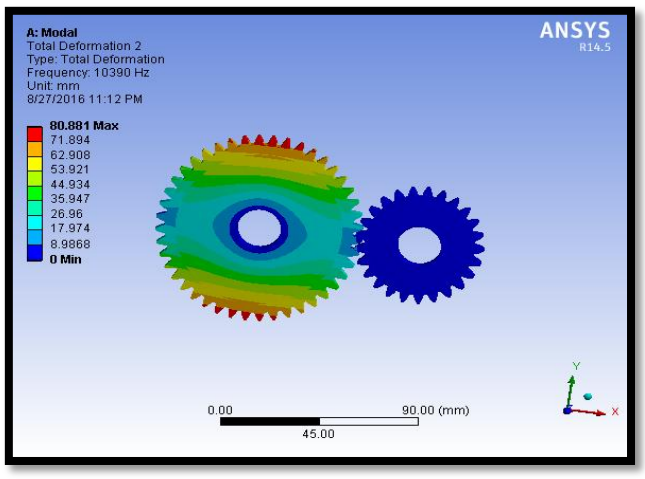


MODAL ANALYSIS

MODE 1



MODE 2



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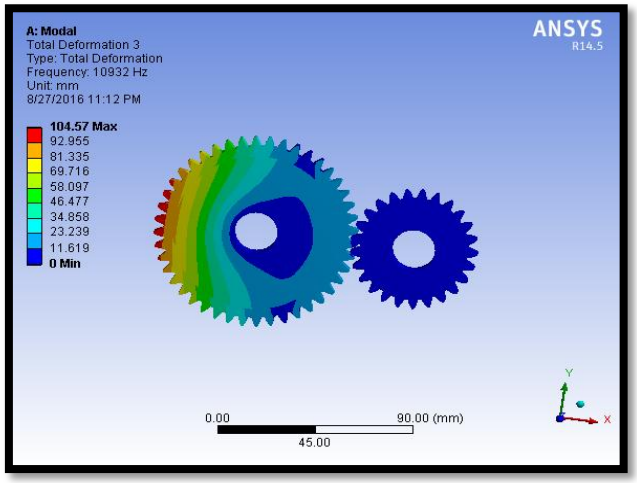
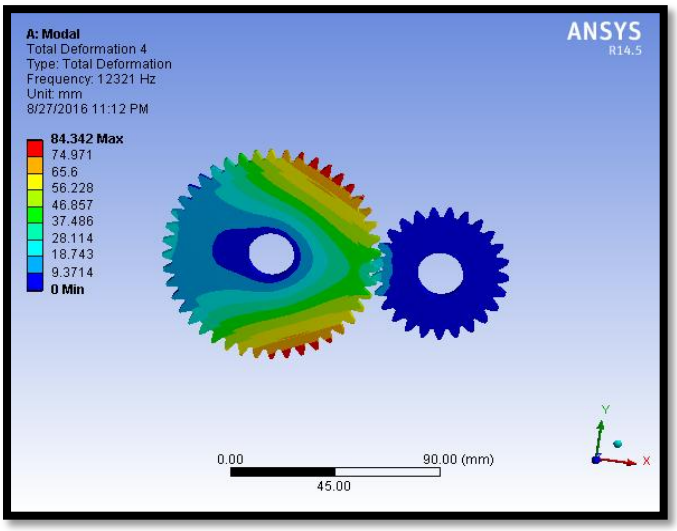
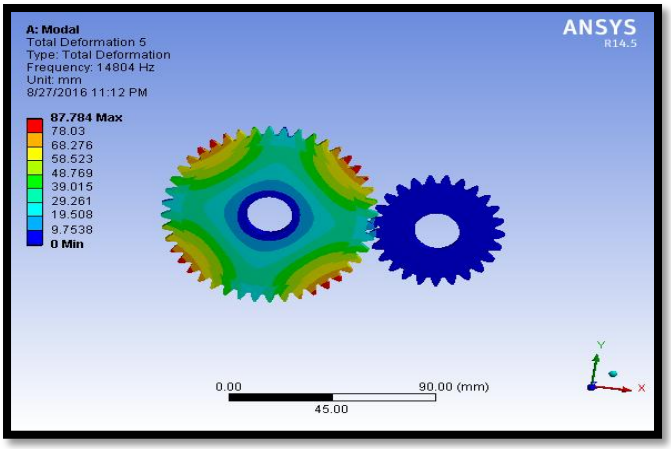
MODE 3



MODE 4

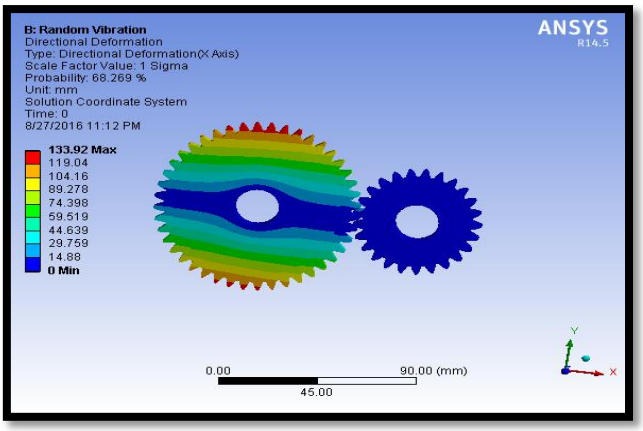


MODE 5

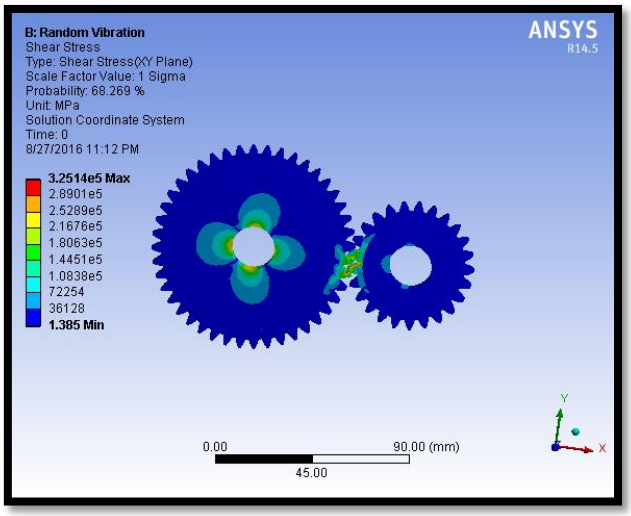


RANDOM VIBRATIONAL ANALYSIS

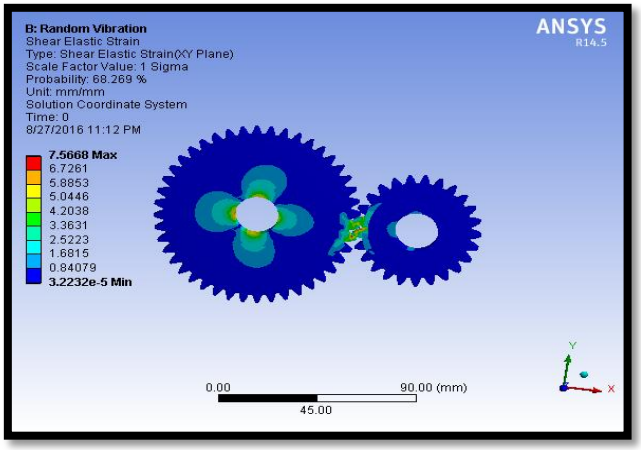
Directional Deformation



Shear stress



Shear strain



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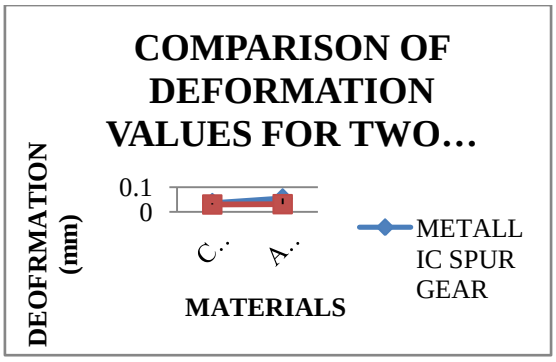
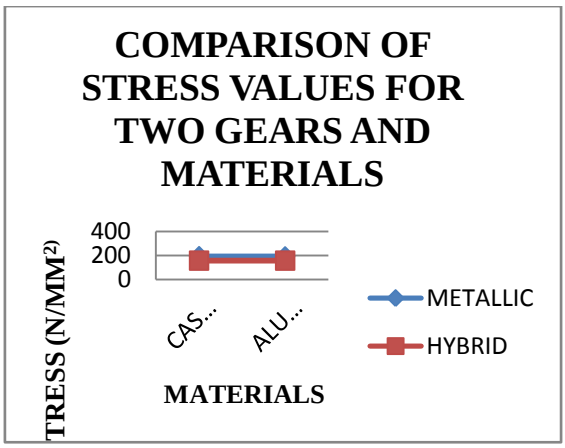
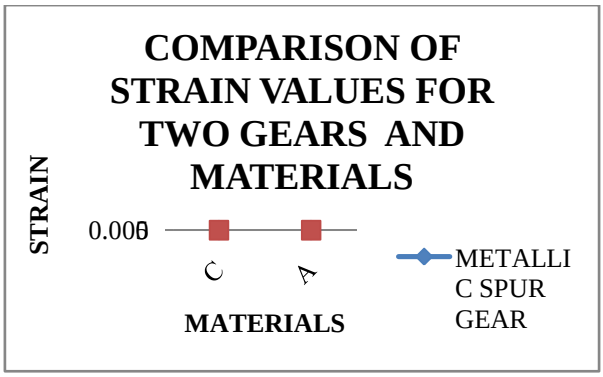
RESULTS AND DISCUSSION

STRUCTURAL ANALYSIS

Materials	Metallic			Hybrid		
	Deformation (mm)	Stress (MPa)	Strain	Deformation (mm)	Stress (MPa)	Strain
Cast iron	0.035505	193.52	0.00017614	0.030033	157.39	0.0014614
Aluminum alloy	0.054245	191.45	0.0027025	0.030852	157.43	0.0014624

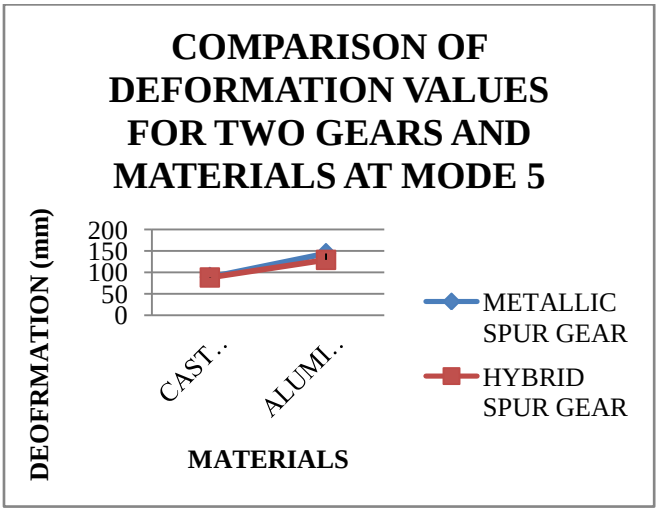


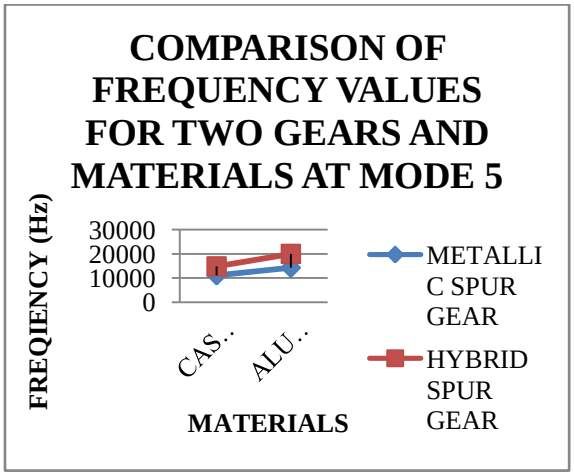




MODAL ANALYSIS

	Materials	Metallic		Hybrid	
		Cast iron	Aluminum alloy	Cast iron	Aluminum alloy
MODE 1	Frequency(Hz)	9440.9	12287	8502	10520
	Deformation(mm)	83.51	133.9	61.043	88.065
MODE 2	Frequency(Hz)	9730.3	12676	10390	13499
	Deformation(mm)	113.41	186.23	80.881	116.64
MODE 3	Frequency(Hz)	10181	12968	10932	14302
	Deformation(mm)	59.235	95.573	104.57	150.54
MODE 4	Frequency(Hz)	10398	13496	12321	16202
	Deformation(mm)	94.123	151.94	84.342	116.24
MODE 5	Frequency(Hz)	11145	14268	14804	19964
	Deformation(mm)	89.037	144.41	87.784	129.12





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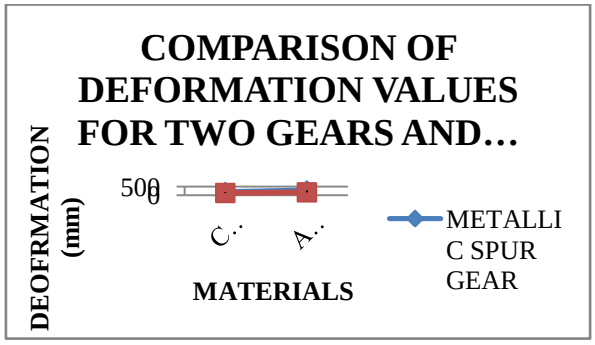
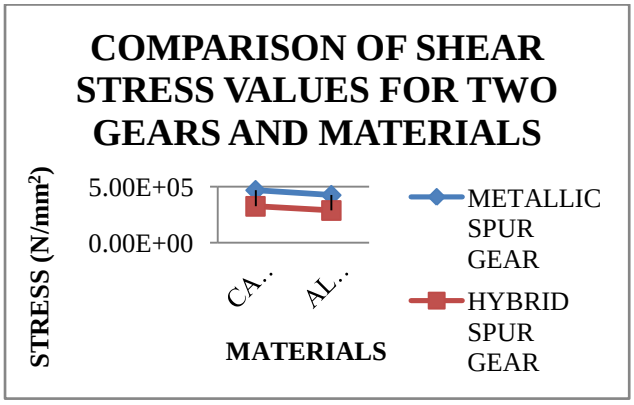
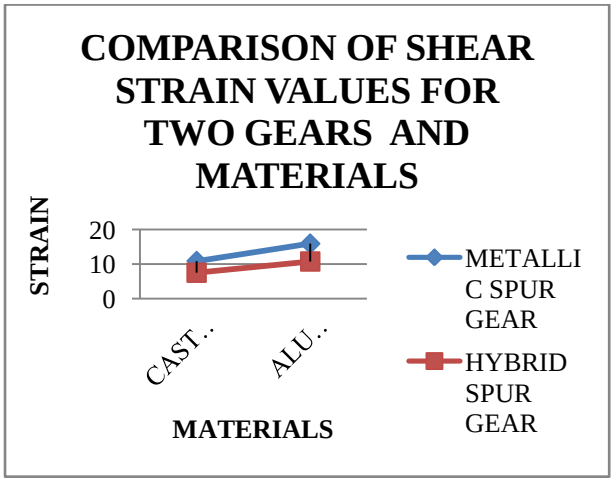
RANDOM VIBRATIONAL ANALYSIS

Materials	Metallic			Hybrid		
	Deformation (mm)	Shear Stress(N/mm²)	Shear Strain	Deformation (mm)	Shear Stress(N/mm²)	Shear Strain
Cast iron	195.78	4.6882e^{5}	10.911	133.92	3.2514e^{5}	7.5668
Aluminium alloy	284.94	4.2503e^{5}	15.924	169.55	2.8834e^{5}	10.803







CONCLUSION

By observing static analysis results, the deformations and stress values are decreasing for hybrid gear than metallic gear. The stresses are decreasing by 18.66% for hybrid gear using Cast Iron with Carbon Fiber than Cast Iron metallic gear and decreasing by 17.78% for hybrid gear using Aluminum with Carbon Fiber than Aluminum metallic gear. By observing the modal analysis results, the frequencies and deformations are reduced for hybrid gear than metallic gear. As the frequencies are reduced, the vibrations for the hybrid gear are lesser. By observing the random vibration analysis, the directional deformations and shear stresses are less for hybrid gear than metallic gear due to lesser frequencies. The shear stresses are decreasing by 30.66% for hybrid gear using Cast Iron with Carbon Fiber than Cast Iron metallic gear and decreasing by 32.16% for hybrid gear using Cast Iron with Carbon Fiber than Cast Iron metallic gear.

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