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# Design and Finite Element Analysis of Metallic Spur Gear and Hybrid Spur Gear

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## ABSTRACT:

In this thesis, comparative analysis is performed on a lathe machine tumbler gear mechanism utilizing metallic gears and hybrid gear. The analysis is performed by taking metals Aluminum alloy, Cast Iron in case of metallic gears. For hybrid gear, the materials for teeth ring and hub are Cast Iron, Aluminum alloy alloy and material for hexagonal hub and 2 outer components is utilizing Carbon Fiber material.3D model of the gear is done in Pro/Engineer. Theoretical calculations are done to calculate forces. Static structural, Modal and Random Vibration analysis are done on the metallic gears and hybrid gears and compared. Analysis is done in Ansys.

## INTRODUCTION TO GEARS

A part of a rotating machine which has cut teeth or cogs that meshes with another toothed part so as to transmit torque is known as a gear. Two or more gears operating tandemly are referred to as a transmission and by a gear ratio can produce mechanical advantage and therefore could also be thought-about as a simple machine. Speed, direction of a source power and magnitude can be modified by Geared devices. The foremost common scenario is for a gear to mesh with another gear, but a gear may also mesh a non-rotating toothed component, referred to as a rack, thereby translation is produced in place of rotation. Spur gears are the foremost common variety of gears. Spur gearshave straight teeth, and are mounted on parallel shafts. Sometimes, creations of large gear reductions, several spur gears are utilized directly. In the available gears, spur gears are the simplest. They're additionally the foremost usually utilized gears within the market.

In the form of a disk or cylinder generally Spur Gears are found. To vary the speed and force of a rotating shaft these gears are applied. These gears have straight teeth. They're typically mounted on parallel shafts. Of late principally the tooth form is predicated on the in volute curve. For making giant gear reductions, several spur gears are utilized together.

## LITERATURE REVIEW

The following papers were studied for this project: Sanjay K. Khavdu[1], main aim of this thesis is of weight reduction of gear mechanism by possible replacing of all metallic gears with composite hybrid gears in that gear mechanism. And calculation of weight is done utilizing ANSYS workbench v11. Robert F. Handschuh[3], Fabrication and testing of Composite spur gears was done at NASA Glenn Research Centre. To mount to shaft where torque is applied the composite material served as the web of the gear between the gear teeth and a metallic hub. The composite web was secured solely to the inner and outer polygonal hexagonal features that were machined from spur gear which is initially aerospace quality. The testing is done on the Hybrid Gear against an all-steel gear and a mating Hybrid Gear. As a result of the composite to metal fabrication method utilized, the concentricity of the gears were cut back from their initial high preciseness worth. No matter the concentricity error, the hybrid gears operated with success for over three hundred million cycles at ten thousand rpm and 553 in.*lb torque. Though the planning wasn't weight optimized, the composite gears were found to be 20% lighter than the all-steel gears.

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Free vibration modes and vibration/noise tests were conjointly performed so that the vibration and damping characteristic of the Hybrid Gear to all-steel gears was compared. The initial results indicate that this sort of hybrid design might have a dramatic impact on drive system weight while not sacrificing strength.

## 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

**Considering the module =2, number of teeth = 18 and $20^0$ full depth**

Torque $T = (P \times 60) / 2\pi N$

Tangential force $F_t = 2000\ T / D_p$

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

## ORIGINAL METALLIC GEAR

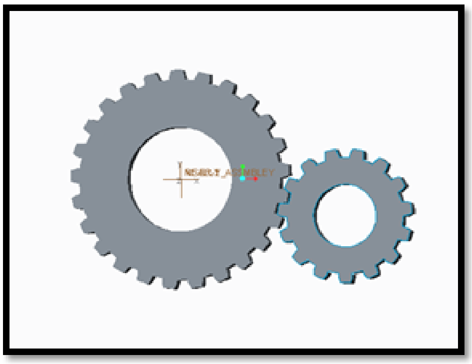

Fig – Assembly of Gear Pair

## 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 – Assembly of hybrid Gear Pair

## ANALYSIS OF METALLIC AND HYBRID GEARS

## HYBRID GEAR

## CAST IRON AND CARBON FIBER

For hybrid gear, the materials considered are Cast Iron for teeth ring, hub and Carbon Fiber for hexagonal web and two outer parts. The boundary conditions are same as that of metallic gear.

## STATIC ANALYSIS

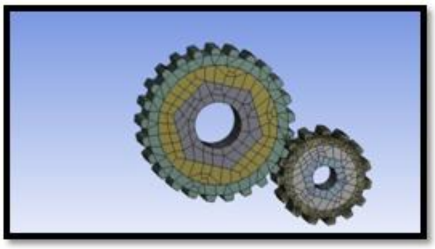

Fig - Meshed model

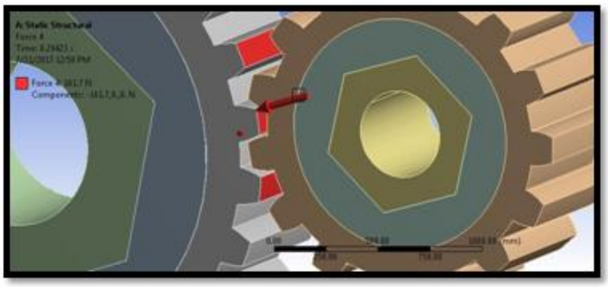

Fig - Normal force

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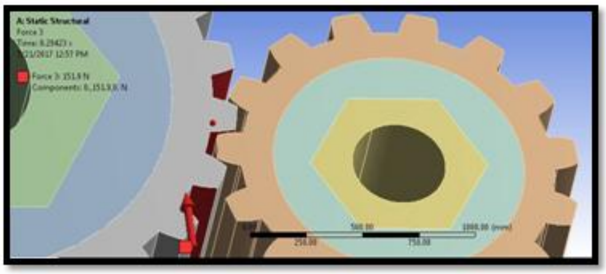

Fig - Tangential force

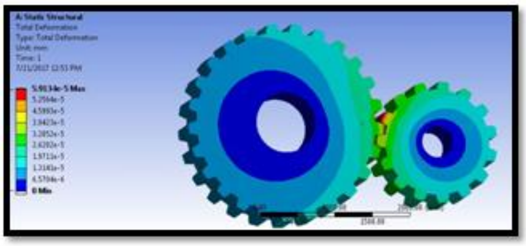

Fig – Deformation

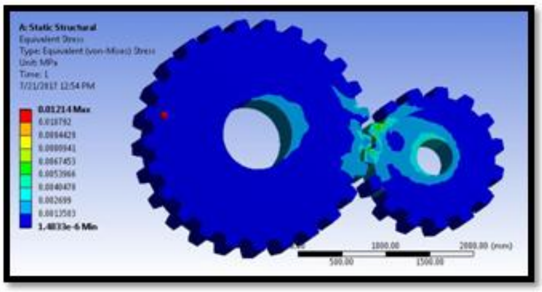

Fig – Stress

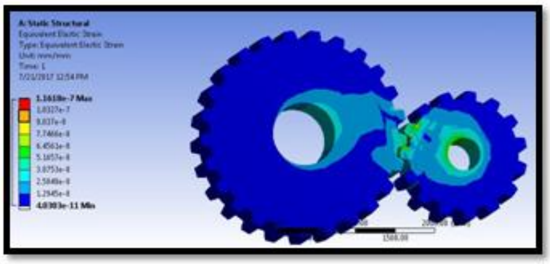

Fig – Strain

By observing the strain results, the maximum strain is developed at the contact area of two gears

## MODAL ANALYSIS

Modal analysis is done by applying deformation inside the gear to determine frequencies and deformations due to frequencies. 3 modes are extracted.

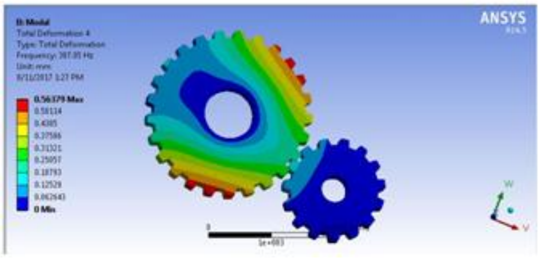

Fig - Mode 1

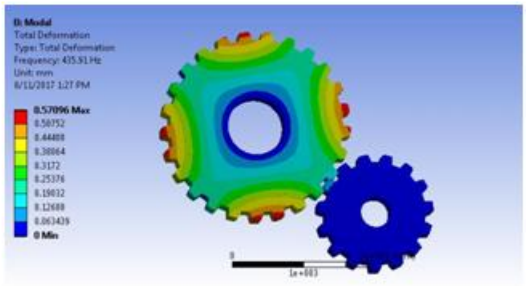

Fig - Mode 2

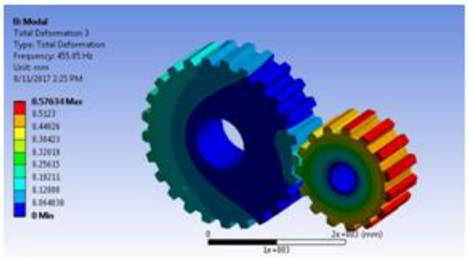

Fig - Mode 3

## RANDOM VIBRATIONAL ANALYSIS

Select PSD displacement.

The analysis is done by taking frequencies obtained from modal analysis to determine directional deformations, shear stresses and strains developed due to the frequencies.

Tabular Data

| | Frequency [Hz] | ✔ Displacement [(mr |
|---|---|---|
| 1 | 387.95 | 0.56379 |
| 2 | 435.91 | 0.57096 |
| 3 | 455.05 | 0.57634 |
| * | | |

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The PSD displacement to be specified for random vibration analysis is shown in the above tabular data taken from the results of modal analysis

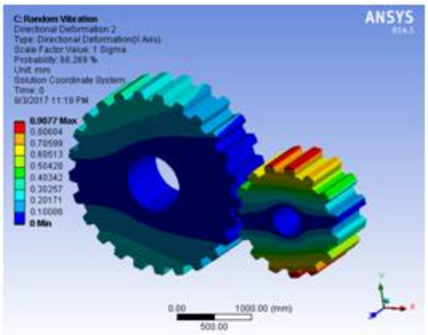


Fig - Directional Deformation

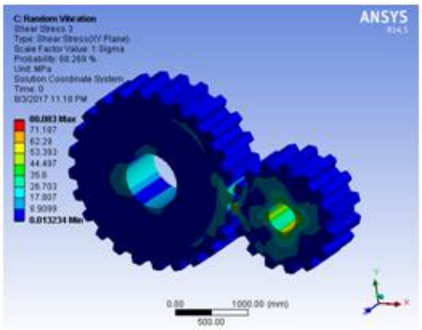


Fig - Shear stress

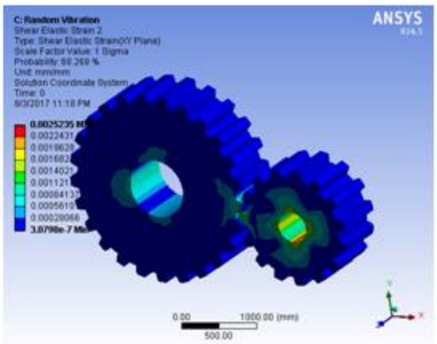


Fig - Shear strain

## RESULTS AND DISCUSSIONS

In this project, the comparison is made between the metallic gears and hybrid gears by performing different analysis. The analysis results, graphs and discussions are given below.

### Table – Results of Static Analysis

| Materials | Metallic | | | Hybrid | | |
|---|---|---|---|---|---|---|
| | Deformation (mm) | Stress (MPa) | Strain | Deformation (mm) | Stress (MPa) | Strain |
| Cast iron | 0.0001396 | 0.0271 | 2.4726e-7 | 0.000059 | 0.0121 | 0.0000001161 |
| Aluminum alloy | 0.000212 | 0.0230 | 0.00000036 | 0.0000737 | 0.0137 | 0.0000001741 |

The deformation values are less for hybrid gear than metallic gears. This is due to the fact that, hybrid gear is a combination of different materials and also composite materials are used for hybrid gear which has more strength than metals. The stress values are less for hybrid gear than metallic gears. This is due to the fact that, hybrid gear is a combination of different materials and also composite materials are used for hybrid gear which has more strength than metals.

### Table – Results of Modal Analysis

| | Materials | Metallic | | Hybrid | |
|---|---|---|---|---|---|
| | | Cast Iron | Aluminum alloy | Cast Iron | Aluminum alloy |
| MODE 1 | Frequency(Hz) | 626.54 | 797.16 | 387.95 | 566.22 |
| | Deformation(mm) | 0.3984 | 0.6420 | 0.56379 | 0.83484 |
| MODE 2 | Frequency(Hz) | 627.28 | 811.13 | 435.91 | 636.73 |
| | Deformation(mm) | 0.5262 | 0.843 | 0.57096 | 0.86015 |
| MODE 3 | Frequency(Hz) | 650.28 | 839.11 | 455.05 | 667.21 |
| | Deformation(mm) | 0.583 | 0.949 | 0.57634 | 0.89279 |

The deformation values are less for hybrid gear than metallic gears. The deformation values are less when Cast Iron is used.The frequency values are more for hybrid gear than metallic gears. That is the vibrations will be more when hybrid gears are used. The frequencies are more when Aluminum alloy is used than Cast Iron.

### Table – Results of Random Vibrational Analysis

| Materials | Metallic | | | Hybrid | | |
|---|---|---|---|---|---|---|
| | Deformation (mm) | Shear Stress(N/mm²) | Shear Strain | Deformation (mm) | Shear Stress(N/mm²) | Shear Strain |
| Cast iron | 0.56146 | 112.12 | 0.0026093 | 0.9077 | 80.083 | 0.0025235 |
| Aluminum alloy | 0.93198 | 118.9 | 0.004456 | 1.5655 | 116.91 | 0.0041435 |

The directional deformation values are less for hybrid gear than metallic gears. The deformation values are less when Cast Iron is used. The shear stress values are less for hybrid gear than metallic gears. The stress values are less when Aluminum alloy is used.

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## CONCLUSION

By observing static analysis results, the deformations and stress values are decreasing for hybrid gear than metallic gear. The stresses are decreasing by 55.35% for hybrid gear using Cast Iron with Carbon Fiber than Cast Iron metallic gear and decreasing by 40.4% 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 28.5% for hybrid gear using Cast Iron with Carbon Fiber than Cast Iron metallic gear and decreasing by 1.66% for hybrid gear using Aluminum with Carbon Fiber than Aluminum metallic gear.

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