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MODELLING AND ANALYSIS OF COMPOSITE GEAR BOX

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ABSTRACT
The main objective of this project is to developed parametric model of differential gear box by using CREO under various design stages. It is observed that Glass filled polyamide composite material is selected as a best material for differential gear box and is found to be suitable for static loading conditions.
Comparison of various stresses and strain result using ANSYS-13 with Glass filled polyamide composite and metallic material (Aluminium alloy, Alloy steel and cast iron)are also being performed and found to be lower for composite material. The model of gear box generated using CREO IS used to perform comprehensive FEM analysis of composite material gear box using ANSYS-13 work.

INTRODUCTION
Gears are the most important component in a power transmission system. Advances in engineering technology in recent years have brought demands for gear teeth, which can operate at ever increasing load capacities and speeds [6]. The gears generally fail when tooth stress exceeds the saf1`e limit. Therefore it is essential to explore alternate gear material [15]. The important considerations while selecting a gear material is the ability of the gear material to withstand high frictional temperature and less abrasive wear [3]. Weight, manufacturability and cost are also important factors those are need to be considered during the design phase. [12] Moreover, the gear must have enough thermal storage capacity to prevent distortion or cracking from thermal stress until the heat can be dissipated [20]. It must have well anti fade characteristics i.e. Their effectiveness should not decrease with constant prolonged application and should have well anti wear properties [4].The upcoming requirement of power saving and efficiency of mechanical parts during the past few years increased the use of composite materials. Moreover the use of composite materials have also increased due to their properties such as weight reduction property with enough strength , high specific stiffness, corrosion free, ability to produce complex shapes, high specific strength, high impact energy absorption and many more[19]. Product development has changed from the traditional serial process of design, followed by prototype testing and manufacturing but to more on computer aids. CAE (Computer Aided Engineering) has greatly influenced the chain of processes between the initial design and the final realization of a product. CAE software helps in product designing, 3-D visualization, analysis, simulation and impacted a lot on time and cost saving to the industry[21], [22].A Gear box is one of the important mechanical components of transmission system used in variety of

machines. Differential Gear box increases effective weight of vehicle which in turn directly affects the performance and efficiency of the vehicle. So there is a requirement to make light and effective gears [15]. Therefore, in the present work composite materials are used to make light weight gears in order to perform such duty efficiently.

BACKGROUNDS

Existing differential has low tensile strength, elastic modulus. Its poison's ratio, mass density and shear modulus is also low. Thus Differential gear box needs to be redesigned providing energy saving by weight reduction, providing internal damping, reducing lubrication requirements and have high tensile strength, elastic modulus, poison's ratio, mass density and shear modulus without increasing cost. Such a scope is provided by application of composite material providing substantial weight reduction in conformance with safety standards and also providing solution to other existing problems in current gears available.

SOLID MODELLING

Solid modelling consists of set of principles for the mathematical modelling and computer modelling of three dimensional solid model. It refers to theories computation that defines and manipulates representations of physical objects, their properties and the associated abstractions, and that support a variety of processes. Solid modelling of bevel and spur gears is done using parametric approach. Bevel gears for different dimensions can be generated by changing the variables (number of teeth, pressure angle, helix angle, tooth thickness, module). Required parameters that are used as variable for generating bevel gear and dependent parameters with relations are shown in table
1) In the reference model there are five bevel gears variable values for each gear as given in table2. Steps involved in the creation of parametric solid model of bevel gear are shown in Figure 2 while Figure 3 (a) - (e) shows the solid model models of gears.

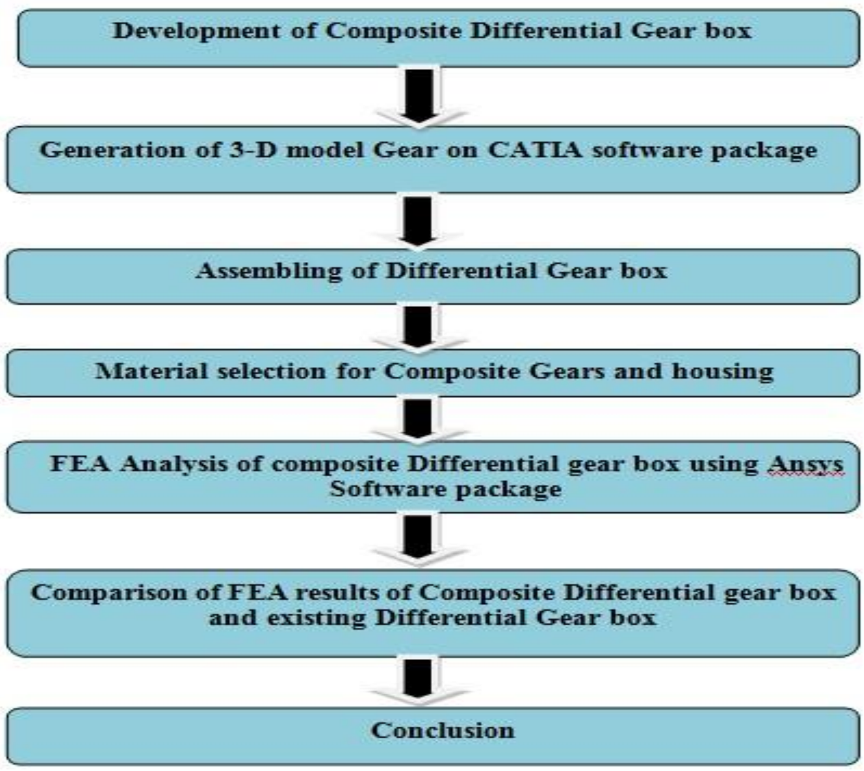

Figure 1 Steps involved in work flow.

Table 1 Variable values for five bevel gear Formulas for Spur and Bevel Gears

Sr. No.	Pressure angle (A) (degree)	Modulus (m) (degree)	No. of teeth (Z1) (integer)	No. of teeth (Z2) (integer)
Gear 1	20	2	20	12
Gear 2	20	2	25	25
Gear 3	20	2	12	20
Gear 4	20	2	48	25
Gear 5	20	2	12	20

Table 2 Product - Design Specification Sheet.

Product Design Specification of Composite material Gearbox	
Density	< 2710 Kg/m 3
Creep	High
Fatigue	High
Corrosion resistance	High
Impact strength	High
Manufacturing method associated with material must be high volume production	
The component made from this material must be dimensionally stable and provides internal damping	
The material should have low friction coefficient	

Table no.3- properties of glass filled polyamide

Final material for Composite Gear	
Material Type	Glass filled Polyamide
Material Supplier	Dura form
Percentage Of Glass Filling	20 % by volume
Tensile Modulus	5910 Map
Tensile Strength	38.1 Map
Poisson's Ratio	0.314
Flexural Modulus	3300 MPA
Density	840 kg/m3
Moisture Absorption	0.30%
Creep Resistance	Good
Corrosion Resistance	Good
Chemical Resistance	Alkalis, hydrocarbons , fuels and solvents

MATERIAL SELECTION

Engineering data imparts the material properties. Composite materials made from two or more constituent materials with significantly different physical or chemical properties. These constituent materials combined to produce a material with characteristics different from the individual components. The composite material selection for gearbox is done using if –then approach, using product design specification sheet [21] Table 3. Glass filled polyamide in particulate form is used for differential gear box(bevel and spur gears)having better tensile strength (38.1 Mpa), recyclability, low density (840Kg/m 3), high creep resistance, fatigue strength, high impact strength, low Von-Misses Stress, less friction and low cost.

Table 4 gives the properties of glass filled polyamide and E-glass/Epo

PROPERTES	NICKEL CROME STEEL	ALUMINIUM ALLOY	ALUMINIUM ALLOY	GLASS FILLED POLYMIDE
MODEL TYPE	Linear Elastic Isotropic	Linear Elastic Isotropic	Linear Elastic Isotropic	Linear Elastic Isotropic
DEFULT FAILURE	Max VON Misses Stress	Max VON Misses Stress	Max VON Misses Stress	Max VON Misses Stress
YIELD STRENGTH	1.72339*10^8 N/m2	1.65*10^8 N/m2	2.75745*10^8 N/m2	5910 M pa
TENSILE STRENGTH	1.13613*10 ^8 N/m2	3*10^7N/m2	4.13613*10^8 N/m2	38.1 M pa
ELASTIC MODULES	2*10 ^11N/m2	7*10^10N/m2	1.9*10 ^11N/m2	1.57e+012 N/m2
POISSION'S RATIO	0.28	0.33	0.27	0.314
MASS DENSITY	7800 kg/ m3	2600kg/ m3	kg/ m3	840kg/ m3

FEA ANALYSIS OF GEAR BOX

It is widely accepted method of accessing product performance without the need for physical building and testing. It also shortens prototype development cycle time & facilities quicker product lunch. FEA consists of a computer model of a material or design that is loaded and analyzed for specific results. It is used in new product design, and existing product refinement. Solid model created by CREO software package is imported in Ansys. Fig. 6.1 show the model imported gearbox housing kept hidden and fig. 6.2 for equivalent (von-misses) stress. Fig. 6.3 shows the meshed gear box with gear housing hidden. Fig.6.4 shows the total deformation. Fig.6.5 shows the maximum principle stresses and fig.no 6.6shows the Maximum shear stress with Glass-filled polyamide Composite material for gears and E glass /epoxy for Shafts and gear housing .

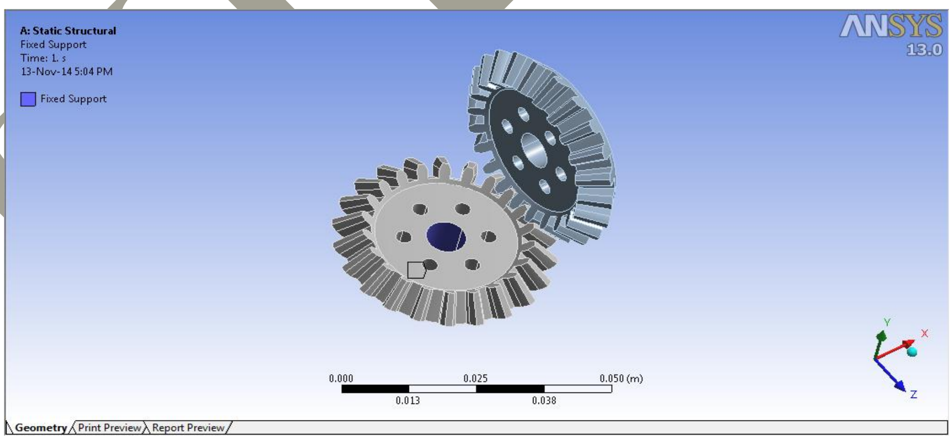

Fig. no.6.1 Imported model of gear box

ADVANTAGES

The inherent advantage of finite element analysis is to evaluate different materials in general load conditions with large numbers and kinds of boundary conditions. Finite element analysis allows entire designs to be constructed, refined, and optimized before the design is manufactured with dynamic effects in low cost. FEA has also been proposed to reduce the number of prototypes required in design process.

RESULT

Table no.5 result of FEA analysis

Sr. No	Properties	Result
1	Density	840 kg m^-3
2	Coefficient of Thermal Expansion	1.2e-005 C^-1
3	Specific Heat	434 J kg^-1 C^-1
4	Resistivity	1.7e-007 ohm m
5	Compressive Yield Strength Pa	2.5e+008
6	Tensile Yield Strength Pa	2.5e+008
7	Tensile Ultimate Strength Pa	4.6e+008
8	GFP >	Isotropic Elasticity
9	Young's Modulus Pa	1.57e+012
10	Poisson's Ratio	0.314

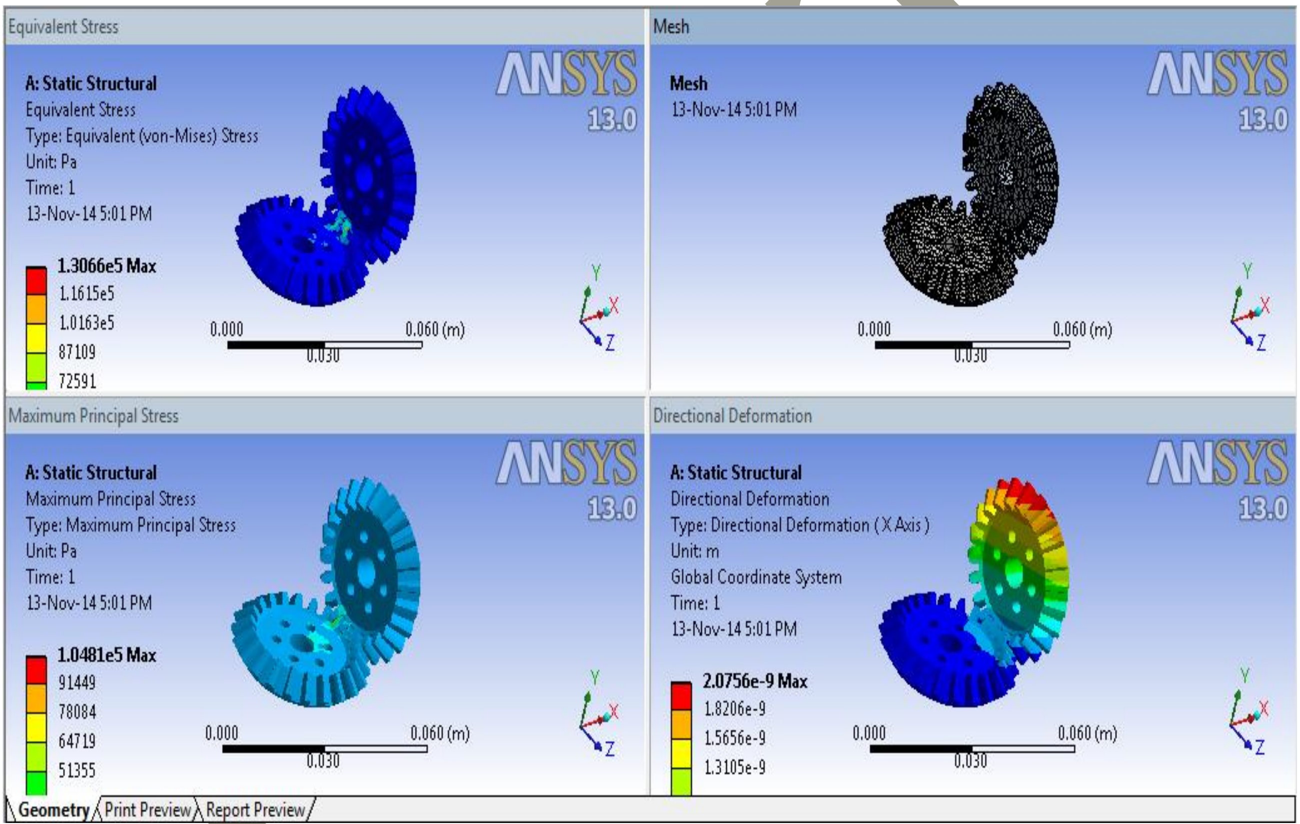

Fig. no.6.1 Ansys Result

Table no.6 Comparison chart for Equivalent (Von-Misses) Stress and Strain

Gear box material		Composite Material gear box	Metallic gearbox
Equivalent (von-Misses) Stress (KPa)	Minimum value	2.92E-11	1.16E-11
	Maximum Value	3.54	4.3652
Equivalent (von-Misses) Elastic strain	Minimum value	1.64E-18	1.63E-20
	Maximum Value	8.70E-07	2.18E-08

CONCLUSION

1) In this work, the exploration of composite material gearbox is done to replace the existing metallic gearbox for weight saving and other composite material benefits. In doing so, computer aided engineering has been found to be very useful and is preferred for various design stages. Reference model of gear box is selected and CREO is used to develop 3D models of various design concepts. Solid model for herringbone gears are done using parametric approach i.e. whole dimensions of gears are controlled by set of five variable parameters. Glass filled polyamide composite material is used for gears and E- glass/Epoxy for shafts and gear housing. CAD models are. Analyzed using ANSYS for Equivalent (von-Misses) stress and Equivalent (von-Misses) elastic strain. . Comparisons of various stress and strain results with composite and metallic material are also performed and found to be lower for composite material. Composite material gear box has provided the substantial weight reduction and designed to carry the same torque as a steel gear box.

2) By using composite material weight reduction up to 60%.

3) All analysis resulted in positive margins of safety and unlimited gear life in the intended application

4) All stress calculations are within the recommended allowable stress values published by the AGMA

5) Design is safe for operation.

6) High weight to strength ratio.

7) Reduction in cost.

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