Spiral Bevel Gears' Dynamic Behavior Analysis Using Composite Material

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ABSTRACT

Gears are an integral and necessary component in our day to day lives for the transmission purpose. Bevel gears are used to transmit power for non-parallel shafts. Many times gear selection is become essential for each machine as per application. In some application it requires smooth function without noise. The study focused on under various design parametric stages. It is observed that E- Glass Epoxy composite material is selected as best material for spiral spur gear under different rotational velocity for dynamic loading conditions. Comparisons of various stress and strain results using ANSYS-16 are also being performed and found to be lower for composite material.

Keywords – *spiral bevel gear, dynamic Analysis, Stress Strain Analysis and Deformation, composite*

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 . The upcoming requirement of power saving and efficiency of mechanical parts during the past few years improved 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. Product development has changed from the traditional serial process of design depending on CAE (Computer Aided Engineering) software for in product designing, three-dimensional visualization, analysis, simulation and impacted a lot on time and costs saving to the industry .The performance and efficiency of the machine greatly affect the gear life. Therefore we use is a requirement to make light and effective gears. Therefore, composite materials are the light weight and high strength in order to increase the perform. Gears are a crucial part of many motors and machines. Gears help increase torque output by providing gear reduction and they adjust the direction of rotation like the shaft to the rear wheels of automotive vehicles. Here are some basic types of gears and how they are different from each other.

The most common gears are spur gears and are used in series for large gear reductions. The teeth on spur gears are straight and are mounted in parallel on different shafts. Spur gears are used in washing machines, screwdrivers, windup alarm clocks, and other devices. These are particularly loud, due to the gear tooth engaging and colliding. Each impact makes loud noises and causes vibration, which is why spur gears are not used in machinery like cars. A normal gear ratio range is 1:1 to 6:1.

Figure 1: spiral bevel gear configuration

1.1 **Helical Gear**

Helical gears operate more smoothly and quietly compared to spur gears due to the way the teeth interact. The teeth on a helical gear cut at an angle to the face of the gear. When two of the teeth start to engage, the contact is gradual--starting at one end of the tooth and maintaining contact as the gear rotates into full engagement. The typical range of the helix angle is about 15 to 30 deg. The thrust load varies directly with the magnitude of tangent of helix angle. Helical is the most commonly used gear in transmissions. They also generate large amounts of thrust and use bearings to help support the thrust load. Helical gears can be used to adjust the rotation angle by 90 deg. when mounted on perpendicular shafts. Its normal gear ratio range is 3:2 to 10:1.

1.2 Bevel Gear

Bevel gears are used to change the direction of a shaft's rotation. Bevel gears have teeth that are available in straight, spiral, or hypoid shape. Straight teeth have similar characteristics to spur gears and also have a large impact when engaged. Like spur gears, the normal gear ratio range for straight bevel gears is 3:2 to 5:1. This engine is using a conjunction of hypoid gears and spiral bevel gears to operate the motor. Spiral teeth operate the same as helical gears. They produce less vibration and noise when compared to straight teeth. The right hand of the spiral bevel is the outer half of the tooth, inclined to travel in the clockwise direction from the axial plane. The left hand of the spiral bevel travels in the counterclockwise direction. The normal gear ratio range is 3:2 to 4:1. Hypoid gears are a type of spiral gear in which the shape is a revolved hyperboloid instead of conical shape. The hypoid gear places the pinion off-axis to the ring gear or crown wheel. This allows the pinion to be larger in diameter and provide more contact area. The pinion and gear are often always opposite hand and the spiral angle of the pinion is usually larger than the angle of the gear. Hypoid gears are used in power transmissions due to their large gear ratios. The normal gear ratio range is 10:1 to 200:1.

1.3 Worm Gear

Worm gears have an inherent safety mechanism built-in to its design since they cannot function in the reverse direction. Worm gears are used in large gear reductions. Gear ratio ranges of 5:1 to 300:1 are typical. The setup is designed so that the worm can turn the gear, but the gear cannot turn the worm. The angle of the worm is shallow and as a result the gear is held in place due to the friction between the two. The gear is found in applications such as conveyor systems in which the locking feature can act as a brake or an emergency stop.

1.3 Composite Materials

Composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. The first modern composite material was fiber glass. It is still widely used today for boat hulls, sports equipment, building panels and many car bodies. The matrix is a plastic and the reinforcement is glass that has been made into fine threads and often woven into a sort of cloth. The glass is very strong but brittle and it will break if bent sharply. The plastic matrix holds the glass fibers together and also protects them from damage by sharing out the forces acting on them. Some advanced composites are now made using carbon fibers instead of glass. These materials are lighter and stronger than fiberglass but more expensive to produce. They are used in aircraft structures and expensive sports equipment such as golf clubs. Carbon nanotubes have also been used successfully to make new composites. These are even lighter and stronger than composites made with ordinary carbon fibers but they are still extremely composite materials expensive. They do, however, offer possibilities for making lighter cars and aircraft.

2. Literature Review

F. K. Choy et al had provided a comparison and benchmarking of experimental results obtained from a damaged gear transmission system with those generated from a numerical model. Specific conclusions for this study can be summarized as:

- ✓ dynamic changes in a gear transmission system due to: no gear tooth damage, single gear tooth damage, two consecutive gear teeth damage, and three consecutive gear teeth damage is successfully conducted
- ✓ The vibration analysis using a joint time-frequency procedure ,seems to be quite effective in identifying single and multiple teeth damage in a gear transmission.

Satya Seetharaman et al, had developed a physics-based fluid mechanics model was proposed to predict power losses for gear pairs operating under wind age conditions. The framework of the model included individual formulations for wind age losses on the periphery and faces of the gears as well as a compressible fluid model for power loss due to pocketing taking place in the meshing zone. The wind age conditions simulate jet lubrication operating conditions or very low oil -level dip lubrication conditions. As an example, the wind age power loss model was applied to two unity-ratio gear sets with varying gear geometry parameters to quantify the contributions of each of the components of the total wind age power loss. For both gear pairs, the wind age pocketing loss was shown to dominate the total gear pair wind age loss. Also, the influence of operating conditions, gear geometry parameters, and lubricant properties on wind age power loss was quantified for the gear pairs in consideration.

B. Venkatesh 1 et al, had obtained Von-Misses stress by theoretical and ANSYS software for Aluminum alloy, values obtained from ANSYS are less than that of the theoretical calculations. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions, which are safe and less than the other materials like steel. Aluminum alloy reduces the weight up to 55.67% compared to the other materials.

Anoop Lega et al. , the main objective of the research is to develop the composite material gear box using computer aided Engineering. The modeling of gears is done using parametric methodology; 3D family is generated by set of variables which controls other gear dimensions related gear design laws. The tool provides 3D models for a wide family of gears used as base for stress & deformation analysis using finite element method. The Solid models of gears are generated using CAD software package. Product Design Specification sheet was developed for the gearbox and simultaneously material selection was carried out through detailed study and past performance of composite materials. Gearbox assembly is imported in Ansys software package and evaluated for equivalent (von-Misses) stress and equivalent (von-Misses) elastic strain for both composite material and existing metallic material. Comparative Results revealed the feasibility of composite material gearbox with approximately 60% weight saving and lower stresses then metallic gearbox with other composite material advantages.

Pankaj Chabra et al , the main objective is to develop 3D Modeled helical gear and stress and deformation analysis using FEM generation of CNC program, rapid prototyping etc. 3D is generated by set of variables which controls other gear dimensions related gear design laws. And shows the characteristics of composite material helical gear at conceptual design stage for specific weight reduction, corrosion resistance, noise reduction, higher natural frequency & more consolidated design the 3D parametric model of helical gears generated using CAD is used to perform comprehensive FEM Analysis of composite helical gears using ANSYS work bench.

Parameter	
Compressive strength - longitudinal	300 MPa
Compressive strength - transverse	415 MPa
Density	1.95 (g cm^{-3})
Tensile strength - longitudinal	490 MPa
Thermal expansion coefficient - long	1 $x10^{-6}$ strain K^{-1}

Table 1: E-Glass Epoxy material specification

3. ANSYS Finite Element Analysis

Modeling has been prepared in CAD software for analysis according to the following parameter

Power transmitted	5kw
Number of teeth	45
Pitch circle diameter	50mm
Module	3mm
Pressure Angle	20^0

Table 1: Gear specification

The different loading and boundary conditions are applied in the form of velocity or torque. The support is applied on the bore of the gear. Frictionless support places a normal constraint on an entire surface. Translational displacement is allowed in all directions except in and out of the supported plane.

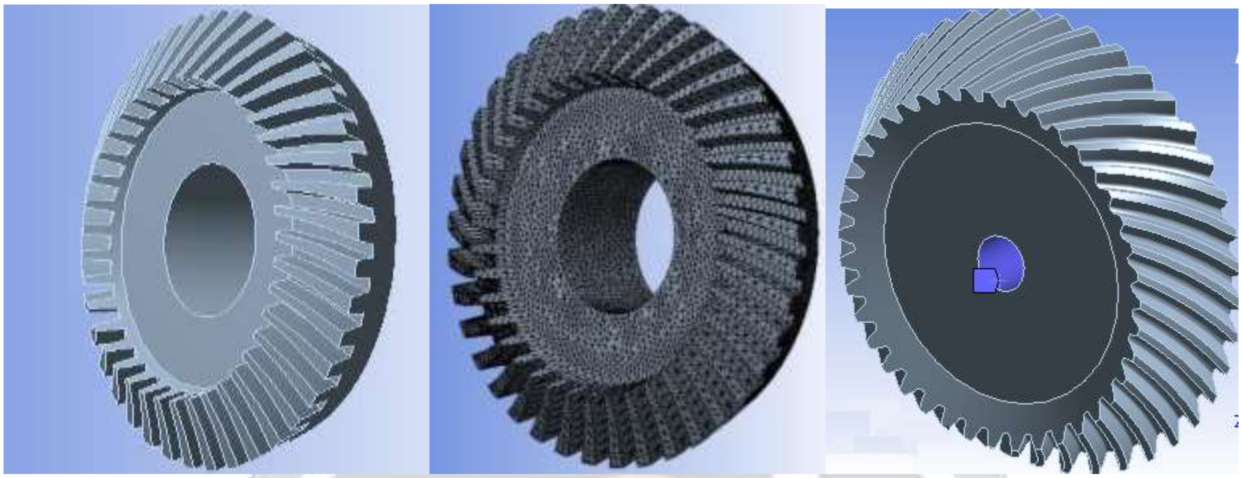
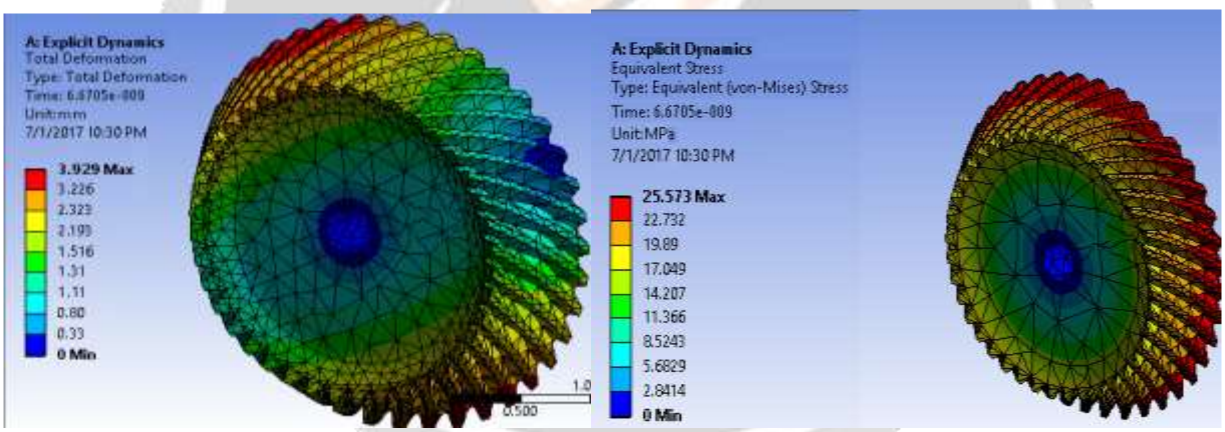


Figure 2: Modeling, Meshing and Boundary Condition of Gear

The finite element model is generated in the ANSYS 16 software and the stresses, deformation, are obtained. The results are taken for gear geometry using E-Glass/Epoxy material. The effect of velocity is taken into consideration. The explicit dynamic analysis is mainly considered for analysis the gear model. This will clearly explain the result of the gear.



CONCLUSION

Since gear model is subjected to different magnitude and constraints used for the analysis. The model is then

Analyzed by an explicit dynamic method using ANSYS Workbench 16.the models used for the explicit dynamic analysis, possesses slightly lower Von Misses stress value and the lower deformation compared to the current gear material, which means that the composite material is the better than conventional material

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