DESIGN AND ANALYSIS OF THE COMPOSITE SPUR GEAR-A REVIEW

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ABSTRACT

Gear is the one of the important machine elements in the mechanical power transmission system. Spur gear is most basic gear used to transmit power between parallel shafts. Spur gear generally fails by bending failure or contact failure. This paper analyses the bending stresses characteristics of an involute spur gear tooth under static loading conditions. The tooth profile is generated using Catia and the analysis is carried out by Finite element method using ANSYS software. The stresses at the tooth root are evaluated analytically using existing theoretical models. The theoretical and FEM results are compared. The results obtained theoretically are in good agreement with those obtained from software. Also, an attempt is made to introduce Stress and displacement characteristics of tooth under dynamic loading conditions.

Keywords— Ansys, Bending stress & Deflection by FEA, Dynamic analysis, Static analysis, Spur gear.

INTRODUCTION

In the today's world of industrialization Gears are the major means for the mechanical power transmission system, and in most industrial rotating machinery. Because of the high degree of reliability and compactness gears dominates the field of mechanical power transmission. Gearbox is used to convert the input provided by a prime mover into an output required by end application. Due to increasing demand for quiet and long-term power transmission in machines, vehicles, elevators and generators, people are looking for a more precise analysis method of the gear systems. Spur gear is the most basic gear used to transmit power between two parallel shafts with almost 99% efficiency. It requires the better analysis methods for designing highly loaded spur gears for power transmission systems that are both strong and quiet. Due to development of computers people are using numerical approach for the analysis purpose as it can give more accurate analysis results. The finite element method is capable of providing information on contact and bending stresses in gears, along with transmission errors, which can be done easily in ANSYS software. Gear analysis in the past was done by using analytical methods which requires complicated calculations. Now with the use of FEA we can calculate the bending stresses in the gear tooth for given loading condition and we can compare the FEA results with existing models to decide the accuracy. Also static as well as dynamic, both loading conditions of gear can be easily analyzed in Ansys which is not the case with Analytical method.

II PROBLEM DEFINITION

For this problem we are doing our calculations analytically and compare results with software results. Any problem can be solved by following same procedure.

1.1. *Question*

The Following data is given for a spur gear pair made of steel and transmitting 5KW power from an electric motor running at 720 rpm to a machine:

No. of teeth on Pinion= 21, No. Of teeth on Gear= 40, Module= 5mm, Face width= 10m, Ultimate Tensile Strength for Pinion material= 600 N/mm^2, Ultimate Tensile Strength for Gear material= 400 N/mm^2, Tooth System =20 Degree Full-Depth Involute, Service Factor =1.25, Load Concentration Factor = 1.6, Tooth Form factor for pinion= .326, Tooth Form factor for gear= .389, Velocity factor= 6/ (6+v).

1.2. *Solution*

As, Strength of gear < Strength of pinion, gear is weaker than pinion in bending. Hence it is necessary to design the gear for bending.

*Pitch Line Velocity (V) = π*Dp*Np/(60000)= 3.9585 m/s*

Theoretical Tangential Force Ft= P/V= 5000/3.9585=1263.1047 N (approx. 1200N)

2. *STATIC ANALYSIS*

2.1. *The Lewis Formula (Stress Calculation)*

*The analysis of bending stress in gear tooth was done by Mr. Wilfred Lewis in his paper, 'The investigation of the strength of gear tooth' submitted at the Engineers club of Philadelphia in 1892. Even today, the Lewis equation is considered as the basic equation in the design of gears [1]. Wilfred Lewis was the first person to give the formula for bending stress in gear teeth using the bending of a cantilevered beam to simulate stresses acting on a gear tooth shown in Cross-section =b*t , height = h, Load=Ft uniform across the face*

Lewis considered gear tooth as a cantilever beam with static normal force F applied at the tip. He took the critical section as parabola through point 'a' and tangent to tooth curves at the root as shown in fig.1. This parabola shown by dotted line is a beam of uniform strength.

Assumptions made in the derivation are:

- The full load is applied to the tip of a single tooth in static condition,
- The radial component is negligible,
- The load is distributed uniformly across the full-face width,
- forces due to tooth sliding friction are negligible and
- Stress concentration in the tooth fillet is negligible.

In the current analysis of spur gear, we follow the Lewis assumptions and equation.

4.1.1.1 Contact Ratio

The gear design is such that when in mesh the rotating gears have more than one gear in contact and transferring the torque for some of the time. This property is called the contact ratio. This is a ratio of the length of the line-of-action to the base pitch

A contact ratio between 1 and 2 means that part of the time two pairs of teeth are in contact and during the remaining time one pair is in contact. A ratio between 2 and 3 means 2 or 3 pairs of teeth are always in contact. Such as high contact ratio generally is not obtained with external spur gears, but can be developed in the meshing of an internal and external spur gear pair or specially designed non-standard external spur gears.

$R_{go} = D_{go} / 2$..Radius of Outside Dia of Gear $R_{gb} = D_{gb} / 2$..Radius of Base Dia of Gear

$R_{po} = D_{po} / 2$..Radius of Outside Dia of Pinion $R_{pb} = D_{pb} / 2$..Radius of Base Dia of Pinion

p = circular pitch.

$a = (d_g + d_p)/2$ = center distance.

4.1 Materials Selection

4.1.1 *Cast Steel*

Cast steel was the first type of steel that allowed alloys to be added to the iron. Prior to this method, manufacturers had not been able to get steel hot enough to melt. By heating blister steel in a clay crucible placed directly into a fire, Huntsman allowed the metal to reach up to 2900°F (1600°C). Melting allowed other elements, such as nickel, to be mixed into the metal, thus strengthening the steel.

Cast steel has a rough finish. It often has surface holes created by gas bubbling during the heating process. An elastic metal, this type of steel is very tough, having four times the tensile strength of cast iron. Tensile strength is

4.1.1.1 *Properties of Cast Steel*

Hardness

The hardness of cast steel varies depending on the mixture of carbon and other ingredients. The heat levels used when mixing the metal also affect the hardness of the finished metal product. Typically, lower levels of carbon and high alloy content result a softer metal. Higher levels of carbon with fewer added allows achieves a cast steel with greater hardness but lower yield strength, which is the flexibility of the metal.

Durability

Several tests are used to determine the strength and durability of cast steel before it starts to break down. These tests include impact tests, drop tests, tear tests and fracture tests. In this area, high carbon and low allow concentrations are actually detrimental.

Ductility

The ductility of steel is the measurement of how much molding or shaping it can take and how small the sheets can become without breaking down. This is determined largely by the material mixture of the cast steel and how it is formed. In general, quenched or tempered steel has higher ductility levels, or the ability to deform without breaking, than traditional annealed steel, which produces a softer metal.

Fatigue

The fatigue properties of cast steel represent how much pressure and use the steel can take before breaking down. The fatigue test of cast steel shows its predicted life.

The Advantage and Disadvantage of Cast Steel

One of the advantages of cast steel is the design flexibility, the designer of the casting have the greatest freedom of design choices, especially the complex shape and hollow cross-section parts.

Cast steel has the metallurgy manufacturing flexibility and strongest variability; you can choose a different chemical composition and control, adapted to the various requirements of different projects. By different heat treatment choice in the larger context of the mechanical properties and performance, and good weldability and workability.

Cast steel is a kind of isotropic material and can be made into the overall structural strength steel castings, thereby improving the reliability of the project. Coupled with the design and weight the advantages of short delivery time, price and economy has a competitive advantage.

Properties of Cast Steel

Density	= 7870 kg/m^3
Young modulus	= 200 GPa
Poisson's ratio	= 0.29
Tensile strength	= 518.8 MPa
Ultimate Tensile Strength	= 540 MPa
Yield Tensile Strength	= 415 MPa
Bulk modulus	= 140 GPa

1.. *Composite Materials*

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties.

The two constituents are reinforcement and a matrix. The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part.

The reinforcing phase provides the strength and stiffness. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are usually much less expensive. Particulate reinforced composites usually contain less reinforcement (up to 40 to volume percent) due to processing difficulties and brittleness.

A fiber has a length that is much greater than its diameter. The length-to-diameter ratio is known as the aspect ratio and can vary greatly. Continuous fibers have long aspect ratios, while discontinuous fibers have short aspect ratios. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation.

Fibers produce high-strength composites because of their small diameter; they contain far fewer defects (normally surface defects) compared to the material produced in bulk. As a general rule, the smaller the diameter of the fiber, the higher its strength, but often the cost increases as the diameter becomes smaller. In addition, smaller-diameter high-strength fibers have greater flexibility and are more amenable to fabrication processes such as weaving or forming over radii.

Typical fibers include glass, aramid, and carbon, which may be continuous or discontinuous.

The continuous phase is the matrix, which is a polymer, metal, or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength and stiffness but are brittle. The matrix (continuous phase) performs several critical functions, including maintaining the fibers in the proper orientation and spacing and protecting them from abrasion and the environment.

In polymer and metal matrix composites that form a strong bond between the fiber and the matrix, the matrix transmits loads from the matrix to the fibers through shear loading at the interface. In ceramic matrix composites, the objective is often to increase the toughness rather than the strength and stiffness; therefore, a low interfacial strength bond is desirable.

There is a practical limit of about 70 volume percent reinforcement that can be added to form a composite. At higher percentages, there is too little matrix to support the fibers effectively.

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while the matrix which glues all the fibers together in shape and transfers stresses between the reinforcing fibers. Sometimes, fillers or modifiers might be added to smooth manufacturing process, impart special properties, and/or reduce product cost.

Primary functions of the matrix are to transfer stresses between the reinforcing fibers (hold fibers together) and protect the fibers from mechanical and/or environmental damages. A basic requirement for a matrix material is that its strain at break must be larger than the fibers it is holding. The primary functions of the additives (modifiers, fillers) are to reduce cost, improve workability, and/or impart desired properties.

4.1.1.2 Carbon Fiber

The principal purpose of the reinforcement is to provide superior levels of strength and stiffness to the composite. In a continuous fiber-reinforced composite, the fibers provide virtually all of the strength and stiffness. Even in particle reinforced composites, significant improvements are obtained

4.2 *Static Structural Analysis*

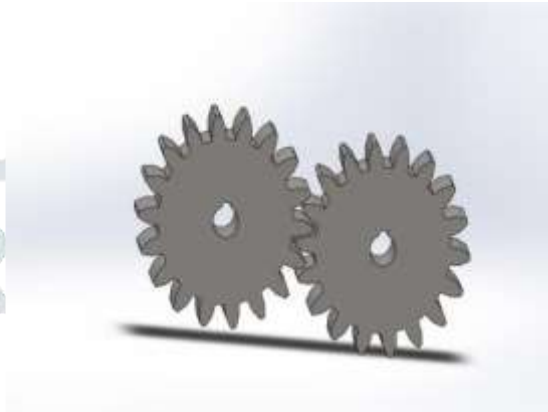
4.2.1 Introduction

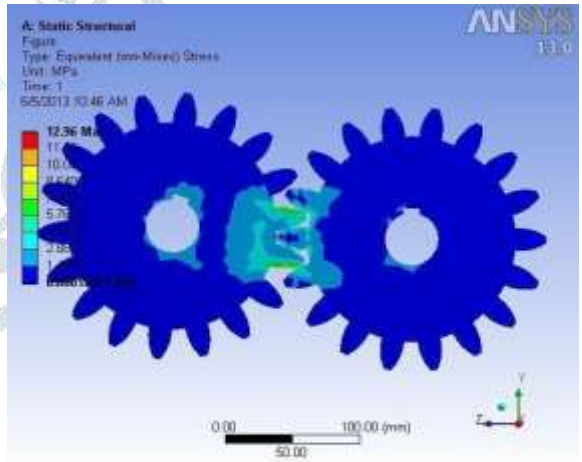
A static structural analysis determines the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. A static structural load can be performed using the ANSYS or ANSYS WORKBENCH solver. The types of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (nonzero) displacements
- Temperatures (for thermal strain)

Design software offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up- front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free- form surface tools.





RESULTS AND DISCUSSION

5.1 Analysis Results for Spur Gear in Various Materials

5.1.1 Reports for Cast Steel Spur Gear in Various Torques

TORQUE T = 140N-m; SPEED N = 2500 rpm

METHODOLOGY

Procedure of Static Analysis

First of all, we have prepared assembly in Pro/ E for spur gear and save as this part as IGES for Exporting into ANSYS workbench Environment. Import IGES mode in ANSYS workbench simulation module. Apply material for spur gear (structural steel).

Figure 1: Part Design of Spur Gear

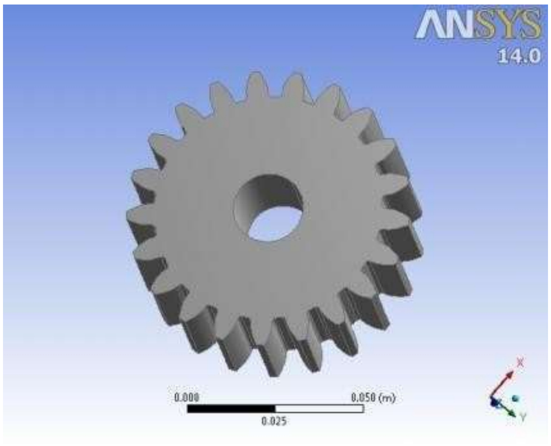


Figure 4: Directional Deformation

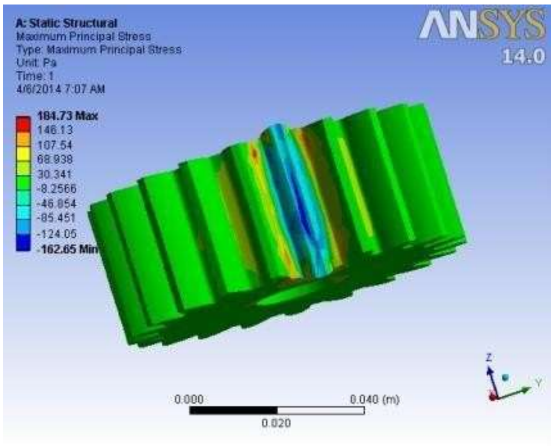


Figure 2: Mess of the Gear

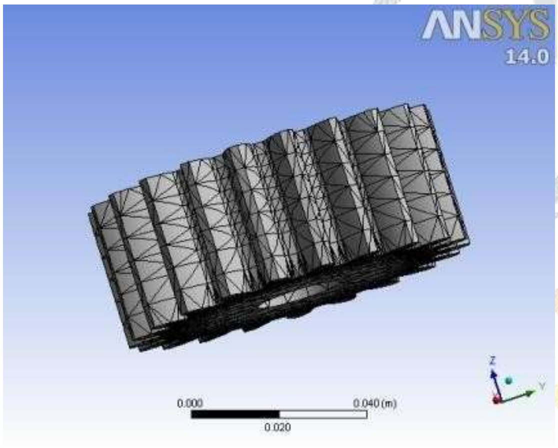


Figure 5: Middle Principal Stress

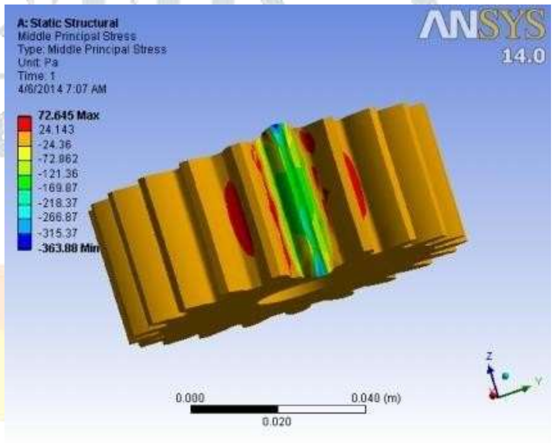


Figure 3: Shear Stresses

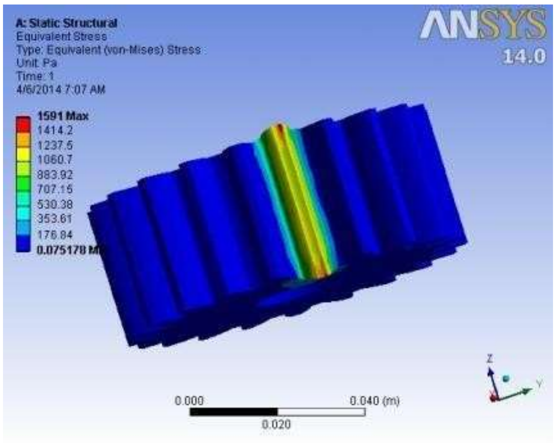
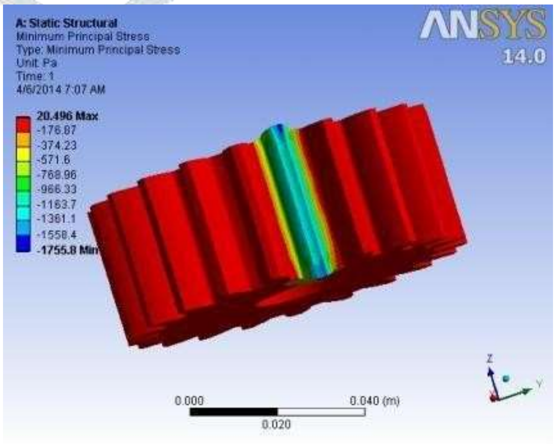


Figure 6: Minimum Principal Stress



FUTURE CONCLUSION

The finite element method is most widely for find a real model of the geared set using the stress analysis in the pair of gears.

The development off finite element analysis model

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