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Research Article

Structural Analysis of Composite Spur Gear using FEA

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A B S T R A C T

This paper proposes a new method for gear tooth contact analysis, which concentrates on solving two considerable disadvantages of the generalized algorithm: 1) Stress reduction in the rotating mating gear. 2) Complexity of the computation process caused by differences in the mathematical models for the tooth surface contact and edge contact. This paper discuss details of the implemented methodology that addresses the design aspects, within a knowledge-based Automated Concurrent Engineering Software (ACES) environment. The ACES system incorporates a constrained-based design environment with bi-directional communication with commercial solid modeling engines (Pro/E & Unigraphics). Domain specific knowledge (Design guidelines, engineering relationships etc.) is represented in the form of constraints.

Keywords: Static Structural, Fatigue Tool, Fatigue Crack Propagation, Gear Tooth Crack

Introduction

A gear is a rotating machine part having cut teeth, which mesh with another toothed part to transmit torque, in most cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear. It is a rotating machine part having cut teeth or, in the case of a cogwheel, inserted teeth (called cogs), which mesh with another toothed part to transmit torque. Geared devices can change the speed, torque, and direction of a power source. Gears almost always produce a change in torque, creating a mechanical advantage, through their gear ratio, and thus may be considered a simple machine. The teeth on the two meshing gears all have the same shape. Two or more meshing gears, working in a sequence, are called a gear train or a transmission. A gear can mesh with a linear toothed part, called a rack, producing translation instead of rotation. The main objective of this paper is stress analysis of prepared model of gear tooth via 3D modeling software CATIA and stress analysis of gear tooth using ANSYS software to maximize the efficiency of spur gear and minimize the interference between two gears with stress reduction.

This paper discuss details of the implemented methodology that addresses these design aspects, within a knowledge-based Automated Concurrent Engineering Software (ACES) environment. The ACES system incorporates a constrained- based design environment with bi-directional communication with commercial solid modeling engines (Pro/E &Unigraphics). Domain specific knowledge (design guidelines, engineering relationships etc) is represented in the form of constraints as shown in Figure 1. The system allows visualization of the constraint dependence tree and offers user-transparent constraint resolution and optimization capabilities based on user-defined objective functions (Esche et al., 1999). This methodology is highly desirable in that it is able to evaluate and optimize the design effectively, and prevent designers from time-consuming iterations. The relationship between design requirements, 3-D solid model creation and 2-D FEM model generation is established with constraints, which are automatically imposed on the system as shown in Figure 1. Once the designer changes design configurations and parameters, the system has the ability to rapidly re-compute and redesign the gear system to reach the desired design configuration. The system integrated knowledge about all aspects of gear design and manufacturing and provides powerful reasoning and decision making capabilities for reducing the time between gears. The gear material and lubricant selection is facilitated through a user interface to three extendable databases, which also contain the shaft material to estimate hole diameters for the gear, the pinion and the wheel. Once the user specifies the basic design requirements in the requirement panel, ACES automatically carries out geometric calculations and strength analysis according to AGMA standard power rating, and generates the suitable gear construction (solid gear, gear with web etc.) as shown in Figure 1, FEM related calculations are also involed at this point.

Figure 1.FEM Related Calculations are Also Involed at This Point

FEM Model of the Gear Teeth in Contact

In order to achieve a fuller understanding of the influence of the real working conditions on the gear and obtain a more accurate estimation of the gear strength, a finite element model that simulates contact between the mating gears is employed. The advantage of this approach is that it provides an early estimation of the full stress fields during the design phase, where there is still Since the loading of a spur gear can be considered as a two dimensional situation without loss generality, a plane stress formulation would be suitable for this analysis. Plane stress is modeled using a unit thickness with PLANE42 (2-D structural solid element) and CONTAC48 (2-D point-to-surface contact element).

The gap element has been employed in this model to simulate the non-linear contact situation around the contact zone. The sectional view shown in Figure 2, represents a worst case loading condition where the load is shared by only one pair of teeth. Other types of load sharing involving additional teeth can be accommodated as well. The geometry is automatically produced from the ACES output into appropriate file-format of ANSYS that carries the coordinates of all the points on the teeth profiles. Material properties such as Young's Modulus, Poisson's ratio and the coefficient of friction between the contacting teeth for the pinion and wheel are automatically transferred to the FEM solver. The coefficient of friction (m) between contacting teeth is calculated by using the equation (Terauchi and Mori, 1974) in which kinematic viscosity of the lubricant (n) is in cSt, relative radius of curvature (r) and speeds of the tooth along the tangent of the Contact.

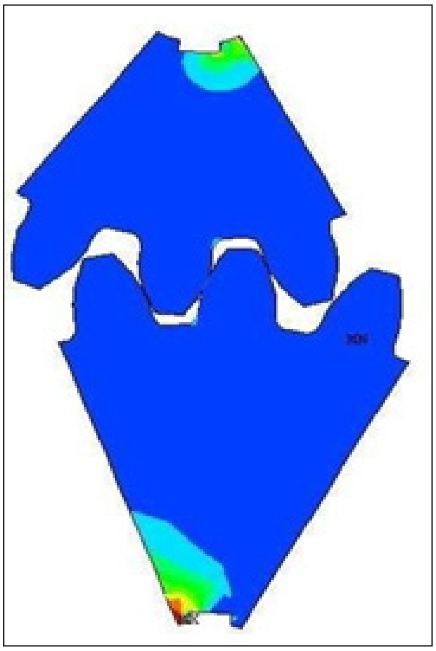

Figure 2.Meshing of Gear

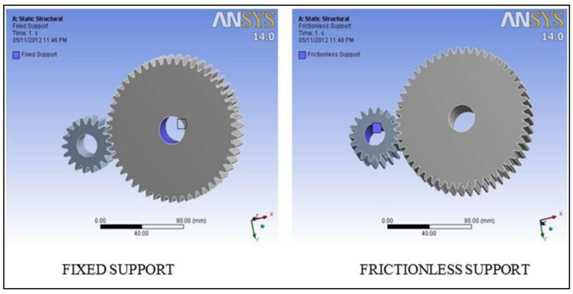

Figure 3.Pinion and Gear Assembly

Stress Analysis of Mating Involute Spur Gear Teeth

This paper presented analysis of Bending stress and Contact stress of Involute spur gear teeth in meshing. There are several kinds of stresses present in loaded and rotating gear teeth. Bending stress and contact stress (Hertz stress) calculation is the basic of stress analysis. It is difficult to get correct answer on gear tooth stress by implying fundamental stress equation, such as Lewis formula for bending stress and Hertz equation for contact stress. The detailed gear stressing is the key of this paper. The design of an effective and reliable gearing system is include its ability to with stand

RBS (Root Bending Stress) and SCS (Surface Contact Stress). Various research methods such as Theoretical, Numerical and Experimental have been done throughout the years. We primarily prefer Theoretical and Numerical methods because Experimental testing can be expensive. So many researchers have utilized FEM to predict RBS and SCS. In this study we use a 3D model of gear and finite element analysis to conduct RBS and SCS calculation for mating involute spur gears. A pair of involute spur gear without tooth modification and transmission error is define in a CAD system (CATIA V5 and AUTODESK INVENTOR etc.) and FEA is done by using finite element software ANSYS. Obtained FEA results is comparable with theoretical and AGMA standard. It is found that Lewis formula and Hertz equation is used for quick stress calculation for gear, whereas the AGMA standards and FEM is used for detailed gear stress calculation for a pair of involute spur gear.

Table 1.Materials Details and Geometry

Object Name	Geometry
Definition	
Source	C:\Users\navneet \ Desktop\final assem 1.IGS
Type	Iges
Length Unit	Meters
Bounding Box	
Length X	4.5333e-002 m
Length Y	2.8625e-002 m
Length Z	1.e-002 m
Properties	
Volume	5.2238e-006 m³
Mass	4.1007e-002 kg
Scale Factor Value	1.
Bounding Box	
Length X	2.3249e-002 m
Length Y	2.32e-002 m
Length Z	1.e-002 m

Table 2

Statistics	
Nodes	166752
Elements	97910
Mesh Metric	None
Span Angle Center	Coarse
Bounding Box Diagonal	5.4539e-002 m
Average Surface Area	5.3077e-006 m²
Minimum Edge Length	1.941e-005 m

Details of material Structural Steel

Table 3

Density	7850 kg m^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1
Resistivity	1.7e-007 ohm m

Spur Gear Tooth Stress Analysis and Stress Reduction

In this work, a gear having specifications of Module (M) 2, No. of teeth (N) 25 to study and experiment is chosen from our reference thesis. A load of 89MPa as given in thesis is applied at the highest point of contact of gear teeth. The stress at root fillet region is of the value 168Mpa which is much higher than the actual applied load. Then the stress relieving features are introduced, which are the circular holes of different dimensions which decreased the stress at the fillet to 124MPa. The stress relieving features used in the gear till date are circular holes or the combination of circular and elliptical holes. Here we have tried an aerodynamic structured hole in the path of stress flow analogy and the results are analyzed. A segment of three teeth is considered for analysis and stress relieving features of various sizes are introduced on gear teeth at various locations.[10-12]

Laminar Flow Analogy: For relieving stress concentration in gears conventional methods used are making Fillets, Notches and Holes.

- Flow analogy with circular-shaped hole
- Flow analogy with square-shaped hole
- Flow analogy with notch

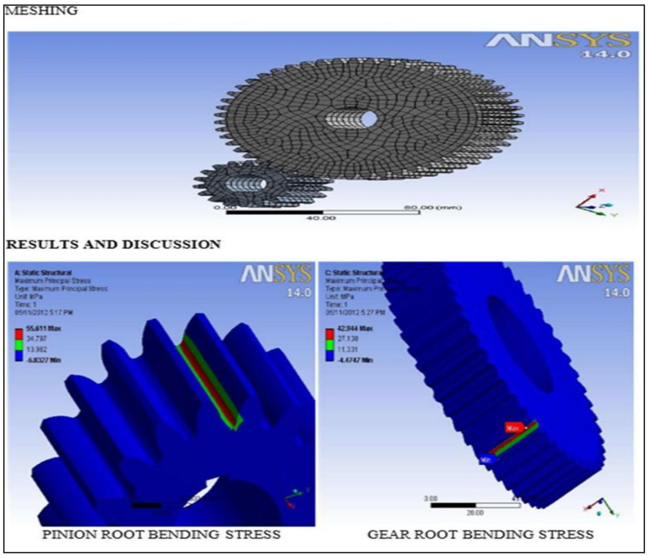

Figure 4.Stress Analysis of Gear Tooth

The flow analogy is used to visualize the stress concentration. It gives us a physical picture of why and where stress concentration exists and it can be used as a tool to decrease stress concentration. The path of flow analogy in gear starts from highest point of application of load and ends at the root fillet of the tooth. This indicates that lines of force travel from contact point to root fillet, with gradual decrease in width of the flow pattern. So, the stress concentration is more at the fillet region which causes breakage of the tooth. The problem of stress concentration is solved by removing material in the path of stress flow analogy. When the material is removed in the path of flow analogy, the lines of force will travel uniformly.

Significance of Aero-fin Hole: The shape of aero-fin selected for this study is such that it modifies the stress flow into a smoother way, i.e., smoother flow of stress is achieved best by an aero-fin type of design because the curvy nature of this helps stress flow lines of stress to find a fluent path without any interruptions, the shape becomes narrowed towards the fillet end which will help the stress lines to flow smoothly.

Result and Discussion

Stresses & Displacements of Analyzed Gears

The gear without hole is examined to determine the maximum stress at the fillet and then the aero-fin hole is introduced to gear. The position and size of the aero-fin hole can be varied by changing input values of center of one of the arcs of hole and scaling factor using Parameterization in Gmsh. Now, the gear is experimented with different modifications done to the aero-fin hole by varying the parameters mentioned above. The stresses and displacements are calculated and analyzed so that the maximum stress at the fillet is reduced.

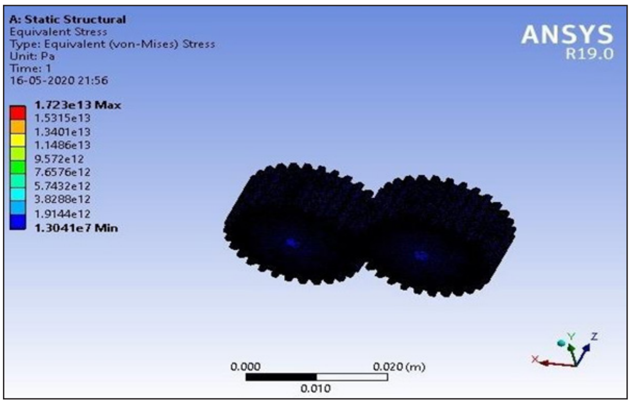

Figure 5.Equivalent Stress Between the Gear

Conclusion

This paper presented a novel method for performing TCA. The key advantage of the new method is the construction of an instantaneous conjugate contact curve and modified curve, to efficiently identify transmission errors and locate both the contact point and instantaneous contact curve.

Difficulties associated with Performing TCA are Reduced

The number of nonlinear equations required for finding each contact point is reduced from 5 to 2 using this method, thereby stabilizing the iteration convergence, and thus reducing the overall complexity of performing TCA. Moreover, precise initial guesses are no longer required for locating the first point on the contact path, which was a major hurdle with the previous approaches.

Accuracy in calculating the instantaneous contact curve is improved. The proposed approach does not simplify the instantaneous contact curve to a straight line; therefore, the previous re-quirement of calculating the principal curvatures and directions, to determine the instantaneous contact line orientation and length, is eliminated. Based on the instantaneous conjugate contact curve, the instantaneous contact curve can be de-termined in a simple, accurate, and computationally efficient way.

Union of the tooth surface contact and edge contact mathematical models. Since the proposed approach can also be applied to edge contact, no additional procedures are needed for ETCA, thus significantly reducing computation times.

The newly defined algorithm is suitable for all gear types. An advanced algorithm for TCA was presented for the spiral bevel gear drive, and can be applied more generally to other forms of gear drives, such as the straight bevel, spur, and helical gear drives.

References

1. Fan Q. Computerized Design of New Type Spur, Helical, Spiral Bevel and Hypoid Gear Drives Ph.D. Thesis, University of Illinois at Chicago, 2001.
2. Litvin FL, Fan Q, Fuentes A et al. Computerized Design, Generation, Simulation of Meshing and Contact of Face-Milled Formate-Cut Spiral Bevel Gears, NASA, 2001 Report No. /CR-2001-210894, ARL-CR-467.
3. Zhang Y, Litvin FL, Handschuh RF. Computerized design of low-noise face milled spiral bevel gears. *Mech Mach Theory* 1995; 30: 1171–1178.
4. SimonV. Influence of tooth modifications on tooth contact in face-hobbed spiral bevel gears. *Mech Mach Theory* 2011; 46: 1980-1998.
5. Simon V. Design and manufacture of spiral bevel gears with reduced transmission errors. *J Mech Des* 2009; 131: 041007.
6. Artoni A, Bracci A, Gabaccini M et al. Optimization of the loaded contact pattern in hypoid gears by automatic topography modification. *J Mech Des* 2009; 131: 011008.

7. Litvin FL, Fuentes A. Gear Geometry and Applied Theory, Cambridge University Press, UK, 2004.
8. Artoni A, Kolivand M, Kahraman A. An ease-off based optimization of the loaded transmission error of hypoid gears. *J Mech Des* 2010; 132: 011010.
9. Eng J, Karuppanan S, Patil S. Frictional stress analysis of spur gear with misalignments. *Journal of Mechanical Engineering and Sciences* 2018; 12(2): 3566-3580.
10. Gedam PV, Dakhore NA. Analysis of Spur Gear by using Composite Material. *International Engineering Journal For Research & Development* 2020; 5(1): 9-9.
11. Khanna R, Sinha PK. Structural Analysis of Spur Gear with Composite Material Under Different Loading Conditions. *Recent Advances in Mechanical Engineering* 2021; 599-604.
12. Panda SK, Mishra PK, Patra B et al. Static and dynamic analysis of spur gear. *International Journal of Hydromechatronics* 2020; 3(3): 268-280.