FINITE ELEMENT ANALYSIS OF HELICAL GEAR : A REVIEW

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Abstract:

The basic aim of this review paper is to provide the information for calculating the stresses of an Involute gear in meshing. Authors have used various approaches and means to attain their main intention. Gears are one of the most critical components in mechanical power transmission systems. The bending and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in a gear set. Thus, analysis of stresses has become popular as an area of research on gears to minimize or to reduce the failures and for optimal design of gears. The researchers throughout the years had given various research methods such as Theoretical, Numerical and Experimental. We prefer the Theoretical and Numerical methods because Experimental testing can be expensive. This study says Finite Element Method is the best numerical solution for calculating gear stress.

Key words: Helical Gear, Stress Calculation, Bending Stress, Hertz Stress, Finite Element Method.

INTRODUCTION:

Gears are use to transmit power and motion from one shaft to another. Helical gears are currently being used increasingly as a power transmitting gear owing to their relatively smooth and silent operation, large load carrying capacity and higher operating speed. Helical gears have a smoother operation than the spur gears because of a large helix angle that increases the length of the contact lines. Designing highly loaded helical gears for power transmission systems that are good in strength and low level in noise necessitate suitable analysis methods that can easily be put into practice and also give useful information on contact and bending stresses **[1].**

FINITE ELEMENT ANALYSIS:

The FEM is a numerical procedure for obtaining approximate solutions to many of the problems encountered in engineering analysis.In the FEM, a complex region defining a continuum is discritized into simple geometric shapes called elements.The properties and the roverning relationships are assumed over these elements and expressed mathematically in terms of unknown values at specific points in the elements called nodes.An assembly process is used to link the individual elements to the given system.When the effects of loads and boundary conditions are considered, a set of linear or nonlinear algebraic equations is usually obtained.Solution of these equations gives the approximate behavior of the continuum or system.The continuum has an infinite number of degrees of freedom, while the discritized model has a finite number of DOF **[2].**

LITERATURE REVIEW :

This study investigates the contact stress and bending stress of a helical gear set with localized bearing contact, by means of finite element analysis (FEA).The proposed helical gear set comprises an involute pinion and a double crowned gear. Mathematical models of the complete tooth geometry of the pinion and the gear have been derived based on the theory of gearing and a mesh-generation program was also developed for finite element stress analysis.The gear stress distribution is investigated using the commercial FEA package, ABAQUS=Standard **[3].** The contents of the paper cover: (i) computerized design, (ii) methods for generation, (iii) simulation of meshing, and (iv) enhanced stress analysis of modified involute helical gears. The approaches proposed for modification of conventional involute helical gears are based on conjugation of double-crowned pinion with a conventional helical involute gear. Double-crowning of the pinion means deviation of cross-profile from an involute one and deviation in longitudinal direction from a helicoid surface. The pinion-gear tooth surfaces are in point contact, the bearing contact is localized and oriented longitudinally, edge contact is avoided, the influence of errors of alignment on the shift of bearing contact and vibration and noise are reduced substantially **[4].** The elastic deflection of gear teeth is analyzed to investigate the deformation overlap. The deformation overlap, which is a numerically calculated quantity through displacement analysis at the initial contact, is defined as the piled region of a contact tooth pair due to the elastic deformation. The deformation overlap is suggested for an effective indicator to represent the whole deformation of a meshing gear pair. The elastic contact theory and finite element method are used to compute the contact force and teeth deflection. The contact problem is defined as a QP problem, and the contact forces between teeth are calculated from the transmitted torque. Then the deformation overlap is calculated with the contact forces as boundary conditions. Deformation overlap is extended to a three-dimensional problem, and implemented to a helical gear pair **[5].** A failure analysis of a helical gear used in gearbox of a bus, which is made from AISI 8620 steel. An evaluation of the failed helical gear was undertaken to assess its integrity that included a visual examination, photo documentation, chemical analysis, micro-hardness measurement, and metallographic examination. The failure zones were examined with the help of a scanning electron microscope equipped with EDX facility. Results indicate that teeth of the helical gear failed by fatigue with a fatigue crack initiation from destructive pitting and spalling region at one end of tooth in the vicinity of the pitch line because of misalignment **[6].** The present paper will concentrate on the gear fatigue wear reduction through micro-geometry modification method. An accurate non-linear finite element method will be employed to provide a quantitative understanding of gear tooth contact behaviour. Shaft misalignment and assembly deflection effects on the gear surface wear damage will be investigated as well. To achieve high accuracy of the gear geometry, the tooth profile will be mathematically generated though using Python script interfacing with the finite element analysis (FEA) software instead of importing from other computer aided design (CAD) packages. Real rolling and sliding contact simulations have been achieved through using the latest non-linear FEA techniques. An investigation has been carried out on automotive transmission gear surface failure due to shaft misalignment and assembly deformations. The solution for the wear is consequently proposed based on gear micro-geometry modification approach, i.e. tip relief, facewidth crowning and lead correction **[7].** This paper deals with determining various time-varying parameters that are instrumental in introducing noise and vibration in a helical gear system. The most important parameter is the contact line variation, which subsequently induces friction force variation, frictional torque variation and variation in the forces at the bearings. The contact line variation will also give rise to gear mesh stiffness and damping variations. All these parameters are simulated for a defectfree and two defective cases of a helical gear system. The defective cases include one tooth missing and two teeth missing in the helical gear. The algorithm formulated in this paper is found to be simple and effective in determining the time-varying parameters **[8].** The methods used in some references assume a uniform load distribution along the line of contact or don't take into consideration the effect of premature mesh between one or more pair of teeth during engagement, which is not in good agreement with numerical results. This paper is focused on analysis of plastic helical gears. The nonuniform load distribution obtained from the proposed mathematical model is based on the calculation of the real contact ratio representing the real number of pairs of teeth in contact. This model also leads to the distribution of the tooth bending stress and the contact stress along the area of contact **[9].** The contents of the paper cover: (i) computerized design, (ii) method for modification, (iii) simulation of meshing, and (iv) finite element analysis of the unmodified and modified double circular-arc gears. The approach proposed of tooth end relief with helix is based on the curves of circumferential displacement differences between before and after tooth surfaces entering in mesh and exiting out mesh. And the solutions under the conditions of different modification parameters are investigated. The results demonstrate that the method enables to decline transmission errors, decrease the maximum contact stress, lessen the tooth end stress, and cut down the circumferential displacement difference, effectively. Therefore, the purposes for modification of reducing noise and vibration and avoiding edge contact are achieved **[10].** An analytical approach for stress analysis of gear drives with localized bearing contact based on the Hertz theory is proposed. The proposed approach provides a complete and effective solution of the contact problem but satisfaction of the hypotheses for application of the Hertz theory is its main drawback. On the other hand, a finite element model has been developed and validated in terms of the contact area, maximum contact pressure, pressure distribution, maximum Tresca stress, and Tresca stress distribution underneath the contacting surfaces. Validation of the finite element model is provided for those cases wherein the Hertz theory can be applied. The obtained results confirm the applicability of the proposed approach for gear drives with localized bearing contact wherein edge contact is avoided by surface modifications and whole crowning of tooth surfaces is provided **[11].** The presence of undercut at the pinion root may affect the load sharing among couples of spur gear teeth in simultaneous contact, as well as the load distribution along the line of contact of helical gears. This occurs if the outside points of the wheel profile do not find, due to undercut, mating profile to mesh with, which is called vacuum gearing. Under these conditions, the effective contact ratio is reduced, and the critical contact points may be shifted from their locations at non-undercut profiles. In this paper, a non-uniform model of load distribution along the line of contact, obtained from the minimum elastic potential criterion, has been used combined with the Hertz equation for the calculation of the contact stress. A complete study on the critical load conditions and the value of the critical contact stress has been carried out, considering a wide range of the values of the geometrical parameters **[12].** The objective of this study was to evaluate the performance of helical gears with applied surface coatings either with or without Inorganic Fullerence Like Material (IFLM) nano-particles. The contact fatigue performance of case-carburised and tempered S156 steel helical gears coated with Balinit C1000, Balinit C*, CrN + IFLM, C6 + IFLM and Nb–S coatings were tested using a 91.5 mm centre distance back-to-back test rig.The endurance contact fatigue tests were conducted at two different contact stress levels with the performance assessed against the extent of micro-pitting damage and the associated average gear tooth profile deviation. It has been found that gears coated with Balinit C showed the lowest micro-pitting damage followed by those with C6 + IFLM and Nb–S coatings. The Nb–S coated gears showed the lowest gear profile deviation followed by those coated with Balinit C. From the results of gear testing, it is concluded that the Nb–S coated gears showed the best overall contact fatigue performance, followed by Balinit C coated gears that gave minimum micro-pitting damage and low levels of gear tooth profile deviation **[13].** In this paper, a non-uniform model of load distribution along the line of contact of spur and helical gears, obtained from the minimum elastic potential criterion, has been used, combined with the equations of the linear elasticity, to evaluate the fatigue tooth-root stress. The critical value of the stress and the critical load conditions have been obtained and a complete analysis of the tooth bending strength has been carried out. As the load per unit of length at any point of the line of contact and any position of the meshing cycle has been described by a very simple analytic equation, a complete study of the location and the value of the tooth-root bending stress has been carried out. From this study, a recommendation for the calculation of the bending load capacity of spur and helical gears is proposed **[14].** The paper presents a contact stress analysis for a pair of mating gears at different contact positions during rotation. Two examples of spur and helical gears are presented to investigate the respective variations of the contact stress in a pair of mating gears with the contact position. The variation of the contact stress during rotation is compared with the contact stress at the lowest point of single-tooth contact (LPSTC) and the AGMA (American Gear Manufacturers Association) equation for the contact stress. In this study, we can see that the gear design that considers the contact stress in a pair of mating gears is more severe than that of the AGMA standard **[15].** This paper presents an approach for the analysis of tooth contact and load distribution of helical gears with crossed axis. The approach is based on a tooth contact model that accommodates the infuence of tooth profile modifications, gear manufacturing errors and tooth surface deformation on gear mesh quality. In the approach the tooth contact load is assumed to be distributed along the tooth surface line that coincides with the relative principal direction of the contacting tooth surfaces. As compared with existing tooth contact (TCA) analysis model that assumes rigidity for the contacting surfaces, the model in this paper provides a more realistic analysis on gear transmission errors, contact patterns and the distribution of contact load. It is found from the analysis that helical gears with small crossing angles have meshing characteristics and load distribution similar to those of parallel-axis gears. The approach may be extended to other types of gearing **[16].** The authors have investigated the generation, geometry, meshing and contact of double circular-arc helical gears. Such gears have been proposed in extension of the idea of single-arc Wildhaber-Novikov gears with the purpose:

(i) to obtain two zones of meshing and reduce the bending stresses, and
(ii) keep the advantage of reduced contact stresses of W.-N. gears.

The proposed methods and developed computer programs cover the solution to the following problems:

(i) Determination of the paths of contact on the gear tooth surfaces.
(ii) Determination of the bearing contact as the set, of instantaneous contact ellipses.
(iii) Determination of transmission errors caused by gear misalignment **[17].** The proposed approach is based on application of (i) computerized simulation of meshing and contact of loaded gear drives, and (ii) the finite element method. Load share between the neighboring pairs of teeth is based on the analysis of position errors caused by surface mismatch and elastic deformation of teeth. The authors have investigated the conditions of load share under a load and determined the real contact ratio for aligned and misaligned gear drives.

respectively. Elastic deformation of teeth and the stress analysis of the double circular-arc helical gears are accomplished by using the finite element method. The finite element models for the pinion and gear are constructed, respectively. Contact pressure is spread over elliptical area. The stress analysis for aligned and misaligned gear drives, respectively, has been performed. The numerical results have been compared with those obtained by other approaches **[18].**

CONCLUSION:

The above literature review presents that the Finite Element Method is widely used for stress analysis in a pair of gear.The gear stress distribution is investigated using the commercial FEA package. The FEM-based contact model gives a reasonable approximation of contact parameters when the mesh size is fine enough. Such as in helical gears, require small element size, i.e. a large number of elements to avoid element dimensional distortion. however, the FEM-based contact model has potential in calculating edge contacts.

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