Review Paper on Optimum Design of Gear Drive for Non Linear Contact and Dynamic Analysis

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Abstract - *Gears are one of the most critical components in power transmission systems. It may be used in a variety of industrial machinery. The bending strength of the gear tooth is main contributors for the failure of the gear. In design of gear system the calculation of bending strength is an important part. The complicated dynamic forces at the gear meshes are the source of vibration and result from parametric excitation and tooth contact nonlinearity. The primary goal of this work is to develop mathematical models for gear with nonlinear and analytical studies of nonlinear and dynamic behaviors.*

Key Words: Spur gear, hertz-contact stress, bending stress, finite element analysis, contact stress, Dynamic Load

1. INTRODUCTION

Gear is the most critical component in a power transmission system we can also call it a speed reducer, which consists of a set of gears, shafts, and bearings that are mounted in an enclosed lubricated housing. Speed reducers are available in a broad range of sizes, capacities, and different speed ratios. Their job is to convert the input of prime mover into a lower speed output and correspondingly higher torque. Many automation tools will necessitate a refined application of gear technology. The increasing demand for smooth power transmission in machines, vehicles, elevators, and generators, has created more demand for a more precise analysis of the characteristics of gear systems. In the automobile industry, the use of gears with high reliability and lighter weight is necessary as lighter automobiles continue to be in demand..

2. LITERATURE SURVEY

Deshpande [1] has carried out finite element analysis (FEA) of spur gear for determining the transmission error. The investigation of FEA for modeling the mechanism properties such as transmission error, load sharing ratio and combined torsion mesh stiffness of involutes spur gears in mesh, over the mesh cycle has been carried out. FEA results have been obtained by using map-mesh with contacts using quad (2D) elements in ANSYS. The handover region is the part of mesh cycle where contact changes from one tooth pair to two teeth pairs and vice versa. The mesh characteristics have been studied in detail in the handover region as it affects the vibration and noise drastically. The effect of tooth profile modification on the gear meshing including the transmission error and load-sharing ratio has been studied.

Yong-Jun Wu et al. [2] have presented the contact analysis using FEM for dynamic meshing characteristics of spur gear pair. The dynamic meshing characteristics of gear drives have been a major concern in the design of power transmission systems as they affect vibration, acoustic noise, durability and efficiency. In this paper, a dynamic contact finite element analysis method, considering the variation of the engaged teeth pairs, the loaded elastic and contact deformations, and the sliding friction, have been presented for the dynamic meshing characteristics analysis of continuous and elastic engaged gear drives. Various kinds of continuous engaged gear models under low and high speed condition have been simulated and compared. The tooth profile modification was designed based on the simulation results. The effects of the tooth profile modification, the sliding friction and the time-varying meshing stiffness upon the dynamic meshing characteristics of continuous engaged gear drives have been discussed in detail. It has been observed that the method is not only effective in designing and evaluating the tooth profile modification, but also in studying the dynamic meshing characteristics of continuous engaged gear drives with realistic time-varying meshing stiffness and tooth sliding friction. The present method could provide an effective tool for vibration mechanism study and dynamic design of the continuous engaged gear drives considering more influence factors.

Jong Boon Ooi et al. [3] have presented the modal and the stress analysis of gear train using FEM. The portal axle is a gearbox that is specially designed for off-road driving conditions. It is installed between the wheel and the axle shaft to give higher ground clearance to the vehicle. The modeling and simulation of spur gears in portal axle is important to predict the actual motion behavior. In this study, modal analysis of portal axle has been simulated using finite element method FEM on three different combinations of gear train system commonly designed for portal axle. FEM static stress analysis has been also simulated on the same three different gear trains to study the gear teeth bending stress and contact stress behavior of the gear trains in different angular positions from 0° to 18°. The single and double pair gear teeth contact have been considered.

Yong-Jun Wu et al. [4] in another paper presented the dynamic contact analysis using FEM and its experimental validation for helical gear pair. In this paper, a precise tooth profile modification (TPM) approach of the helical gear pairs has been presented first. The type and amount of the TPM have been accurately determined by the static contact FEA results. Then dynamic contact simulations for the helical gear pairs with and without TPM have been carried out respectively to evaluate the effect of the presented TPM approach on vibration reduction. No additional assumptions and simplifications have been required for the static and dynamic contact analysis models. Vibration comparison experiments have been also carried out on an open power flow test rig. It has been observed that simulated and experimental results show presented precise TPM of helical gears is effective on vibration reduction around the working load, and the dynamic contact simulation is effective in estimating the effect of the TPM on vibration reduction in the designing stage.

Atanasovska et al. [5] have presented FEM analysis for stress analysis and nonlinear contact analysis of helical gears. In this paper development of the finite element model for simultaneously monitoring the deformation and stress state of teeth flanks, teeth fillets and parts of helical gears during the tooth pair meshing period have been described. The Finite Element Method simulation of contact conditions for helical gears teeth with an involute profile also presented in the paper. A suitable analysis has been performed in order to select a meshed gears model which is sufficiently economic and in same discipline sufficiently geometrically accurate. The special algorithm for the tooth involute profile drawing has been developed and built in currently available software for Finite Element Analysis to assure drawing of real flanks contact geometry. The optimal mesh size level has been chosen, too. The described finite element models have been made for the particular helical gear pair. The obtained numerical results have found to be suitable for tracking deformation and stress variables during the tooth pair meshing period.

Jian and Parker [6] have presented the investigations on mesh stiffness variation instabilities in two stage gear system. Mesh stiffness variation, the change in stiffness of meshing teeth as the number of teeth in contact changes, causes parametric instabilities and severe vibration in gear systems. The operating conditions leading to parametric instability have been investigated for two-stage gear chains, including idler gear and countershaft configurations in the paper. Interactions between the stiffness variations at the two meshes have been examined. Primary, secondary, and combination instabilities have been studied. The effects of mesh stiffness parameters, including stiffness variation amplitudes, mesh frequencies, contact ratios, and mesh phasing; on these instabilities have been analytically identified. For mesh stiffness variation with rectangular waveforms, simple design formulas are derived to control the instability regions by adjusting the contact ratios and mesh phasing. The analytical results have been compared to numerical solutions.

Jeong [7] has investigated the nonlinear behavior of gear pairs considering hydro dynamic lubrication and sliding friction. An analysis of the nonlinear behavior of gear pairs according to the direct contact elastic deformation model over a wide range of speeds, considering the hydrodynamic effects and friction force have been described in this paper. The inclusion of the hydrodynamic effect facilitates nonlinearity by increasing the overlap range (i.e., multiple solution regimes) and damping, as well as decreasing elastic deformation and tooth reaction forces. The effects of various lubrication parameters, such as viscosity and film width, on the nonlinear dynamic behavior have been analyzed. It has been observed that the viscosity has a strong effect on the behavior of gear pair systems; friction has very little effect on torsional behavior. Although the model of direct contact without friction has overall nonlinear behavior similar to the model including hydrodynamic effects with friction, the time data of these models are different due to the squeeze effect.

Kahraman and Blankenship [8] have presented the investigations on the effect of contact ratio on the spur gear dynamics. The influence of involute contact ratio on the torsional vibration behavior of a spur gear pair have been investigated experimentally by measuring the dynamic transmission error of several gear pairs using a specially designed gear test rig. Measured forced response curves have been presented, and harmonic amplitudes of dynamic transmission error have been compared above and below gear mesh resonances for both unmodified and modified gears having various involute contact ratio values. The influence of involutes contact ratio on dynamic transmission error has been quantified and a set of generalized, experimentally validated design guidelines for the proper selection of involutes contact ratio to achieve quite gear systems have been presented. A simplified analytical model also has been proposed which accurately describes the effects of involutes contact ratio on dynamic transmission error.

Ognjanovic and Agemi [9] have presented the study of gear vibrations due to the tooth impact in super critical mesh frequency. After gear teeth impact, natural free vibrations arise, attenuating in a short period of time. Teeth impacts repeat with the frequency of teeth entering the mesh, vibrations become restorable, and restore with teeth mesh frequency. In the range of sub-critical teeth mesh frequency range these natural free vibrations are covered by forced vibrations caused by the fluctuation of teeth deformations. In the supercritical mesh frequency range, restorable free vibrations dominate in the frequency spectrum of gear system vibrations. These restorable free vibrations effectuate the increase of total vibration level with the speed of rotation increase. Also, in this frequency range the modal structure (natural frequency) of the gear system is not stable and effectuates super-critical resonances arising. Gear vibration measurements and frequency analysis (FFT-Analysis) have been performed in very high speeds of gear rotations as high as 40,000 rpm. A mathematical model for experimental results synthesis has been established. For this purpose, the theory of singular systems has been used. Gear teeth mesh has been treated as a singular system, with a continual process of load transmission with singularities caused by teeth impacts. Damping coefficients and energy attenuation have been determined using the developed mathematical model.

Podzharov et al. [10] have presented the static and dynamic transmission error in spur gear. In high precision and heavily loaded spur gears the effect of gear errors is negligible, so the periodic variation of tooth stiffness is the principal cause of noise and vibration. High contact ratio spur gears could be used to exclude or reduce the variation of tooth stiffness. The analysis of static and dynamic transmission error of spur gears cut with standard tools of 20° profile angle have been presented in this paper. A simple method to design spur gears with a contact ratio nearly 2.0 has been used. It consists of increasing the number of teeth on mating gears and simultaneously introducing negative profile shift in order to provide the same center distance. Computer programs to calculate static and dynamic transmission error of gears under load have been developed. The analysis of gears using these programs showed that gears with high contact ratio have much less static and dynamic transmission error than standard gears.

Abhishek Tiwari [11] have presented the study of a unique and comprehensive process for the design and optimization of Spur gear bending stress and related fatigue life. By the means of stress relief features we can reduce the bending stress and increase the fatigue life of spur gear, but along with this they discussed about the optimization of the Bending stress and fatigue life with respect to the size and location parameters of the stress relief holes. This will lead us to some unique result where the Bending stress has been reduced by approx. 21% and life has been enhanced approx. In the field of gear analysis, it can be seen that the light weight construction and the compactness of the gears leads to the higher stress levels. Industries are also giving attention towards smooth working of gear drives in order to reduce noise and vibrations. In automobile industries, an extensive research has been carried out in the contact stress analysis of gears.

3. CONCLUSIONS

In this paper we have been presented a brief review of the design and analysis of gears in mesh. Contact stress and bending stress for gear mesh is calculated using hertz, Lewis and AGMA equations used along with ANSYS software for analysis. Some studies used different variations in geometry and their effect due to bending and contact stress. Also different materials are tried for weight reduction and cost optimization. Most researchers used the fundamental Lewis Bending Equation and AGMA Standards with modifications to induce the primary read of substances tooth strength.

From the literature review, it is seen that there is some scope for research work in the area of dynamic analysis of gear pair used in power transmission. It is also seen that there is inadequate literature on linear and nonlinear analysis of gear mesh pair. It is proposed to carry out some theoretical and experimental studies on dynamic analysis of gear pair using FEM and analyze optimum solution for it.

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