A Review On Design, Analysis And Manufacturing Of Spiral Bevel Gear

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Abstract:-

This review paper gives a detailed approach to spiral bevel gear design, analysis and manufacturing. Key design parameters are investigated in accord with industry standards and recommended practices for use. A final gear design is proposed and analyzed to show that proper margins of safety have been included in the design. In this report we try to cover some of the methods of analytical method of designing a spiral bevel gear, and FEM approach, and prediction of crack in gear teeth. Using simulator setup experimental result can be derives and necessary changes can be acceptable.

Keywords: - Design of spiral bevel gear, analysis of spiral bevel gear.

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1. Introduction

The design, analysis and manufacturing of spiral bevel gear is still a hot topic of research that is vital for application of such gears in helicopter transmissions, reducers, motorcycle gears and in other branches of industry. Now a day, the requirements of reduction of noise and increase of the endurance of gear drives make the design of spiral bevel gear drives very challenging. The bases of design of low-noise spiral bevel gears with localized bearing contact have been represented. The design of low-noise spiral bevel gear drives is based on application of the local synthesis algorithm [1].

A new approach for design, tooth contact analysis and stress analysis of formate generated spiral bevel gear is proposed. The advantage of formate generation is the higher productivity. [2]

In general design of spiral bevel gear is on the basis of load and application calculated and some of the methods are discussed below.

In this paper we try to cover methods which are used to design, manufacturing and test of spiral bevel gears

1. Computerized design:

A new approach for design, tooth contact analysis (TCA) and stress analysis of formate generated spiral bevel gears is proposed. The advantage of formate generation is the higher productivity. The purposes of the proposed approach are to overcome difficulties of surface conjugation caused by formate generation, develop a low noise and stabilized bearing contact, and perform stress analysis. The approach proposed is based on application of four procedures that enable in sequence to provide a predesigned parabolic function of transmission errors with limited magnitude of maximal transmission errors, a bearing contact with reduced shift of contact caused by misalignment, and perform stress analysis based on application of Finite Element Method. The advantage of the approach developed for finite element analysis (FEA) is the automatic generation of finite element models with multi-pairs of teeth. The stress analysis is accomplished by direct application of ABAQUS. Intermediate auxiliary CAD computer programs for development of solid models are not required.

The computational procedure is divided into four separately applied procedures performed as follows:

Procedure 1. The purpose of the procedure is to obtain the assigned orientation of the bearing contact. In this procedure the parameter η_2 initially find out.

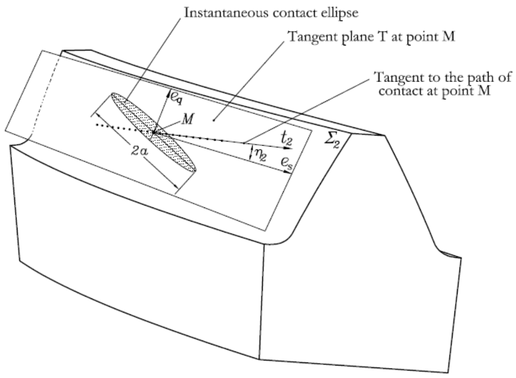

Fig. 1:- Illustration of parameter η_2 and a applied for local sysnthesis.

Procedure 2. Procedure 1 is accomplished with obtaining $L_T^{(n)}$,T as a straight line. However, the output of the TCA for the function of the transmission errors is of unfavorable shape and magnitude. The goal is to transform $\Delta\Phi_2^{(n)}(\Phi_1)$ into a parabolic function and limit the magnitude of maximal transmission errors. This goal is achieved by application of modified roll for pinion generation.

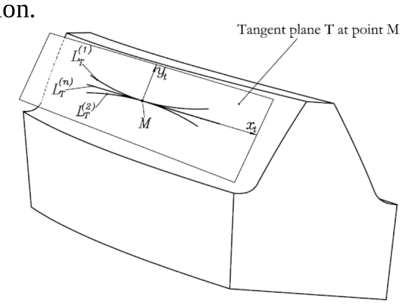

Fig. 2:- Projection of various path of contact L_T on tangent plan T

Procedure 3. Procedures 1 and 2 discussed above enable one to obtain: (i) a longitudinally oriented projection L_T of the path of contact and represent L_T as a straight line; (ii) a parabolic function of transmission errors with the assigned level of maximal transmission errors. However, these results have been obtained for an aligned gear drive.

Procedure 4. After completion of Procedures 1–3, the obtained pinion machine-tool settings guarantee that the designed gear drive is indeed a low-noise gear drive with reduced sensitivity to errors of alignment.

2. Application of FEA:-

The goals of application of FEA are: (i) simulation of bearing contact by considering multitooth meshing and investigation of the movement and formation of the real bearing contact and load sharing among the meshing teeth under the given load (usually a torque is applied); (ii) determination of the contact stress and bending stress of the gear teeth. Application of finite element method requires the development of the finite element models formed by finite element mesh, the definition of contacting surfaces, and establishment of boundary conditions for loading the gear drive with the desired torque. The commercial software ABAQUS [3] is used for FEA computation. The authors have developed a modified approach to perform the FEA that has some advantages:

Application of the existing procedure based on the use of CAD computer program as an intermediate stage would require the following steps:

(1) Determination of wire models formed by splines obtained numerically. The wire models consist of tooth planar sections of the teeth. The increase of sections is in favor of the precision of wire models but it is time expensive.

(2) Generation of the solid models using the sections that form the wire models.

(3) Generation of the finite element meshes of solid models for ABAQUS computer program.

(4) Setting boundary conditions for the models. [9]

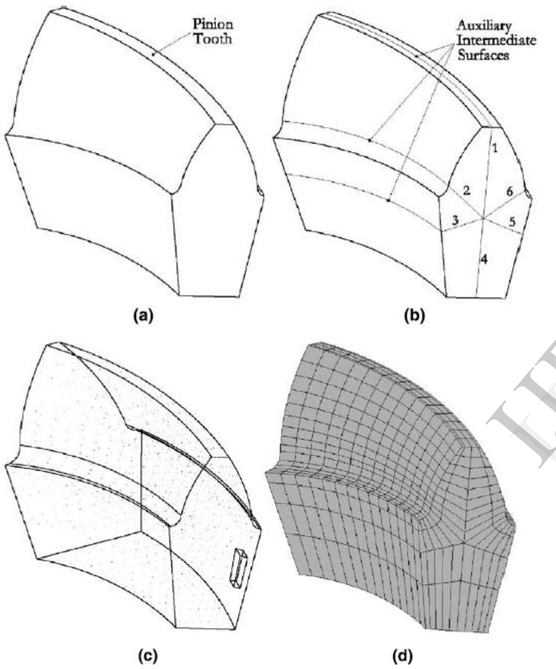

Fig. 3:- (a) Illustration of volume of the tooth body; (b) illustration of auxiliary intermediate surfaces (c) Illustration of generation of nodes for the tooth volume; (d) Illustration of discretization of the volume by finite elements. [2]

3. Generation of gear surface:

Fig. 4 shows schemedically the generation of a spiral bevel gear. The head cutter mounted on the cradle and performs a planetary motion: (i) rotation in transfer motion (with the cradle) about the cradle axis, and (ii) rotation in relative motion (relative to the cradle) about the head cutter axis. The spiral bevel gear (pinion) to be generated is installed with the angle Υ_{mi} with respect to the head cutter and rotates about the gear (pinion) axis. Rotation of the cradle and the gear are related. The angular velocity of rotation of the head cutter about its axis is not related with the process of generation and chosen to provide the desire velocity of cutting. Hence forth, we will consider that the head – cutter is provided with a generating surface (a cone) formed by the blades when they are rotated about the head cutter axis.[11]

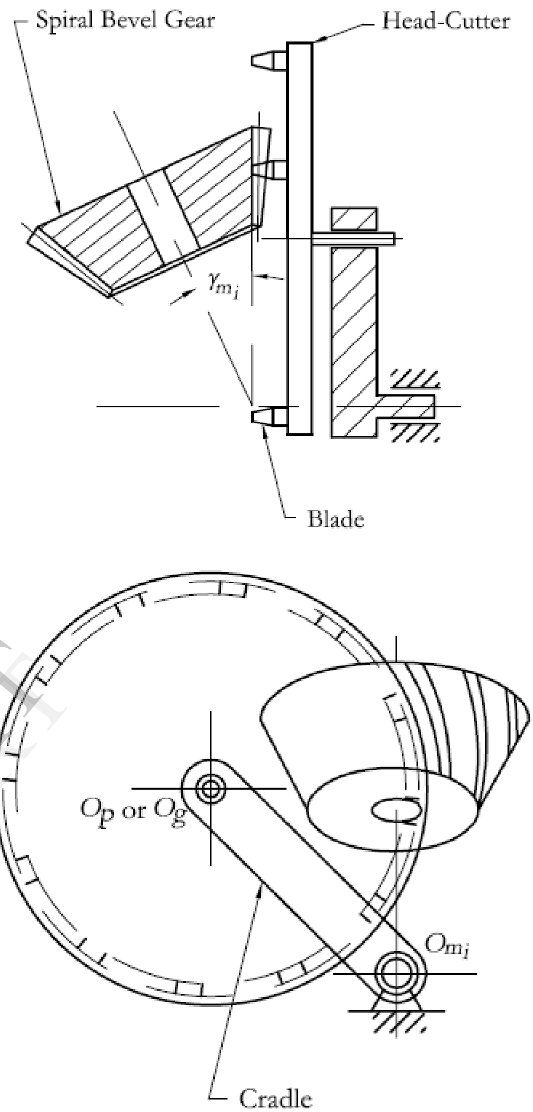

Fig. 4:- Schematic of generation of a spiral bevel gear [4]

Each space of the gear or pinion is generated separately. The process of generation is interrupted after generation of the current space is finished and the workspace is indexed to the next space, and the process of generation is repeated. [4]

4. Computer - aided manufacturing:

Manufacturing spiral bevel gears requires state of the art machinery and techniques because such gears have complex tooth surface geometry. Many analytical efforts such as tooth contact analysis, loaded tooth contact analysis, under cut checking, stress analysis, among others, are successfully applied to the design of spiral bevel gear to obtain optimal tooth surface with permissible contact pattern position, length, bias, smoothness of motion, and adjustability of assembly. Therefore, it is significant to develop a methodology that minimizes, within acceptable tolerances, the surface deviation of real cut spiral bevel gear tooth surfaces with respect to theoretical ones.

Recent technology development on CNC machinery makes it possible to manufacture and inspect spiral bevel gears using full quantitative and qualitative control. Several computer aided inspection systems and closed loop manufacturing system that combine CNC co ordinate measuring machine with theoretical gear tooth surface data, have been developed in past few years. Theoretical gear tooth surface data can be obtained from mathematical models of bevel gears. However, all these studies investigated minimization of surface deviations by means of the so called linear regression method. Since the tooth surface geometry of spiral bevel gear is quite complex and sensitive to machine tool settings, gears with different characteristics should be generated using different manufacturing machines and methods.

However, from a practical point of view the linear regression method is not adequate for solving this problem because the corrective machine tool setting obtain by the linear regression method cannot be constrained to a permissible range that matches the physical machine tool relationship. [5]

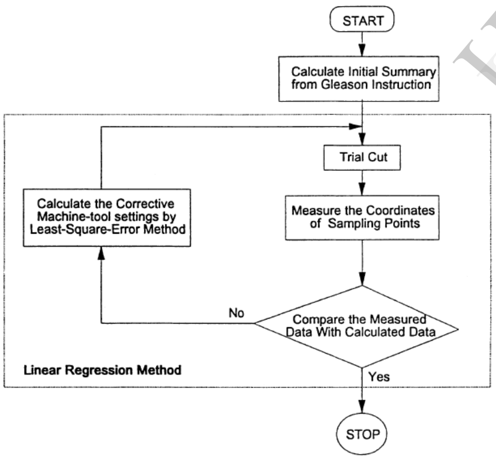

Fig. 5:- Spiral bevel gear development flow chart using the linear regression method. [5]

5. Controlling contact path

Fig.6 shows the three contact points on the gear tooth surface. r2 is the pitch angle of the gear. The contact path is designed to be a straight line and η2 is the orientation of contact path.

By controlling the three points as shown in fig. 6, reduced vibration and misalignment in gear box. [6]

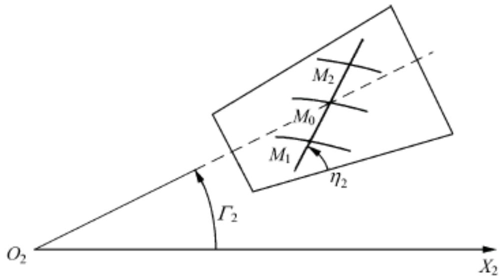

Fig. 6: Three control meshing points and contact path. [6]

6. Fault diagnosis of gear box:

A faulty gear system could result in serious damage if defects occur to one of the gears during operation condition. Early detection of the defects, therefore, is crucial to prevent the system from malfunction that could cause damage or entire system halt. Diagnosing a gear system by examining the vibration signals is the most commonly used method for detecting gear failures. The conventional methods for processing measured data contain the frequency domain technique, time domain technique, and time frequency domain technique. These methods have been widely employed to detect gear failures. The use of vibration analysis for gear fault diagnosis and monitoring has been widely investigated and its application in industry is well established. This is particularly reflected in the aviation industry where the helicopter engine, drive trains and rotor systems are fitted with vibration sensors for component health monitoring. The raw vibration signal in any mode from a single point on a machine is not a good indicator of the health or condition of a machine. Vibration is a vectorial parameter with three dimensions and requires to be measured at several carefully selected points.

Vibration analysis can be carried out using Fourier transform techniques like Fourier series expansion, Fourier integral transform and discrete Fourier transform. After the development of large-scale integration and the associated microprocessor technology, fast Fourier transform analyzers became cost effective for general applications. The raw signatures acquired through a vibration sensor needed further processing and classification of the data for any meaningful surveillance of the condition of the system being monitored. [7]

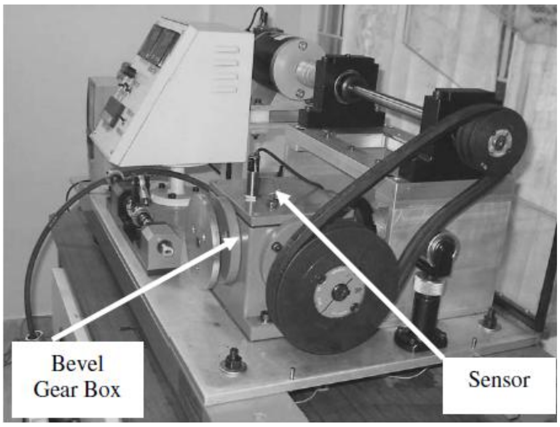

Fig. 7: Fault simulator setup.

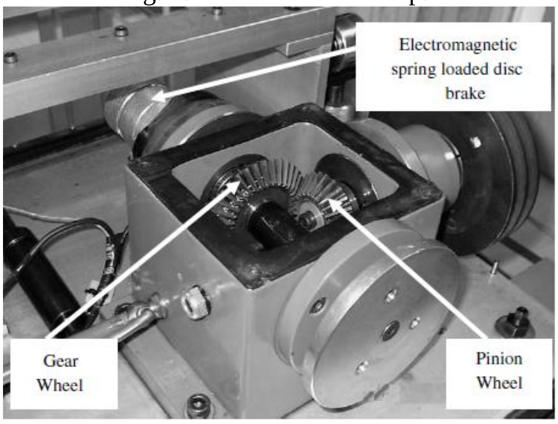

Fig. 8: Inner view of bevel gear box [7]

7. Prediction of crack in gear teeth.

Predicting crack shapes is important in determining the failure mode of a gear. Cracks propagating through the rim may result in catastrophic failure, whereas the gear may remain intact if one tooth fails allowing for early detection of impending failure. Being able to predict crack trajectories is insightful for the designer. However, predicting growth of three-dimensional arbitrary cracks is complicated due to the difficulty of creating and evolving three-dimensional geometry and mesh models, the computing power required and absence of closed-form solutions of the problem. [8, 10]

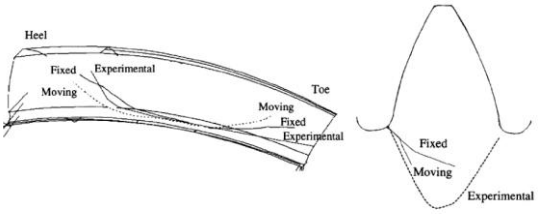

Fig. 8: Comparison of predicted crack trajectories from moving load method, fixed load method, and experiment. [8]

8. CONCLUSION:

The design of spiral bevel gear is very necessary to reduce vibration and wear in gear. By following the design procedure we get the optimize design of spiral bevel gear and by FEM analysis we can calculate the stress in gear and by simulating software one can predict the crack in the gear teeth, and fault diagnosis simulator setup check the gear box for experimental result.

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