Design, Analysis and Optimization of a Planetary Gearbox: A Review

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Abstract- **A two stage planetary reduction gear unit is designed to meet the output specifications. In industries, where the bevel gears are used to transmit the power that unit is replaced by this epicyclic planetary gearbox. The advantage of using this type of gearbox is to get better efficiency and also the manufacturing of the bevel gear is more complex than the spur gears. The main purpose of the project is to design a gearbox with epicyclic gear train. In industries the power transmission from gearbox to vessel is done through the bevel gears, which transmit the power at right angle. In this work, planetary gearbox is designed that the power is to be transmitted vertically from gearbox to vessel, which will increase the efficiency and life of gears.**

***Keywords*— Planetary Gearbox, Analysis, Optimization**

I. INTRODUCTION

Gears are commonly used for transmitting power. They develop high stress concentration at the root and the point of contact. The repeated stressing on the fillets causes the fatigue failure of gear tooth**.** Gears in the Epicyclic gear trains are one of the most critical components in the mechanical power transmission system in which failure of one gear will affect the whole transmission system, thus it is very necessary to determine the causes of failure in an attempt to reduce them. Manufacturing worm gears often requires use of the contact pattern test to check worm–gear coupling quality. If the result is not satisfactory, it is necessary to modify worm gear cutting and repeat the contact pattern test.

Bending stress plays a significant role in gear design wherein its magnitude is controlled by the nominal bending stress and the stress concentration due to the geometrical shape. The bending stress is indirectly related to shape changes made to the cutting tool. This work shows that the bending stress can be reduced significantly by using asymmetric gear teeth and by shape optimizing the gear through changes made to the tool geometry. Two primary fatigue related failure modes determine gear strength; failure due to bending stress and failure due to contact pressure. The latter failure is primarily due to pitting while the former is due to tooth breakage.

II. FE MODELING

An assumption of plane stress is made in the present paper since the optimizations are made for external spur gears. The Poisson's ratio used is ν=0.3 and linear elasticity is assumed. The geometry, the loads and the supports need to be specified for the FE modeling. The geometry is given by the cutting tool design. The load is acting perpendicular to the surface. In reality the load does not act as a single load but is spread out as given by the Hertzian pressure distribution and could be used in the FE simulations.

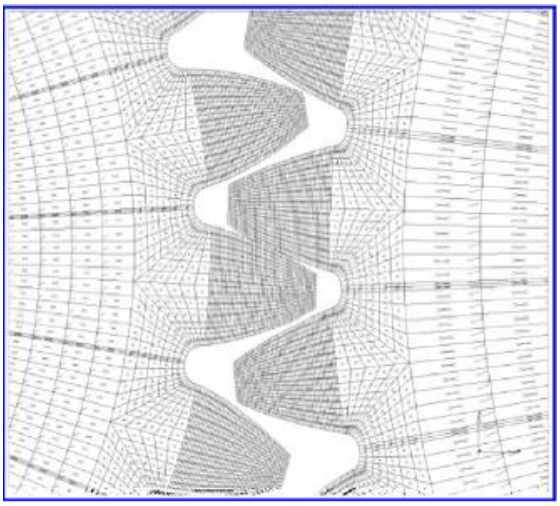

Fig. 1 Finite Element Model

III. OPTIMIZATION PROCEDURE

Minimizing the tooth contact pressure and angular displacement error of the driven gear are regarded here as a mathematical optimization problem.

A. TOOTH SURFACE GEOMETRY

The concept of an imaginary generating crown gear is used to explain the generating cutting process of the face-hobbed hypoid pinion and gear teeth. This imaginary generating gear is a virtual gear whose teeth are formed by the traces of the cutting edges of the head-cutter blades, although its tooth number is not necessarily an integer.

B. LOADED TOOTH CONTACT ANALYSIS

The proposed optimization procedure relies heavily on the loaded tooth contact analysis for the prediction of the tooth contact pressure and the angular displacement error of the driven gear. In the applied loaded tooth contact analysis it is assumed that the point contact under load is spreading over a surface along the “potential” contact line, which is made up of the points of the mating tooth surfaces in which the separations of these surfaces are minimal, instead of assuming the usually applied elliptical contact area.

C. MANUFACTURE VARIABLES

The contact properties and the loaded transmission error are extremely sensitive to any small-level variations in the head-cutter geometry and machine tool setting. Appropriate modifications of existing basic manufacture parameters can significantly enhance the performance characteristics of a gear drive.

IV. LOAD OPTIMIZATION OF GEARS

Here the load calculations for analysis of Gears having module 3,4,5 and 6 and power 10 HP, from the Epicyclic Gear train, in which the calculations of the four loads acting on the gears (Tangential Tooth Load (Wt), Static Tooth Load (Ws), Dynamic Tooth Load (Wd) and Wear Tooth Load (Ww))are calculated.[2]

A. Tangential Load(WT):-

Tangential tooth load is also called the beam strength of the tooth. It is the load acting perpendicular to the radial tooth load (Wr) and normal tooth load (Wn).

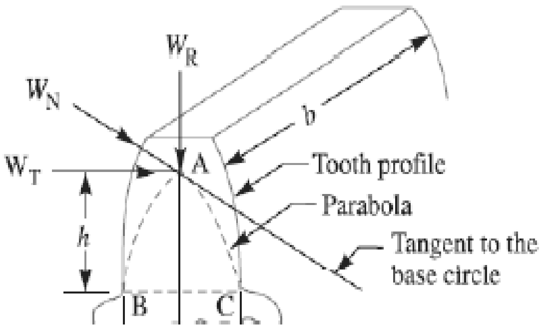

Fig 2. tangential tooth load direction on the gear tooth profile

B. Dynamic Tooth Load (WD):-

The dynamic tooth loads act due to inaccuracies in tooth spacing, tooth profiles and deflection of tooth under loads.

C. Static Tooth Load (W_S):-

The static tooth load (beam strength or endurance strength of the tooth) is derived from lewis formula with the substitution of elastic limit stress (σ_e) instead of Permissible working stress (σ_w). It is said that for preventing tooth breakage (Ws) should be greater than Dynamic tooth load (Wd).

D. Wear Tooth Load (WW):-

It is maximum load that a gear tooth can carry without premature wear. It depends upon the curvature of tooth profile, elasticity and surface fatigue limit of the gear material.

V. OPTIMIZATION METHODS

A. Brute force optimization

The optimization is carried out using two parameters and linear profile modifications. The parameter space is uniformly spanned in order to get directly the optimal parameter set. This also allows checking the smoothness of the objective functions.

a. Variation of the start tip radius

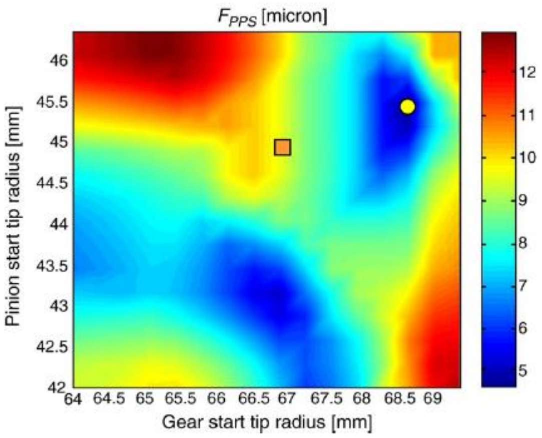

Fig. 3 Variation of start tip radius

The square indicates the minimum

b. Variation of the tip amplitude

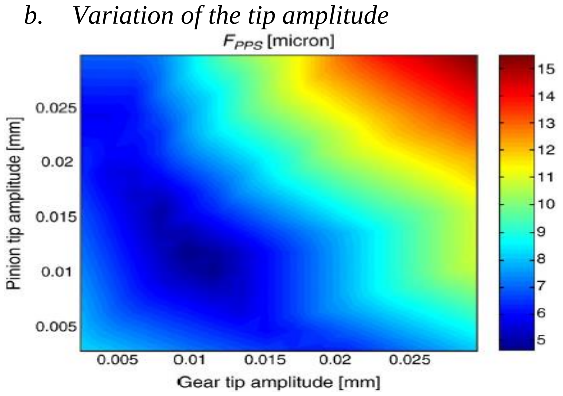

Fig. 4 Variation of tip amplitude

B. Random–Simplex optimization

The second optimization strategy proposed in this paper is based on the combination of a Random search of the optimum, followed by a refinement carried out using the Simplex method; the latter one is very robust and does not require derivative evaluation of the objective function; however, it is not suitable for global optimization.

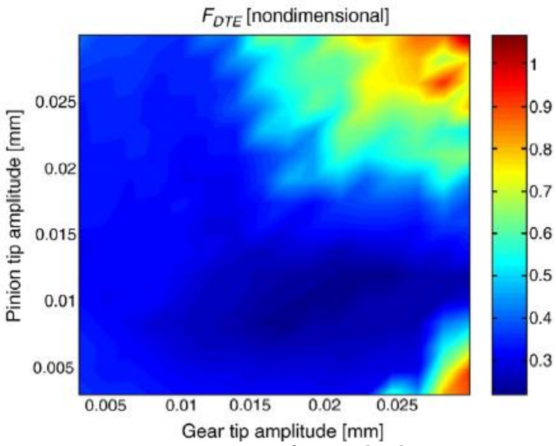

Fig. 5 Variation of tip amplitude

C. Macro-geometric optimization

It is well known in literature that High Contact Ratio (HCR) gears allow to obtain good results in terms of vibration behavior; in particular, if the contact ratio (average number of teeth in contact) is an integer value (for HCR it means at least 2), the vibration is reduced. Our intent is to apply the Random–Simplex technique to a suitable HCR gear pair "equivalent" to the original one, having a higher contact ratio with respect to the original gears. The geometry of the original gears is altered with the following constraints: i) the same operating center distance; ii) the same face width; iii) variation of transmission ratio less than 1%; and iv) the same or smaller stresses.

CONCLUSION

In the design of the gears, conditions should satisfy that Static Tooth Load (Ws) should always be greater than the Dynamic Tooth Load (Wd) also the Wear tooth load (Ww) should not be less than the Dynamic tooth load (Wd). A global optimization method, based on the Random plus Simplex approach, has been developed in order to suggest the best geometry of spur gears versus vibration reduction. The dynamic optimization produces better results than the static optimization. Coupling macro and micro geometric optimizations allows to reduce dramatically the vibration level for all operating conditions.

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