International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 - 5161

Available at http://inpressco.com/category/ijcet

Research Article

Investigate the Combined Effect of gear ratio, helix angle, face width and module on beam strength and Wear tooth load of Steel alloy Helical Gear

B Venkatesh [Ȧ*], SV Prabhakar Vattikuti [Ȧ] and V Mahidhar Reddy [Ȧ]

[Ȧ] Vardhaman College of Engineering, Hyderabad, India

Accepted 10 January 2014, Available online 01 February 2014, **Special Issue-2, (February 2014)**

Abstract

In the present era of sophisticated technology, gear design has evolved to a high degree of perfection. The design and manufacture of precision cut gears, made from materials of high strength, have made it possible to produce gears which are capable of transmitting extremely large loads at extremely high circumferential speeds with very little noise, vibration and other undesirable aspects of gear drives. Gears have been manufactured for a number of years with extensive ongoing research related to their efficiency, operational quality and durability. They are relatively complex and there is a number of design parameters involved in gear design. The design of gears requires an iterative approach to optimize design parameters, which govern both the kinematics as well as the strength performance. The present study is proposed to investigating the combined effect of gear ratio, helix angle, face width and normal module on beam strength and wear tooth load of steel alloy helical gear.

Keywords: *Helical gear design, Lewis equation, Optimum design parameters, wear tooth load, beam strength.*

1. Introduction

Gear design is a highly complicated art. The constant pressure to build less expensive, quieter running, light weight, low cost and more powerful machinery has resulted in a steady change in gear design. The extensive ongoing research deals with the analysis of gear stresses, transmission errors, dynamic loads, noise, and failure of gear tooth, which are very useful for optimal design of gear set. The systematic studies were started on gears in 1920 (Venkatesh et al.2011). In gear analysis, form input parameters which influence the output parameters (Venkatesh et al. 2010) viz. bending stress, compressive stress, tangential force, dynamic tooth load, wear tooth load, beam strength, are of interest to researchers and manufacturers. A method for the determination of load and stress distribution along the contact lines of the instantaneously engaged teeth of spur and helical gears (Simon et al. 1989) was reported. This method includes the tooth profile modification and crowning, manufacturing and alignment error of gears, tooth deflections, local contact deformations of the teeth. It also covers the influence of gear parameters on the load and stress distributions. An alternative method of analysis and design of spur and helical involute gears (Alexander et al. 2002) was investigated. They considered the direct gear design method, which separates gear geometry definition from tool selection, to achieve the best possible performance for a particular product and application. The direct design approach that is commonly used for most parts of mechanisms and machines, determines their profiles according to the operating conditions and desired performance. The benefits of synthetic lubricants over mineral lubricants for transmission applications, as well as the feasibility of automotive high speed gear meshes that reduce scuffing was investigated (Martin Buerkle 2005). An experiment on an aerospace quality helical gear train to investigate the thermal behavior of the gear system and many important operational conditions was carried out (Handschuh and Kilmain 2006). They also carried out analytical studies comparison with the measured results.A new approach to analyze the loading and stress distribution of spur and helical gears accounting for the varying meshing stiffness, geometric modification and elastic deflection of engaged gears (Zhang et al. 1999) was proposed. They also presented combining a discretized gear model with finite element analysis it has both good computational accuracy and efficiency. Evaluate the contact force and tooth deflection in helical gear pair (Park and Yoo 2004) was discussed. The contact forces between teeth are determined from the transmitted torque, and then the deformation overlap is calculated with the contact forces as boundary conditions. They also extended the theory to three dimensional problems and implemented to helical gear pair. The tooth flank correction of power transmission helical gears with wide face width using a finite element based shaft deflection analysis program in conjunction with a numerical load distribution analysis procedure (Shan Chang et al. 2005) was studied. The load distributions along the line of action, the elastic deflections and transmission errors are of gear pairs obtained by

*Corresponding author: **B Venkatesh**

solving the equations of compatibility of displacement and equilibrium of forces. The authors also discussed the influence of tooth flank corrections (tip relief, root relief, load modification, end relief and their combinations) on gear stresses and transmission errors due to shaft deflections. This technique has the capability of modeling all significant geometric and elastic contributions due to tooth contact of the pair being analyzed as well as other gears mounted on the same shafts. Their results indicate that it is possible to optimize, at the design stage, the gear micro-geometry for minimum stresses and transmission errors without changing the gear macro-geometry.A computer model for simulation of the wear behaviour in helical gears (Flodin and Andersson 2000) was developed. The method used can deal with tooth modifications and different profiles. The objective of their work was to compare the wear behaviour of gears using different approaches. The gear teeth in this model are regarded as thin uncoupled slices; the slicing method is valid when the contact area is narrow in the rolling direction, which is the case for contacting gear teeth. The pressure distribution on each slice is calculated using the well-known theories of Hertz assuming an infinitely wide line-contact. When the pressure and velocity on the surfaces are known, a modified Archard's wear equation (Flodin and Andersson 2001) can be applied to calculate wear depths on the teeth.
A model accommodates the modification of the tooth surfaces, gear misalignments and the deformation of tooth surfaces caused by contact load (Zhang and Fang 1999). In their model, the gear contact load is assumed to be nonlinearly distributed along the direction of the relative principal curvature between the two contacting tooth surfaces and the proposed model is applied to a pair of helical gears.

2. Design methodology

The design of helical gear is almost similar to spur gear design with slight modifications in Lewis and Buckingham equations due to helix angle.
According to Lewis equation, the Beam Strength of helical gear tooth is given by

$$F_b = [\sigma_b] \cdot b \cdot \pi m_n \cdot y_v \qquad (1)$$

Where, $[\sigma_b]$ =Allowable contact stress in kgf/cm^2

b = Face width of gear blank =10 m_n,

m_n = Normal module which must be standardized.

y_v = Lewis form factor which depends on the virtual number of teeth

$$Z_v = [z/\cos^3\beta] \qquad (2)$$

Buckingham equation

$$F_d = F_t + \frac{21v\left(Cb\cos^2\beta + F_t\right)\cos\beta}{21v + \sqrt{Cb\cos^2\beta + F_t}} \qquad (3)$$

The wear tooth load is given by

$$F_w = \frac{d_1 \cdot b \cdot Q \cdot K_w}{Cos^2\beta} \qquad (4)$$

3. Results and discussions

Fig.1 shows the variation of wear strength of tooth, beam strength for different modules and different face width for Steel alloy. The gear ratio (i) = 7 and helix angle (β) = 25 are kept constant. The face width of 41 is kept constant and the module is varied from 16 to 24. The corresponding wear strength of tooth and beam Strength were gradually increased from 369066.4kgf to 553599.7kgf and 331222.3kgf to 496833.4kgf respectively. The face width of 43 is kept constant and the module is varied from 16 to 24. The corresponding wear strength of tooth and beam strength were gradually increased from 387069.7kgf to 580604.5kgf and 347379.5kgf to 521069.2kgf respectively. The face width of 45 is kept constant and the module is varied from 16 to 24. The corresponding wear strength of tooth and beam strength were observed to gradually increase from 405072.9kgf to 607609.4kgf and 363536.6kgf to 545305kgf respectively. The face width of 47 is kept constant and the module is varied from 16 to 24. The corresponding wear strength of tooth and beam strength were gradually increased from 423076.2kgf to 634614.2kgf and 379693.8kgf to 569540.7kgf respectively. The face width of 49 is kept constant and the module is varied from 16 to 24. The corresponding wear strength of tooth and beam strength were observed to gradually increase from 441079.4kgf to 661619.1kgf and 395851kgf to 593776.5kgf respectively.

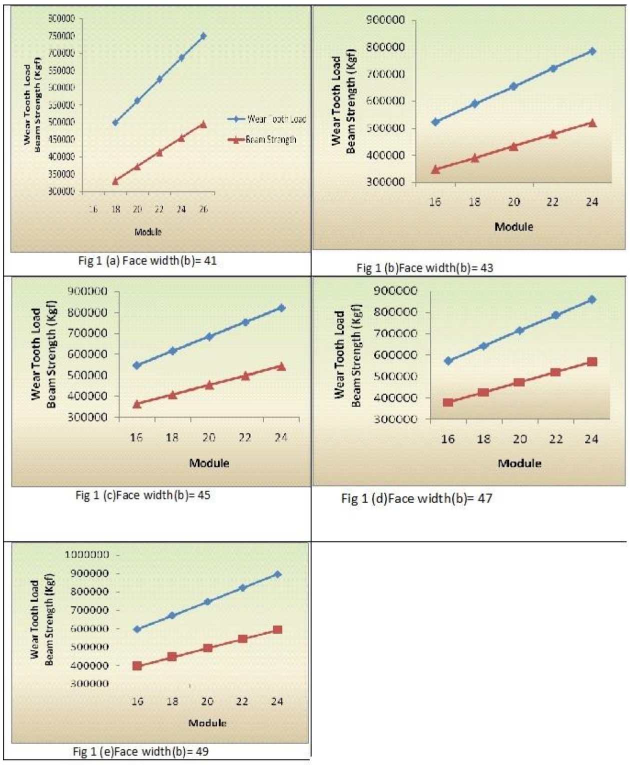

Fig.1 Effect of module on beam strength and wear tooth load

3.1 Optimum values

Optimum values of wear strength of tooth, beam strength to achieve low cost manufacturing for Steel alloy has been carried out.

3.1.1 The effect of gear ratio, face width, helix angle, module on Wear strength of Tooth for steel alloy

The variations of Wear strength of Tooth for different input variables (Venkatesh et al. 2011) are shown in figs. 2(a) – (d). The speed is kept constant. The fig 2(a) shows

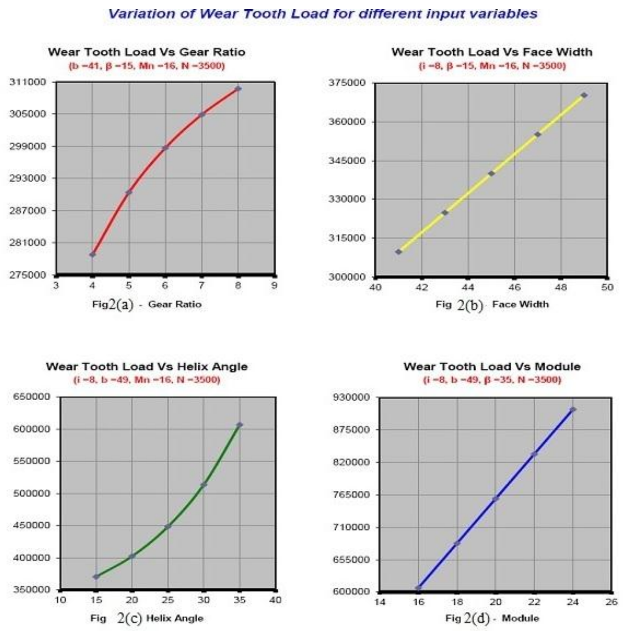

Fig.2 Variation of wear tooth load for different input variables

relationship between Wear strength of Tooth and gear ratio. The helix angle, face width, and module except gear ratio are kept constant. When gear ratio is increased from 4 to 8, the corresponding Wear strength of Tooth increased from 278785kgf to 309762kgf. The fig 2(b) shows the relationship between Wear strength of Tooth and Face width. The Helix angle, gear ratio, module are kept constant. When face width is increased from 41 to 49, the corresponding Wear strength of Tooth increased from 309762kgf to 370203kgf.The fig 2(c) shows the relationship between Wear strength of Tooth and Helix angle. The face width, gear ratio, Corresponding to optimum value obtained earlier and module are kept constant. When helix angle is increased from 15o to 35o, the corresponding Wear strength of Tooth increased from 370203kgf to 606655kgf. The fig 2(d) shows the relationship between Wear strength of Tooth and module. The values of face width, gear ratio, and Helix angle for maximum wear strength of tooth are kept constant. When module is increased from 16mm to 24mm, the corresponding Wear strength of Tooth increased from 606655kgf to 909982kgf. Thus the maximum wear strength of tooth 909982kgf is obtained for input parameters viz. gear ratio (i) = 8, helix angle (β) = 350, face width (b) = 49 and Module (Mn) =24.

3.1.2 The effect of gear ratio, face width, helix angle, module on Beam Strength for steel alloy

The variations of Beam Strength for different input variables are shown in figs. 3(a) – (d). The speed is kept constant. The fig 3(a) shows the relationship between Beam Strength and gear ratio. The helix angle, face width, and module are kept constant. When gear ratio is increased from 4 to 8, the corresponding Beam Strength remained constant. The fig 3(b) shows the relationship between Beam Strength and Face width. The Helix angles, gear ratio, module except face width are kept constant. When face width is increased from 41 to 49, the corresponding Beam Strength increased from 331222kgf to 395851kgf. The fig 3(c) shows the relationship between Beam Strength and Helix angle. The face width, gear ratio, corresponding to optimum value obtained earlier and module are kept constant. When helix angle is increased from 15^o to 35^o, the corresponding Beam Strength remained constant. The fig 3(d) shows the relationship between Beam Strength and module. The values of face width, gear ratio, and Helix angle for maximum beam strength are kept constant. When module is increased from 16mm to 24mm, the corresponding Beam Strength found to increase from 395851kgf to 593776kgf. Thus the maximum beam strength 593776kgf is obtained for input parameters viz. gear ratio (i) = 6, helix angle (β) = 150, face width (b) = 49 and Module (Mn) =24**.**

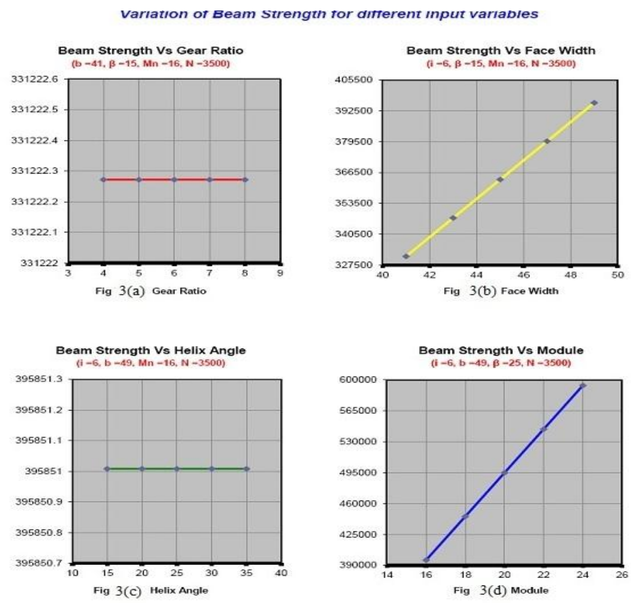

Fig.3 Variation of beam strength for different input variables

3.2 Results of steel alloy material (40 Ni2 Cr1 Mo 28 Steel)

3.2.1 Optimum parameters for maximum wear strength of tooth:

The effect of gear ratio, face width, helix angle, module on optimum wear strength of tooth is carried out (Venkatesh et al. 2011). The helix angle, face width, speed and module are kept constant, the gear ratio is increased, and the corresponding wear strength of tooth increases. The gear ratio 8, corresponding to maximum wear strength of tooth is taken as constant. Keeping the helix angle, gear ratio, speed, module except face width is kept constant and for variation of face width, the wear strength of tooth increases. In the next step the face width 49cm, corresponding to maximum wear strength, the gear ratio, speed and module are kept constant and the helix angle is increased, the corresponding wear strength of tooth is increasing. The helix angle 350, corresponding to maximum wear strength is taken for further optimization. The face width, gear ratio, speeds, helix angle are kept constant and when module is varied, the corresponding wear strength of tooth increases. The module 24mm, corresponding to maximum wear strength is taken as constant.

3.2.2 Optimum parameters for maximum beam strength

The effect of gear ratio, face width, helix angle, module on optimum beam strength is carried out. The helix angle, face width, speed and module are constant, when the gear ratio is increased; the corresponding beam strength remained constant. Keeping the helix angles, gear ratios, speed, module except face width are kept constant and for variation of face width, the beam strength increases. In the next step the face width 49cm, corresponding to maximum beam strength, the gear ratio, speed and module are kept constant and helix angle is increased, the corresponding beam strength remained constant. The face widths, gear ratio, speed, helix angle are kept constant and module is varied, the corresponding beam strength found to increase. The module 24mm, corresponding to maximum beam strength is taken as constant.

Conclusions

Competitive business in global market has brought increasing awareness to optimize gear design. This can lead to various benefits including reduction in redundancies, cost containment related to adjustments between manufacturers for missing part interchangeability, and performance due to incompatibility of different standards. From the study was investigated the effect of wear strength of tooth and beam strength and obtained optimum parameters of helical gear.

References

B.Venkatesh, V.Kamala, A.M.K.Prasad, (2011) Parametric Approach to Analysis of helical gear for High Speed Marine Applications, *International Journal on Mechanical & Automobile Engineering,* Volume 17, Issue 1, pp 13-2

B.Venkatesh, V.Kamala, A.M.K.Prasad, (2010) Design, Modeling & Manufacturing of helical gear, *International Journal of Applied Engineering Research*, Volume 1,No 1, pp 103 -11

V. Simon, (1989) Optimal Tooth modifications for spur and helical gears, *ASME journal of mechanisms, Transmissions and automation in design*, vol.111, pp.611-615

L.Alexander, Kapelevich and E.K. Roderick , (2002) Direct Gear Design for Spur and helical Involute Gears, *Gear Technology,* pp 29-35.

Martin Buerkle, (2005) Examination of High-speed Helical Gear Mesh Efficiency and influences, Doctor of Engineering in Manufacturing Oral defense.

B.Venkatesh, V.Kamala, A.M.K.Prasad,(2011) Parametric Approach to Analysis of high Speed Helical Gear with 40 Ni2 Cr1 Mo28 Steel for Marine Applications, *International Journal of RES Engineeria*, vol.1, Issue 4, pp 6-10

R.F. Handschuh, C.J. Kilmain, (2006) Operational influence on Thermal Behavior of High-Speed Helical Gear Trains, Prepared for Forum 62 Sponsored by the American Helicopter Society International, Inc, phoenix, Arizona.

J.J.Zhang, I.I.Esat, Y.H.Shi, (1999) Load Analysis with varying Mesh Stiffness, Computers and Structures, 70, pp.273-280.

S.J.Park and W.Yoo, (2004) Deformation Overlap in the Design of spur and Helical Gear pair, *Journal of Finite Elements in Analysis and Design,* 40, pp.1361-137

Shan Chang, R.H.Donald, Jonny Harianto, (2005) Tooth Flank corrections of Wide Face width Helical Gears that Account for Shaft Deflection, *Gear Technology*, pp.34-41

Anders Flodin, Soren Anderson,(2000) Simulation of mild wear in helical gears, Journal of Wear 241, pp. 123-128

Anders flodin, Soren Anderson,(2001) A simplified model for wear prediction in helical gears, *Journal of wea*r 249, pp 285-292

Y.Zhang, and Z. Fang, (1999) Analysis of Tooth Contact and Load Distribution of Helical Gears with Crossed axes, *Journal of Mechanism and Machine Theory*, 34, pp.41-57.