ISSN No: 2348-4845
International Conference on Mechanical, Mechatronics and Robotics Engineering (ICMMRE-2015)
October 18, 2015 - Hyderabad, India
Papers Published in IJMETMR, A Peer Reviewed Open Access International Journal.

Static and Dynamic Analysis of High Speed Helical Gear

Ramaswamy Sravani
MTech Student
Department of Mechanical Engineering
Spoorthy Engineering College

R.Nava Sai Divya, MTech
Assistant Professor
Department of Mechanical Engineering
Spoorthy Engineering College

ABSTRACT

Gears are of the one most important component in mechanical power transmission systems. The bending stress of the gear tooth is considered to be one of the main contributors for the failure of the gear in the gear set. Thus, analysis of stresses has become popular as an area of research on gears to minimize the chances of failures and also for the optimal design of gears. This work investigates the characteristics of an involute helical gear system mainly focused on bending stresses using ANSYS. To estimate the bending stress, modeling is generated by CATIA5 and numerical analysis is done by ANSYS. The analytical study is based on Lewis formula. Study is conducted by varying the face width to find its effect on the bending stress of helical gear. It is therefore observed that the maximum bending stress decreases with increasing face width. The study in this work shows that complex design problem of helical gear required superior software skills for modeling and analysis. The bending stress found from ANSYS results are compared with those from Lewis equation (theoretical) and AGMA values. A maximum deviation of 1.4% is observed at a face width of 34 mm.

INTRODUCTION

A gear is a rotating machine part having cut teeth, which mesh with another toothed part in order to transmit torque. Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, magnitude, and direction of a power source. Involute shaped gears found to be almost everywhere because of the contact forces act along a straight line. Helical gears 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. Designing highly loaded helical gear 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 stress [1].

The finite element method is proficient to supply this information but the time required to generate proper model is large amount. CATIA5 can generate model of gear. In CATIA5 the generated model geometry is saved as a file and then transferred to ANAYS for analysis. Gear analysis can be performed using analytical methods which required a number of assumption and simplifications which aim at getting the maximum stress values only but gear analyses are multidisciplinary including calculations related to the tooth stresses .In this work, an attempt will been made to analyze bending stress to resist bending of helical gears, as both affect transmission error. Due to the progress of computer technology many researchers tended to use numerical Methods to develop theoretical models to calculate the effect of whatever is studied. Numerical methods are capable of providing more truthful solution since they require very less restrictive assumptions. However, the developed model and its solution method must e selected attentively to ensure that the results are more acceptable and its computational time is reasonable.

The dimension of the model have been arrived at by theoretical methods. The stress generated of the tooth have been analyzed for materials. Finally the results obtained by theoretical analysis, AGMA calculations and finite element analysis are compared to check the correctness. Vijayaragan and Ganesan [2] presented a static analysis of composite helical gears system using three dimensional finite element methods to study the displacements and stresses at various points on a helical gear tooth. Huston et al [3] discussed a new approach to modeling gear tooth surfaces. A computer graphics solids modeling procedure is used to stimulate the tooth fabrication process. This procedure is based on the principle of differential geometry that pertains to envelopes of curves and surfaces. The procedure is illustrated with the modeling of spur, helical, bevel, spiral bevel and hypoid gear teeth. In the same year, a new approach was introduced by Zhang Et Al[4] to analyze the loading and stress distribution of spur and helical gear accounting for varying meshing stiffness, geometric modification and elastic deflection of engaged gears. Combining a discretized gear model with finite element analysis it has both good computational accuracy and efficiency.

Zhang and Fang [5] presented an approach for the analysis of teeth contact and load distribution of helical gear with crossed axis. The approach was based on tooth contact model that accommodate the influence of tooth profile modifications, gear manufacturing errors and tooth surface deformation on gear mesh quality. Cheng and Tsay [1] investigate the contact and the bending stresses of helical gear set with localization contact by means of finite element analysis (FEA)The proposed helical gear set comprises an involute pinion and double crowned gear. Mathematical models of the complete teeth geometry of the pinion and the gear have been derived based on the theory of gearing. Accordingly, a mesh generation program was also developed for finite element stress analysis. The computerized design, methods for generation, simulation of meshing, And enhanced stress analysis of modified involute helical gears was considered by Litvin et al [6].

The approaches proposed for modification of conventional involute helical gears were based on conjugation of double – crowned pinion with a conventional helical involute gear. Hedlund and Lehtovaara [7] presented a study focuses on the modeling of helical gear contact with tooth deflection. Their paper introduced a mathematical model for helical gear contact analysis. Helical gear surface profiles are constructed from gear tooth geometry by simulation the hobbing process. The three - dimensional finite element model for the calculation of tooth deflection including tooth bending, shearing and tooth foundation flexibility. The model combines contact analysis with structural analysis to avoid large meshes. A basis for solid modeling of gear teeth with application in design and manufacture was investigated by Huston et al [3]. They discussed a new approach to modeling of gear tooth surface. A computer graphics solid modeling is used to simulate the tooth fabrication processes. This procedure is based on the principles of differential geometry that pertain to envelopes of curves and surfaces. The procedure is illustrated with modeling of spur, helical bevel, spiral bevel and hypoid gear teeth. Applications in design and manufacturing are discussed. Extensions to nonstandard tooth forms, to cams and to rolling element bearings are proposed.

Vera and Ivan [8] used the numerical method for modeling the contact of tooth flanks to analyzed and determine the shape of the function which defines the change of contact stresses on tooth flanks along the path of contact for a tooth pair. The paper provides the detailed description of model development procedure. The results provided for the stress state of tooth flanks are also presented and discussed. The comparison of analytically and numerically obtained curves of change in the stress state on meshed tooth flanks, confirmed the accrual of the developed model. Pushpendra kumar [9] has used MATLAB Simulink environment which provides equivalent results to the AGMA and also with ANSYS.

In this paper he modeled helical gear by PRO ENGINEER wildfire 5.0 and stress is done by ANSYS 12.0. The results are compared with both AGMA and FEA procedure. The modeling and stress analysis of the helical gear has been done in CATIA5 and ANSYS respectively, taking various constraints and boundary conditions imposed by the company. The necessary design modifications have also been made to rectify the problems being faced by the firm.

ISSN No: 2348-4845
International Conference on Mechanical, Mechatronics and Robotics Engineering (ICMMRE-2015)
October 18, 2015 - Hyderabad, India
Papers Published in IJMETMR, A Peer Reviewed Open Access International Journal.

Design calculations: Theoretical calculation for bending stress

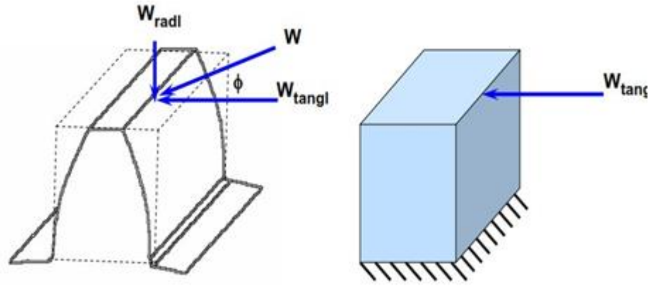

Figure 1. Tangential force

$$\sigma_b = \frac{W_T}{b.\pi.m.y.Cv}$$

σ_b = allowable static stress, W_T = tangential tooth load, Cv = velocity factor,

b = face width, m = module and $\bar{y}$ = Lewis factor corresponding to the formative or equivalent number of teeth

$Cv = \frac{0.75}{0.75+\sqrt{v}}$ = for peripheral velocities greater than 20m/s

Torque transmitted (T), $T = \frac{P*60}{2\pi N}$, P = power in (Kw), N = revolution per min,

$v = \frac{\pi D \cdot N}{60}$, D = Diameter of gear, t = Number of teeth

$y = 0.175 - \frac{0.841}{T_E}$, $t = \frac{D}{m}$, $T_E = \frac{t}{\cos^3 \alpha}$

Table 1. Geometrical parameters of helical gear

symbol	Parameter	Value
Wt	Tangential load(N)	358
b	Facewidth(mm)	(32, 33, 34, 35)
m	Module(mm)	2.5
d	Diameter of gear (mm)	80
t	Number of teeth	32
α	Helixangle(degree)	20

Table 2. Results of maximum bending stress from lewis eq.

Face Width (mm)	σbending (Mpa)
32	89.48
33	86.79
34	84.24
35	81.83

3.8.2 AGMA bending stress:- The AGMA: - is a group of flexi able coupling manufacturers and interested participants whose goal is to develop standard relating to flexible couplings. The goal of these standards is to provide consistency among the manufacturers and to assist the purchaser in procuring the best product for the best price. helical gears bending method be viewed as a detailed refinement of the Lewis method(modify Lewis equation)[27].

$$\sigma_{AGMA} = \frac{W_t P_d K_a K_s K_m K_B}{Y_j K_v}$$

$$P_d = \frac{N}{D \cos \alpha}$$

Factors are used to adjust the stress computed by the Lewis equation. Factor is also used to adjust the strength due to various environmental conditions. The AGMA has developed a number of factors to be used with the lewis equation that will lead to an acceptable design.

Table 3. AGMA Factors

Symbol	parameter	value
Ka	Application factor	1–2.75
Ks	Size factor	1–1.4
Km	Load distribution factor	1–2
Kv	Dynamic factor	0.5–0.98
yj	Lewis factor	0.4

Table 4. Results for bending stress from AGMA calculations

Face Width (mm)	σ bending (Mpa)
32	89.27
33	86.57
34	83.97
35	81.57

Table 5. Geometrical parameter of helical gear

α	Helix angle	20 degree
β	Pressure angle	23 degree
b	Face width(mm)	32
t	Number of teeth	32
add	Addendum(mm)	(0.8×m) Max
ded	Dedendum(mm)	(1×m) Min
m	Modul	2.5

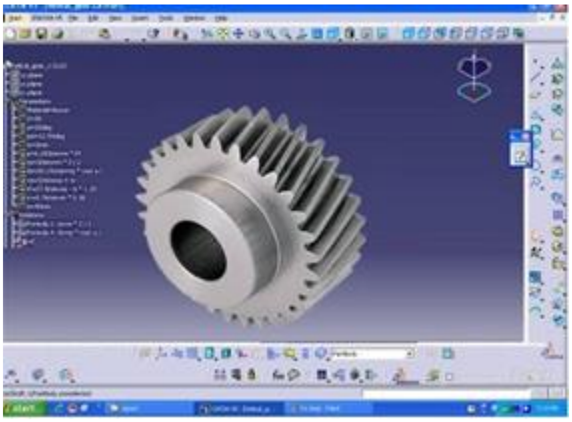

Figure 2. Model of helical gear generated by CATIA5

Analysis:- structural analysis procedure:- the Structural analysis involves the following procedure:

- **Pre-Processing:** It include the description of the geometry or model, the physical characteristics of the model.

Definition of type of analysis, material properties, Element type, Loads and boundary conditions

- **Solution:** it involves the application of the finite element analysis

➢ Run analysis to obtain solution (stresses).

- **Post-Processing:** It includes the visualization and interpretation of the results of the solution.

➢ Graphical display of stresses and interpretation of results.

Steps involved in carry out analysis using ANASYS:- The steps involved in carry out analysis using ANASYS are **:**

1) Import model 2) Define the element type 3) Define the element length. 4) Apply loads Apply constraints /boundary conditions 5) Define the analysis type and 6) Run the analysis :

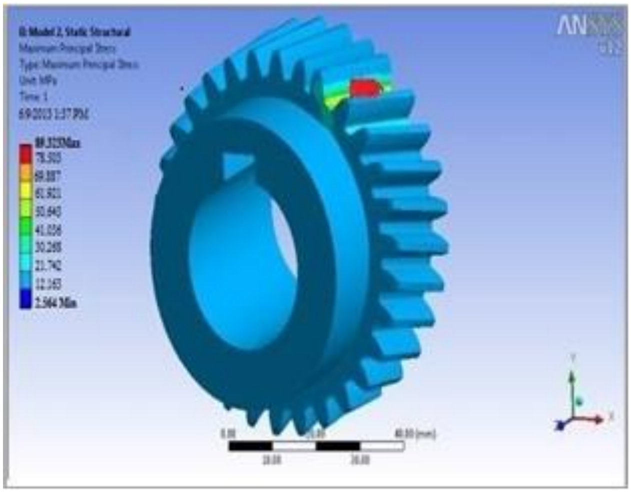

Figure 3. Static Structural Analysis of Helical Gear Having 32 Teeth (face width = 32mm)

RESULTS AND DISCUSSION

The structural stress analysis of the helical gear tooth model is carry out using the FEA in ANSYS 12.0. The load applied at the tooth of the helical gear .by applying the analysis over the tooth which is facing the load we get the stress distribution in the numeric as well as in the form of the color scheme. By varying the face width and keeping the other parameters constant various models of the helical gear are created. For determining at any stage during the design of the gear face width is an important parameter. The results of the variation in face width from (32 mm to 35 mm)there is continuous decrement in the value of the stress of the tooth of the helical gear stress. results of theoretical, AGMA, and ANSYS are closer, therefore the design are accepted. As it is seen clearly from all tables and graphs the maximum bending stress values are increase with the decrease of face width. In this work we got on three results as follow

- Theoretical results (from Lewis equation directly)
- AGMA results (modify lewis equation)
- ANSYS results
- And all results are closer as shown in graphs.

Effect of face width

The effect face width on maximum bending stress is study by varying the face width for five values which are **(b=32mm, 33mm, 34mm, 35mm).** the magnitude of the stresses obtained for those face widths are displayed.

Table 6. Theoretical stresses (by Lewis eq), AGMA stresses and ANSYA stresses

Face width (mm)	Bending stress(Mpa) from lewis eq	Bending stress(Mpa) from AGMA	Bending stress(Mpa) from ANSYS
32	89.48	89.27	89.323
33	86.79	86.57	86.392
34	84.24	83.97	82.77
35	81.83	81.57	81.913

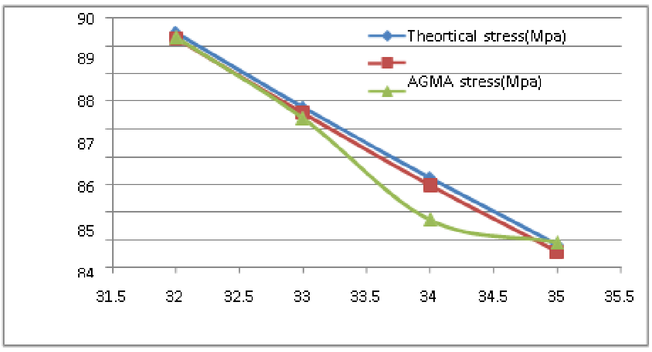

Figure 4. Graphical representation of maximum bending stress from theoretical, AGMA and ANSYS calculations

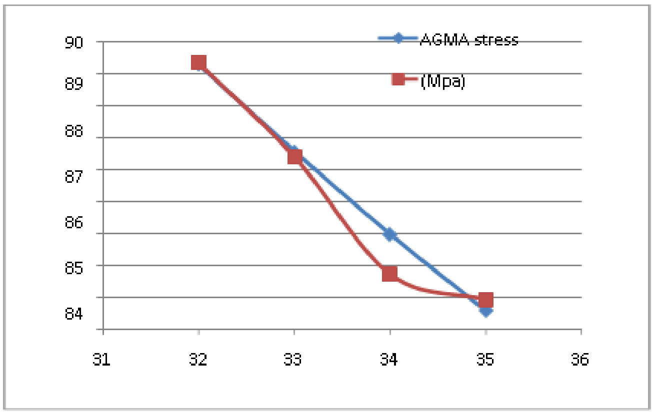

Figure 5. Graphical representation of maximum bending stress from AGMA and ANSYS calculation

CONCLUSIONS

Maximum bending stress occurred in the upper half of the helical gear .In theory of helical Gear, we are considering that the load is acting at one point and the stress is calculated. The calculation of maximum stresses in a helical gear at tooth root is three dimensional problems. The accurate evaluation of stress state is complex task. The contribution of this thesis work can be summarized as follows:

❖ The strength of helical gear tooth is a crucial parameter to prevent failure. In this work, it is shown that the effective method to estimate the root bending stress using three dimensional model of a helical gear and to verify the accuracy of this method the results with different face width of teeth are compared with theoretical and AGMA formulas.

❖ The face width is an important geometrical parameter in design of helical gear as it is expected in this work the maximum bending stress decreases with increasing face width.

REFERENCES

[1]. Cheng, Y., And Tasy C.B., Stress Analysis Of Helical Gear Set With Localized Bearing Contact,

Finite Element In Analysis And Design, 38,Pp. 707-723, 2002

[2]. Vijayarangan, s., and Ganesan, n., a static analysis of composite helical gears using three dimensional finite element method, computers & structures, 49,pp.253-268,1993.

[3]. Huston, R.L., Mavriplis, D., Oswald, B.F., and Liu Y.S., A Basis for Solid Modeling of Gear Teeth With Application In Design And Manufacturing, NASA Technical Memorandum 105392, 1992.

[4]. Zhang, J.J., East, I.I., Shi, And Y.H., Load Analysis with Varying Mesh Stiffness, Computer And Structures, 70, pp.273-280, 1999

[5]. Zhang, Y., And Fang. Z, Analysis Of Teeth Contact and Load Distribution of Helical Gears With Crossed Axes, Mechanism And Machine Theory, 34,Pp.41-57, 1999.

[6]. Litvin, L.F., Fuentes, A., Perez, I.G., And Sep , T.M., New Version Of Nivikon-Wildhaber Helical Gears: "Computerized Design, Simulation Of Meshing And Stress Analysis", Computational Methods In Applied Mechanics And Engineering, 191,Pp.5707-5740, 2002.

[7]. Hedlund, J., And Lethovaara, A., Modeling Of Helical Gear Contact With Tooth Defection, Tampere University Of Technology, Machine Design, P.O. Box 589,33101 Tampere, Finland.

[8]. Vera, N.S., And Ivan, C., The Analysis Of Contact Stress on Meshed Teeth'S Flanks Along The Path Of Contact For A Tooth Pair, Mechanics Automatic Control and Robotics, 3, Pp, 1055-1066, 2003.

[9]. Pushpendra Kumar Mishra, Dr. M. S. Murthy", Comparison of Bending Stresses for Different Face Width of Helical Gear Obtained using Matlab Simulink with AGMA and ANSYS" pp45-51, 2013.

[10]. Ajeet Kumar Rai and Mustafa S Mahdi, "A Practical Approach to Design and Optimization of Single Phase Liquid to Liquid Shell and Tube Heat Exchanger", International Journal of Mechanical Engineering & Technology (IJMET), Volume 3, Issue 3, 2012, pp. 378 - 386,

ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.

[11]. Ajeet Kumar Rai and Ashish Kumar, "A Review on Phase Change Materials & Their Applications", International Journal of Advanced Research in Engineering & Technology (IJARET), Volume 3, Issue 2, 2012, pp. 214 - 225, ISSN Print: 0976-6480, ISSN Online: 0976-6499.

[12]. Ajeet Kumar Rai, Shalini Yadav, Richa Dubey and Vivek Sachan, "Application of Taguchi Method in the Optimization of Boring Parameters", International Journal of Advanced Research in Engineering & Technology (IJARET), Volume 4, Issue 4, 2013, pp. 191 - 199,

ISSN Print: 0976-6480, ISSN Online: 0976-6499.

[13]. Ajeet Kumar Rai, Shahbaz Ahmad and Sarfaraj Ahamad Idrisi, "Design, Fabrication and Heat Transfer Study of Green House Dryer", International Journal of Mechanical Engineering & Technology (IJMET), Volume 4, Issue 4, 2013, pp. 1 - 7, ISSN Print:

0976 – 6340, ISSN Online: 0976 – 6359.

[14]. Ajeet Kumar Rai, Pratap Singh, Vivek Sachan and Nripendra Bhaskar, "Design, Fabrication and Testing of a Modified Single Slope Solar Still", International Journal of Mechanical Engineering & Technology (IJMET), Volume 4, Issue 4, 2013, pp. 8 - 14, ISSN Print:

0976 – 6340, ISSN Online: 0976 – 6359.

[15]. Ajeet Kumar Rai, Ashish Kumar and Vinod Kumar Verma, "Effect of Water Depth and Still Orientation on Productivity of Passive Solar Still", International Journal of Mechanical Engineering & Technology (IJMET), Volume 3, Issue 2, 2012, pp. 740 - 753, ISSN Print:0976 – 6340, ISSN Online: 0976 – 6359.

[16]. Ajeet Kumar Rai, Vivek Sachan and Maheep Kumar, "Experimental Investigation of a Double Slope Solar Still with a Latent Heat Storage Medium", International Journal of Mechanical

Engineering & Technology (IJMET), Volume 4, Issue 1, 2013, pp. 22 - 29,

ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.

[17]. Ajeet Kumar Rai, Richa Dubey, Shalini Yadav and Vivek Sachan, “Turning Parameters Optimization for Surface Roughness by Taguchi Method”, International Journal of Mechanical Engineering & Technology (IJMET), Volume 4, Issue 3, 2013, pp. 203 - 211,ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.

[18]. Gajanan S. Rao and Prof. R. R. Deshmukh, “Art of Fatigue Analysis of Helical Compression Spring used in Two-Wheeler Horn”, International Journal of Mechanical Engineering & Technology (IJMET), Volume 4, Issue 2, 2013, pp. 196 - 208, ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.

[19]. Ajeet Kumar Rai, Vivek Sachan and Bhawani Nandan, “Experimental Study of Evaporation in a Tubular Solar Still”, International Journal of Mechanical Engineering & Technology (IJMET), Volume 4, Issue 2, 2013, pp. 1 - 9, ISSN Print: 0976 – 6340, ISSN Online: 0976 – 6359.