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FEA and Analytical Analysis of Contact Stress of Helical Gear 20MnCr5 of PTO drive

M. K. Khunti[1]
[1]*Mechanical Department, Government Engineering College, Rajkot*

Abstract: In a mechanical power transmission system and all rotating machinery, gears are mostly used to transmit torque and angular velocity. The design and manufacture of precision cut gears are one of the most complicated in mechanical power transmission system. Gear teeth in action are subjected bending stresses with fatigue and contact stresses causing contact fatigue. The bending and surface stresses of the gear tooth are considered to be one of the main contributors of the failure of the gear in a gear set. Thus analysis of stresses is more important in a area of research on gear to minimize or to reduce the failure and for optimal design of gear. This paper presents the stress analysis of mating teeth of Helical gear to find maximum contact stress in the gear teeth. The results obtained from finite element analysis are compared with theoretical Hertzian equation value for analysis 20MnCr5 material is chosen. The helical gear are sketched, modeled and assemble in ANSYS 15 design modular. The results obtained from ANSYS values are compared with theoretical values are in close agreement. The present analysis is useful in quantifying the contact stress that helps in safe and efficient design of the helical gear.
Keywords: Helical gear, ANSYS, Contact stress, Finite Element Analysis, Hertz equation

I. INTRODUCTION

One of the best methods of transmitting power between the shafts is gears. Power transmission has always been of high importance. Helical gear are most suitable to transmit power owing to their smooth and silent operation, large load caring capacity and higher operating speed. Helical gear transmit power and motion from one shaft to another more efficiency than spur gear because of a large helix angle and that increases the length of contact line. It is good in strength and law level in noise. But the design of helical gear is much crucial. Here, the commercial finite element software used is ANSYS and the results were compared with analytical calculations.

II. LITERATURE REVIEW

S. Jyothirmai, R. Ramesh, T. Swarnalatha, D. Renuka et al (2014) presented a comparative study on helical gear design and its performance based on various performance metrics through finite element as well as analytical approaches. The theoretical analysis for a single helical gear system based on American Gear Manufacturing Association (AGMA) standards has been assessed in Matlab. The effect of major performance metrics of different helical gear tooth systems such as single, herringbone and crossed helical gear are studied through finite element approach (FEA) in ANSYS and compared with theoretical analysis of helical gear pair. Structural, contact and fatigue analysis are also performed in order to investigate the performance metrics of different helical gear systems. The benefit of such a comparison is quickly estimating the stress distribution for a new design variant without carrying out complex theoretical analysis as well as the FEA analysis gives less scope for manual errors while calculating complex formulas related to theoretical analysis of gears. It will significantly reduce processing time as well as enhanced flexibility in the design performance. [1]

Babeeta Vishwakarma et al (2014) investigated finite element model for monitoring the stresses during meshing of gear. To estimate bending and contact stresses, 3D models are generated by software CATIA V5 and simulation is done by ANSIS 14.0. Analytical method of calculation gear bending stresses uses Lewis and AGMA bending equation. For contact stresses Hertz and AGMA contact equation. She has concluded by varying the face width to find its effect on bending stress of helical gear and observed that the maximum bending stress decreases with increasing face width. The results from ANSIS are compared with those from theoretical and AGMA values. [2]

A.Y Gidado, I. Muhammad, A. A. Umar et al (2014) obtained from ANSYS when compare with the AGMA rocedure, it shows that there is a little variation with a higher difference in percentage of 4.70%. From the results we can conclude that ANSYS can also be used for predicting the values of bending stress at any required face width which is much easier to use to solve complex design problems like gears. [3]

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Yi-Cheng Chen, Chung-Biau Tsay et al (2002) Evaluated the contact stress and bending stress of a helical gear set with localized bearing contact, by means of finite element analysis (FEA). The gear stress distribution is investigated using the commercial FEA package, ABAQUS/Standard. [4]

P. Mishra et al (2013) et al has solved the complex design problem of helical gear by using MATLAB simulink environment and compare results to the AGMA and also with ANSIS. He obtained different results bending stress for different face width. To determine the stress variation at different face width the various models of helical gears are made by keeping other parameters that is number of teeth, helix angle etc. constant. All the results are close to each other and from the result it is justified that the simulink can also be used for predicting the values of bending stresses at any required face width which is much easier to use to solve complex design problem. [5]

J. Venkatesh, Mr. P. B. G. S. N. Murthy et al (2014) in this paper analytical and Finite Element Analysis methods were used to predicting the Bending and contact stresses of involute helical gear. Bending stresses are calculated by using modified Lewis beam strength equation and Ansys software package. Contact stresses are calculated by using AGMA contact stress equation and Ansys software package. Finally compare both the resulta. [6]

Rao and Muthuveerappan et al (1993) have explained the geometry of helical gears by simple mathematical equations. A parametric study was made by varying the face width and the helix angle to study their effect on the root stresses of helical gears. [7]

III. MODELING OF HELICAL GEAR

To determine maximum contact stress during the transmission of torque of 68.53Nm by 20MnCr5 using finite element analysis we sketched and modeled helical gear in the ANSIS design modeler. The dimension of gear is in table given below.

PTO GEAR SPECIFICATIONS

Parameters	Pinion	Gear
No. of teeth(Z)	22	30
Module(m)	3mm	
Pitch circle diameter(D)	66mm	90mm
Face width(b)	20mm	
Pressure angle(α)	20°	
Helix Angle(β)	30°	
Addendum(ha)	3mm	
Dedendum(hf)	3.75mm	
Circular Pitch(d)	76mm	
Poission ratio	0.3	
Youngs modulas	2.1e5	
Shaft radius	16	
Yield Tensile stress	465MPa	
Ult imate Tensile stress	650MPa	

A. CREO Parts – Helical Gear

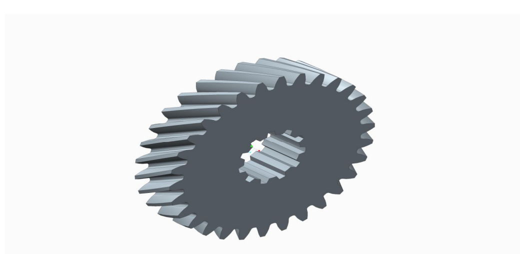

Fig.1. Helical Gear

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B.Selection of Mesh Size

Mesh size of model can be justify by comparing of their relative performance for different mesh size. Total deformation are used to justify mesh size.

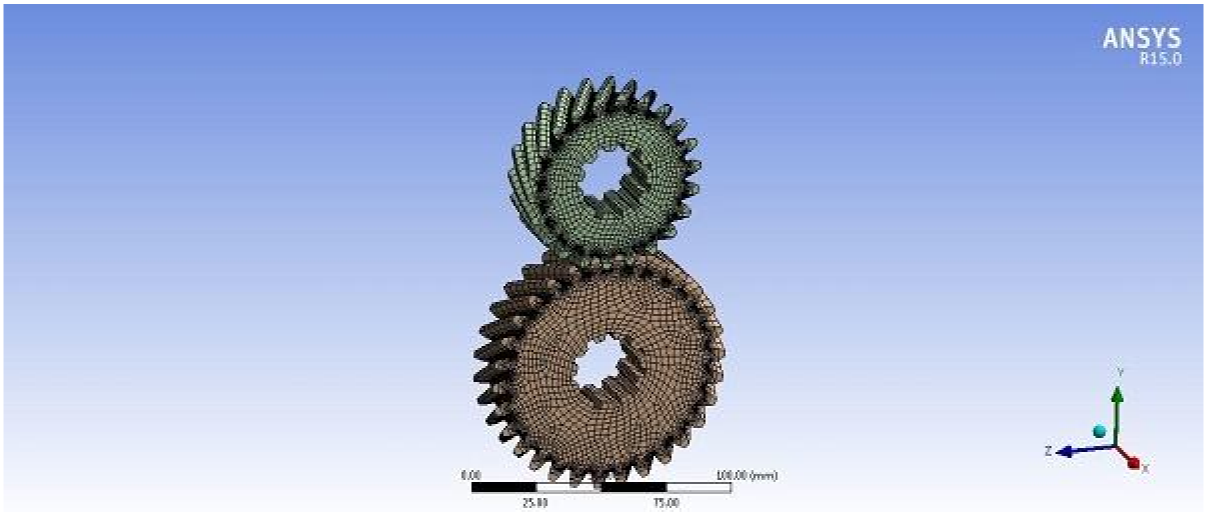

Fig.2. Selection of Meshing Size

Nodes	148209
Elements	29431

C. Boundary Condition

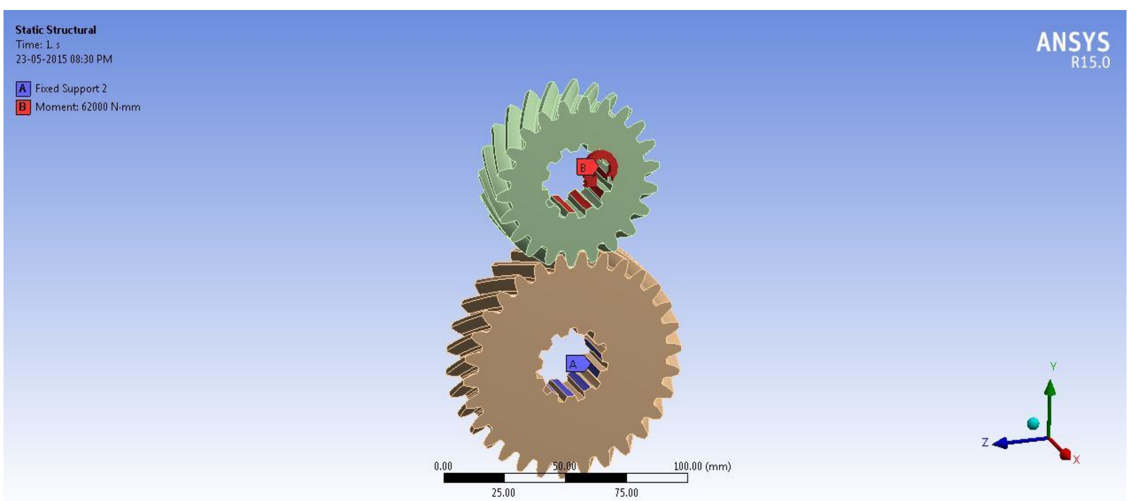

Fig.3. Boundary Condition

IV. HERTZ EQUATION FOR HELICAL GEAR FOR CONTACT STRESS

One of the main gear tooth failure is pitting which is a surface fatigue failure due to repetition of high contact stresses occurring in the gear tooth surface while a pair of teeth is transmitting power. Contact failure in gears is currently predicted by comparing the calculated Hertz contact stress to experimentally determined allowable values for the given material. The method of calculating gear contact stress by Hertz's Equation (2) originally derived for contact between two cylinders. In machine design, problems frequently occurs when two members with curved surfaces are deformed when pressed against one another giving rise to an area of contact under compressive stresses. Of particular interest to the gear designer is the case where the curved surfaces are of cylindrical shape because they closely resemble gear tooth surfaces. The surface compressive stress (Hertzian stress) is found from the equation.

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$$\sigma_c = \sqrt{\frac{F_t}{\pi B \cos\phi} \times \frac{\frac{1}{r_1} + \frac{1}{r_2}}{\frac{1-\nu_1{}^2}{E_1} + \frac{1-\nu_2{}^2}{E_2}}}$$

Where, r1 and r2 are the instantaneous values of the radii of curvature on the pinion- and gear-tooth profiles, respectively, at the point of contact. The radii of curvature of the tooth profiles at the pitch point are

$$r_1 = \frac{d_p \sin\phi}{2}, \qquad r_2 = \frac{d_g \sin\phi}{2}$$

Where σc is the contact stress in mating teeth of spur gear, F is the force, and R1 and R2 are pitch radii of two mating gears, B is the face width of gears, ϕ is the pressure angle, $\nu 1$, $\nu 2$ are the Poisson ratios and
E1,E2 are the modulii of elasticity of two gears in mesh.

V. ANALYTICALY CALCULATION FOR CONTACT STRESS FOR HELICAL GEAR

Engine power = 16.5HP
PTO rpm=1686 rpm
Torque = 68.53 Nm
Tangential force Ft = 2000
Tp / Pitch diameter Ft = (2000 × 68.53) / (76.4423) = 1792.72N
r1 = dp Sin ϕ / 2
r2 = dg Sin ϕ / 2 r1 = 66 Sin 20 / 2 r2 = 90 Sin 20 / 2 r1 = 11.286mm
r2 = 15.390mm

$$\sigma_c = \sqrt{\frac{1792.724}{\pi * 20 * COS20} * \frac{\frac{1}{11.286} + \frac{1}{15.390}}{\frac{1-0.3^2}{2.1*10^5} + \frac{1-0.3^2}{2.1*105^5}}}$$

$= 758.69$ Mpa

(For 20MnCr5 Poission ratio=0.3 and Youngs Modulus = $2.1e^5$)

VI. FINITE ELEMENT ANALYSIS RESULT

A. Total Deformation

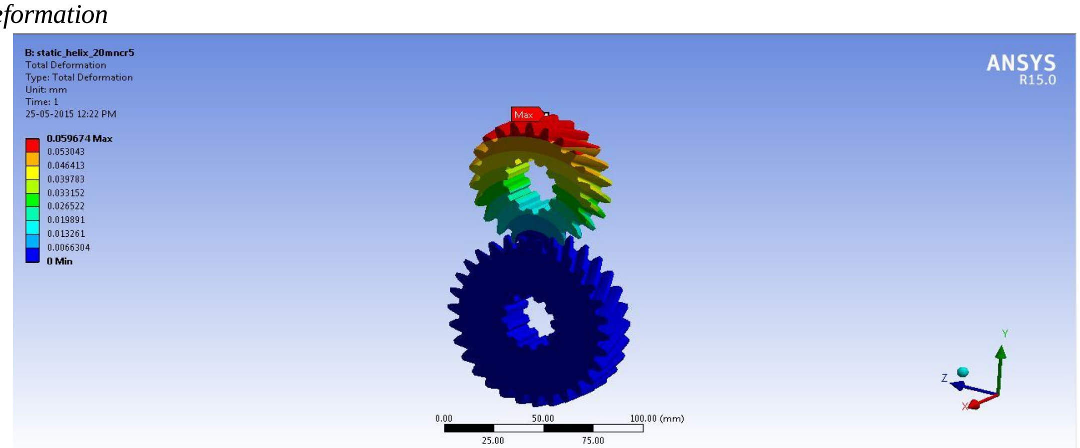

Fig. 4 Total Deformation is 0.059674 mm

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B. Maximum contact stress

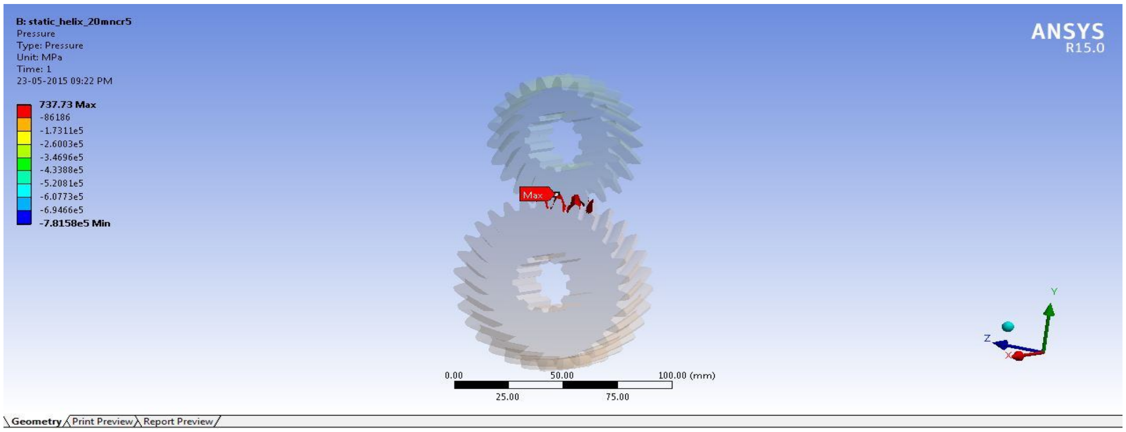

Fig. 5. Max. contact stress is 737.73 MPa.

VII.RESULTS AND DISCUSSIONS

Material	Contact Stress Analytical Results (MPa)	Contact Stress ANSYS Results (MPa)
20MnCr5	758.69	737.73

For material 20MnCr5, designed model of helical gear of PTO drive analysis gives analytical values of contact stress 758.69 MPa and von-misses stresses are nearly same as analytical value 737.73 MPa obtained from Hertzian equation. The structural stress analysis of helical gear also carried out by using FEA in ANSYS.

VII. CONCLUSION

Maximum contact stress occurs in the upper half of the helical gear at mating point of gear teeth. Both the results of contact stress obtained by analytically and ANSYS workbench are near to close each other that significant to use ANSYS software to solve complex design problems of helical gear and enables designer to optimize the design procedure in an iterative manner based on the final plots of post-processing phase of gear.r

REFERENCES

[1] S. Jyothirmai, R. Ramesh, T.Swarnalatha, D. Renuka, "A Finite Element Approach to Bending, Contact and Fatigue Stress Distribution in Helical Gear Systems",3rd International Conference on Materials Processing and Characterisation, pp.907- 918, (ICMPC 2014).

[2] Babita Vishwakarma, Upendra Kumar Joshi, "Finite Element Analysis of Helical Gear Using Three- Dimensional Cad Model", International Journal of Engineering Sciences & Research Technology (2014).

[3] A.Y Gidado, I. Muhammad, A. A. Umar," Design, Modeling and Analysis of Helical Gear According Bending Strength Using AGMA and ANSYS", International Journal of Engineering Trends and Technology (IJETT) – Volume 8 Number 9- Feb 2014

[4] Yi-Cheng Chen, Chung-BiauTsay, "Stress analysis of a helical gear set with localized bearing contact", Finite Elements in Analysis and Design 38, pp707-723,(2002).

[5] Pushpendra Kumar Mishra, International Journal of Engineering Trends and Technology (IJETT) - Volume4 Issue7- July 2013

[6] J. Venkatesh, Mr. P. B. G. S. N. Murthy," Design and Structural Analysis of High Speed Helical Gear Using Ansys ", Journal of Engineering Research and Applications, Vol. 4, Issue 3(Version 2), March 2014, pp.01-05

[7] Rao C.M, and Muthuveerappan G, "Finite Element Modeling and Stress Analysis of Helical Gea"r, Teeth, Computers & structures, PP.1095-1106, 1993.

[8] Shigley, J.E., and Mischke, C.R., Standard Handbook of Machine Design, McGrawHill, USA, 1996.

[9] Design of machine elements, V.B. Bhandari, The TATA Mcgraw-Hill