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Contact Stress Analysis of Helical Gear of PTO drive using Finite Element Analysis

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Abstract — In a mechanical power transmission system and all rotating machinery, gear is one of the most complicated components 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 spur 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 EN8 material is chosen. The helical gear are sketched, modeled and assemble in ANSYS 15 design modular. The results show that the difference between maximum contact stresses obtained from hertz's equation and finite element analysis is very less and it is acceptable.

Keywords- Helical gear, ANSYS, Contact stress, Finite Element Analysis

I. INTRODUCTION

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.

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.

PUSHPENDRAKUMAR MISHRA et al (2013), 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.

SWAPNIL R. NIMBHOKAR et al (2013) [15] research about basically concentrate on to study the effect of case hardening treatment on the structure and properties of automobile gears which consists of carburizing process which is a case hardening process. He did Procedural study, microstructure studies and testing of hardness gradient of automobile gears viz. grade of EN353, SAE8620 and 20MNCR5. Inclusion ratings are within the desire limit and micros cropping examination shows the fact that there exist the amount of retained austenite along with the martensite and it is in EN353 is more than SAE8620, 20MNCR5 due to higher hardening temperature. Hardness gradient value shows in EN353 grade sudden drop at the case depth 0.6mm. This may due to less amount of chromium.

VIVEK KARAVEER et al (2013**)** presents the stress analysis of matting teeth of spur gear to find maximum contact stress by theoretical Hertizian‟s equation and by finite element analysis. For the analysis steel and gray cast iron are used as the materials of the spur gear. FEA is done in finite element software ANSIS 14.5 and also deformation for steel and gray cast iron is obtained as efficiency of the gear depends on its deformation. The result show that the difference between maximum contacts stresses obtained from Hertz‟s equation and finite element analysis is very less and it is acceptable.

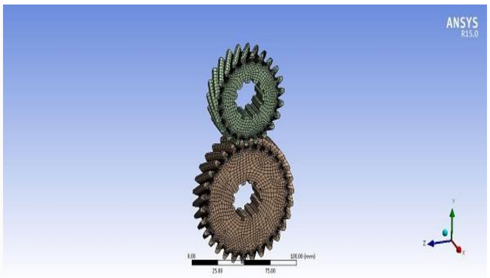
II. PTO GEAR SPECIFICATIONS AND MATERAIL PROPERTIES

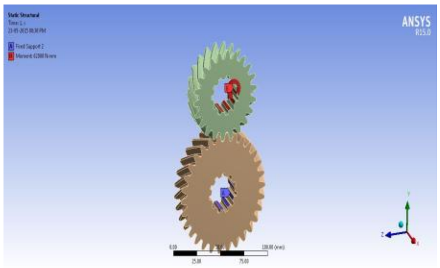
Parameters	Pinion	Gear
No. of teeth(Z)	22	30
Module(m)	3mm	
Pitch circle diameter(D)	66mm	90mm
Face width(b)	20mm	
Pressure angle(α)	20°	
Helix Angle(β)	30°	
Addendum(ha)	3mm	
Dedendum(hf)	3.75mm	
Circular Pitch(d)	76mm	
Poission ratio	0.3	
Youngs modulas	2e5	
Shaft radius	16	
Yield Tensile stress	465MPa	
Ultimate Tensile stress	650MPa	

Table 1

III. MODELING OF HELICAL GEAR

To determine maximum contact stress during the transmission of torque of 68.53Nm by EN8 using finite element analysis we sketched and modeled helical gear in the ANSIS design modeler. The dimension of gear is given table 1.





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

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

Where, r_1 and r_2 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 σ_c 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,
ν_1, ν_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 = 16.5 HP
PTO rpm=1686 rpm
Torque = 68.53 Nm
Tangential force $F_t = 2000\, T_p /$ Pitch diameter
$F_t = (2000 \times 68.53) / (76.4423) = 1792.72$N

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

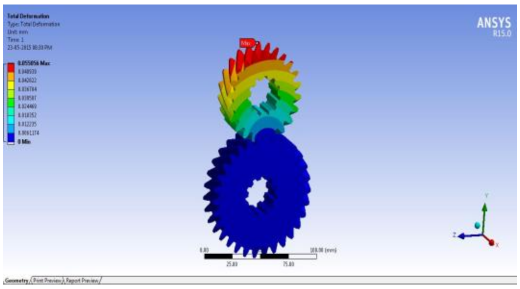
$r_1 = d_p \text{ Sin } \phi / 2$
$r_1 = 66 \text{ Sin } 20 / 2$
$r_1 = 11.286$mm

$r_2 = d_g \text{ Sin } \phi / 2$
$r_2 = 90 \text{ Sin } 20 / 2$
$r_2 = 15.390$mm

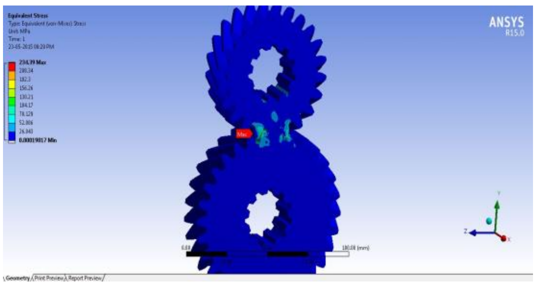
$$\sigma_c = \sqrt{\frac{1792.724}{\pi \times 20 \times Cos\, 20} \times \frac{\frac{1}{11.286} + \frac{1}{15.390}}{\frac{1-0.3^2}{2\times 10^5} + \frac{1-0.3^2}{2\times 10^5}}}$$

(For EN8 Poission ratio=0.3 and Youngs Modulus = 2e5)
= 715.79 MPa

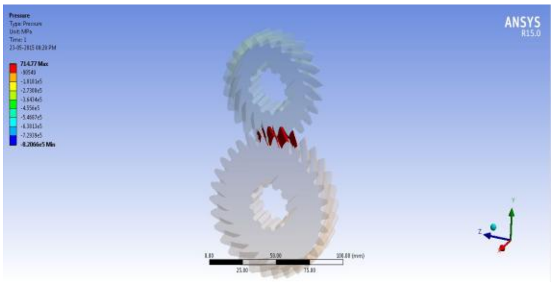
FINITE ELEMENT ANALYSIS RESULT



Deformation Pattern



Von-misses stresses



Max contact stress

VI. RESULTS AND DISCUSSIONS

For material EN8, designed model of helical gear of PTO drive analysis gives analytical values of contact stress 714.77 MPa and von-misses stresses are nearly same as analytical value 715.69 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.

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