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The finite element Analysis and modification of Helical gear design

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Abstract—

The theoretical basis and performance characteristics of helical gear design, this work is to conduct a comparative study on helical gear design and finite aliment as well as analytical approaches finite element approach in ANSYS one of the most critical in mechanical power transmission system the gear are generally used to transmit power or torque and the efficiency of transmission is very high when compared to other kind of transmissions.

1. INTRODUCTION

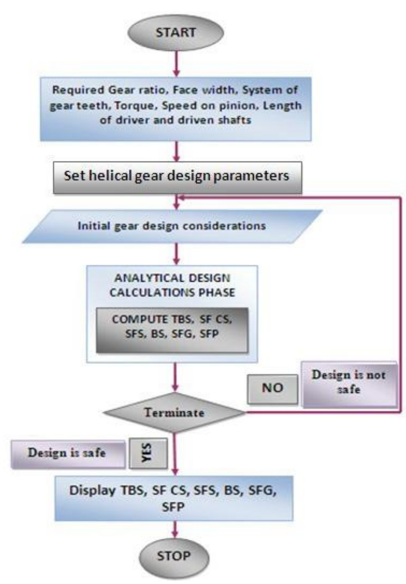
The gear analysis is one of the most significant issues is in the machine elements theory particularly in the field of gear design and gear manufacturing. Many of the researchers have proposed several concepts for gear design optimization to enhance the performance of gear system .caviar et al. [1]

Has developed a loaded tooth contact analysis program to calculate all of the three-dimensional, thinc-rimmed gear structures with all of the gear parameters .kapelevich [2]

Has developed a surface wear for helical gear pairs to study the influence of tooth modifications on helical gear wear .the model uses a finite element based gear contact mechanics model to predict the contact pressures at a number of discrete rotational gear positions and a computational procedure for determining relative sliding distances of mating point son each gear for each rotational increment. In this method a simplified design formula was also proposed that links modification parameters directly to initial wear rates.fong it al.[3]

2. THE MODELING OF HELICAL GEAR SYSTEM

Each of the above tooth geometrics were first modeled using pro/E and then later analyzed. Initially, modeling of the gear was carried out in pro/E. The model was done by sketching the base circle using relation and parameters and after the extrude part is generated the curve is created and the sweep option is performed to obtain the truth profile. Letter on complete gear is generated using pattern future. In the same way modeling of the pinion was also accomplished. Finally assembling of both gear and pinion was done to obtain the gear pair. The modeling of single, double and crossed helical gear models in pro/E is show in fig. 234.The meshing of crossed helical gear in pro/E fig 5.



Fig(a).Algorithm for analytical analysis of helical gear design [5]

Thus the models required for analysis are generated using pro/E and the input required for designing are taken from table1. Further on this model are imported batch and the structural, fatigue and contact illstrates in To ANSYS stress analysis is which performed will be work next section.[4]

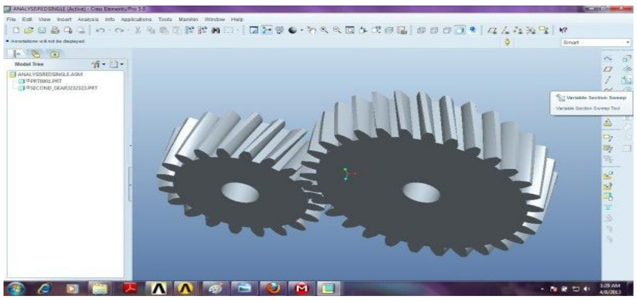
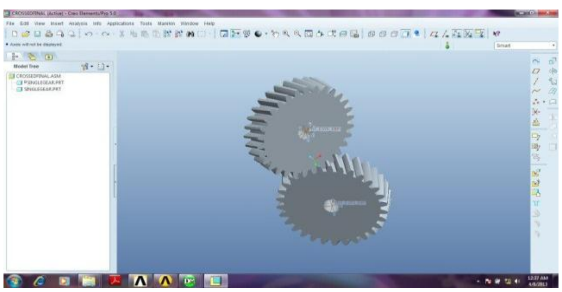


Fig (b) Modeling of single helical gear model in Pro/E[6]



Fig(c): Modeling of double helical gear model in Pro/E[7]

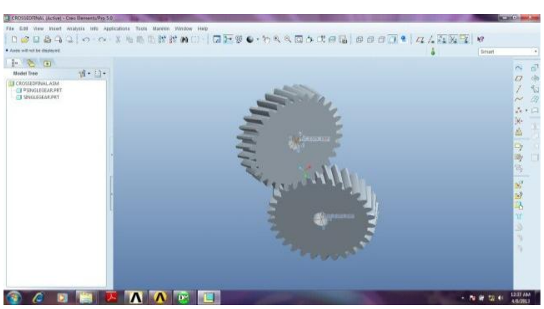


Fig. (d)Modeling of crossed helical gear model in pro/E[8]

3. DESIGN METHODOLOGY

The design of helical gear is almost similar to spur gear design with slight modifications in lewis in Buckingham equation (venkatesh et 2010)due to helix angal

According to lewis eqation ,the beam strength of helical gear tooth is given by

$$F_b = [\sigma_b].b.\pi m_n.y_v$$

Where

$[\sigma_b]$ =Allowable contact stress in kgf $/cm^2$
b =face width of gear bank $=10m_n$
m_n =Normal module which must be standardized.
y_v =Lewis form factor which depends on the virtual number of teeth
z_v $=[z/\cos^3\beta]$

Buckingham equation $F_D = F_t + \frac{21(Cb\cos^2\beta + F_t)\cos\beta}{2lv + \sqrt{Cb\cos^2\beta + F_t}}$

Compressive stress is given by:

$$\sigma_c = 0.7[(i+1)/a]\sqrt{(i+1)E[M_T]/(ib)}$$

Bending stress is given as

$$\sigma_b = 0.7(i+1)[M_T]/(ab\ m_n Y_V)[9]$$

4. THE ANALYSIS OF HELICAL GEARS

It deals with the development of finite element analysis that has been implemented for various gear systems that were dveloped in the previous chapter. The main objective of developing finite element analysis was in order to estimate bening, fatigue and contact stress distribution in the pinion and gear. Finite element analysis of the developed helical gear pair was executed in ANSYS. The first step is to perform structural analysis in order to calculate tooth bending stress and permible bending stress, bending fatigue strength of pinion.The second step in the finite element analysis approach is to perform contact stress analysis in order to calculate contact stress. The final step involved is to performed is fatigue stress analysis in order to calculate allowable surface fatigue stress, surface ftigue of pinion. Each of these step was executed and is dscribed below.

The structural analysis of helical gear train was performed in six stages namely input of engineering data, definition of geometry development of model, step and generation of solution and results. Structural steel was use in this problem having material properties of elastic moduluas 207 GPa and poission's ratio 0.3. after input of these data, the model created in Pro/E was imported.after the model was imported, meshing operation was performed on the model to divide the model in to several elements or models. The type of node element considered was tetrahedron and the torque, angular velocity of required range as specified in table i were applied on the helical gear pair entities after the meshing operation. Two coordinate systems were taken for helical gear pair in one is global coordinate system for gear and another is normal coordinate system for pinion. Torque was applied on the pinion by considering normal coordinate system means torque will be applied on pinion about pinion central axis and angular velocity of pinion is considered by considering the coordinating system for pinion about pinion central axis. After completion of pre-processing step post processing steps were accomplished in ANSYS. In order to execute these several tools were imported such as fatigue tool, contact tool etc. In addition vomits' stresses, principal stress were also given for analysis in order to calculate the performance metrics of helical gear pair. Based on these input details, the solutions were generated by ANSYS. This structural analysis was executed for all the three helical gear listed earlier. The tooth bending stress distribution for various helical gears. [10]

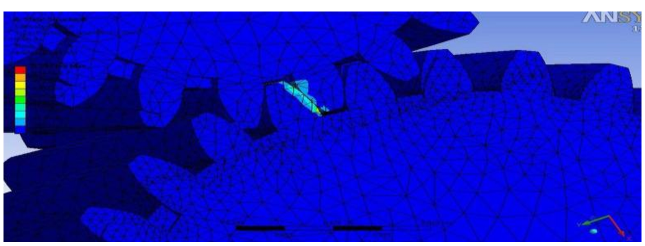
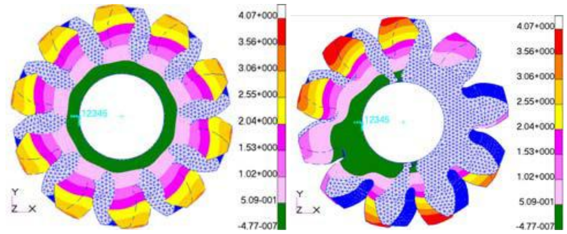


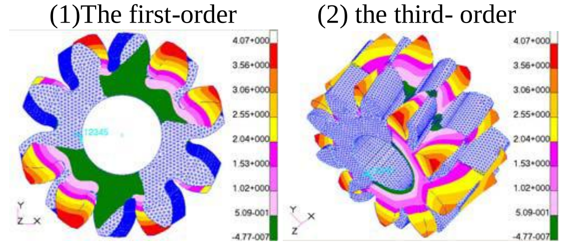
Fig.(e): Tooth bending stress distribution for single helical gear [11]

5. THE STUDY ON TRANSMISSION EFFICIENCY

Generally speaking, the line speed of high – speed, heavy-load gear transmission is higher, large dynamic load which influence the safety and stability will be caused. When the transmission is large, the tooth surface relative sliding speed is higher, leading to adhesion, wear .large loads corresponds large deformation. Therefore,gear especially large power gear transmission ,transmission device has higher efficiency requirements . gear transmission device for power consumption are two important sources,namely the gear loss ,bearing and oil seal power loss .in the machinery industry in various fields,have attached great importance to study on transmission efficiency of gears ,such as the gear transmission efficiency even by one percentage point but also has very important significance.



(1)The first-order (2) the third- order



(3) The fifth –order (4) the sixth- order

The study on the powder metallurgy helical gear transmission efficiency characteristics of fire fighting vehicle power take-off have important significance for the analysis of the meshing process of dynamic performance, guiding the design of efficient gear drive, promoting the economic benefits. This paper intends to carry out 38CrMoAI alloy helical gear and powder metallurgy helical gear driving efficiency comparison test to find out the material factors in transmission efficiency effect [12]

6. THE FACTOR OF SAFETY FROM PITTING FOR PINION AND WHEEL

The factor of safety constraints of pitting are deduced from contact stress, elasticity,contact ratio and poisons ratio for pinion and wheel.

$$\varepsilon_{\alpha 1} = \frac{x_3[0.681 - \tan\left[cos^{-1}\left[\frac{\frac{1}{x_1 cos x_5}(x_3 + x_4)}{595.94}\right]\right]]}{6.28}$$

$$\varepsilon_{\alpha 2} = \frac{\left[0.531 - \tan\left[cos^{-1}\left[\frac{\frac{1}{x_1 cos x_5}(x_3 + x_4)}{595.94}\right]\right]\right]}{6.28}$$

$$g_1(x) = 1.2 - \frac{1261.82}{189.81 * \sqrt{\frac{1}{\varepsilon_{\alpha 1}+\varepsilon_{\alpha 2}}} * \sqrt{cos\, x_5} * 38.251 * \sqrt{\frac{1}{x^2}} * 1.14} \le 0$$

$$g_1(x) = 1.2 - \frac{1262.44}{189.81 * \sqrt{\frac{1}{\varepsilon_{\alpha 1} + \varepsilon_{\alpha 2}}} * \sqrt{\cos x_5} * 38.251 * \sqrt{\frac{1}{x^2}} * 1.14} \leq 0$$

factor of safety from tooth breakage the tooth breakage involves factor like relative toughness ,life size, reliability ,application, dynamic load ,distribution of load and helix angle for bending stress

$$g_3(x) = 1.4 - \frac{435.43}{\frac{280850}{x_1 x_2} * 1.818 * \left(0.25 + \frac{0.75}{\varepsilon_{\alpha 1} + \varepsilon_{\alpha 2}}\right) * \left(1 - \frac{x_2 \sin x_5}{\pi x_1} * \frac{x_5}{120}\right) * 1.255} \leq 0$$

$$g_4(x) = 1.4 - \frac{519.08}{\frac{280850}{x_1 x_2} * 1.818 * \left(0.25 + \frac{0.75}{\varepsilon_{\alpha 1} + \varepsilon_{\alpha 2}}\right) * \left(1 - \frac{x_2 \sin x_5}{\pi x_1} * \frac{x_5}{120}\right) * 1.255} \leq 0$$

- Number of teeth constraints
  The minimum number of tooth constraints are based on avoidance of interference

$$g_5(x) = 25 - x_3 \leq 0$$
$$g_6(x) = x_3 - 56 \leq 0$$
$$g_7(x) = 130 - x_4 \leq 0$$
$$g_6(x) = x_4 - 290 \leq 0$$

- Face width constraints
  The constraints for minimum and maximum face width are based on earlier computations.[13]

$$g_9(x) = 50 - x_2 \leq 0$$
$$g_{10}(x) = x_2 - 250 \leq 0$$

7. CONCLUSION

This can lead to various benefits including reduction in redundancies, cost containment related to adjustment between manufacturers for missing part interchangeability and performance due to incompatibility of different standards. From this analysis , it was investigated that the effect of gear ratio,helix angle,face width and normal module on bending and compressive stress of high speed helical gear .[14]this paper has been attempt to compare the performance of various helical gear systems for a given set of specification through an analytical approach based on AGMA standards as well as a finite element analysis approach. Three different helical gear systems namely single,herringbone, crossed helical gear systems were evaluated.[15].

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