A Review Paper on Bending & Contact Stress Reduction Techniques in Spur and Helical Gear

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Abstract— Gears are used at very high speed and varied environmental conditions and are subjected to fail mainly because of higher bending & contact stresses produced. So in order to keep this value at lower side, various authors have come up with different solutions. This review article summarizes solutions for problems related to bending and contact stress reduction methods.

Keywords— **Helical gear, AGMA, Ansys,Pressure angle, Helix angle, Face width, bending strength, FEM, surface fatigue strength; contact stress; tooth surface strength of gear.**

Introduction

Gears are the most important part of a transmission system, which are used to transmit power from the source, to the point of its use. It has a wide range of classification, depending upon different application, power, size, speed, and torque requirements. In developing different area such as automobile, aircraft and shipping industries, they have been used widely and wisely to get very good transmission efficiency. Because of these broad areas of applications, gears are used at a wide range of speed and torque limit, due to which the chances of gear failure are enormous. For a designer, if a task is been put to design a gear, the first and foremost thing which is to be consulted is the American Gear Manufacturers Association (AGMA) manual. There are two basic equations in this, the first is for bending and the second for contact stress calculation. If the main interest is to evaluate stress, then AGMA is enough. While there are other very much important parameters e.g. low noise and vibration requirements. Due to the number of possible gear reduction systems, it is not possible to have a single equation to evaluate all vibration levels. But increase in gear size and contact ratio, surely reduce the vibration level. In the area of gear, researchers have worked in different aspects such as static load condition, dynamic load condition etc. For static and dynamic behavior of a gear system, there are a lot of experiments made and performed, while there are some, which need to be performed yet [1] [10].

LITERATURE REVIEW:

Kyle Stoker [2010] compared bending and contact stresses as calculated by Lewis equation and Hertz theory of contact stresses with the FEM method. It is concluded that the values of stresses by both the method matches very closely. It was also concluded that the values of the contact and bending stresses changes with respect to the relative position of gear and pinion. It was revealed that the maximum contact and bending stress occur at non-reference configurations, which must be taken in consideration for evaluating safety factor. The second aim of the study was to calculate, effect of these uncertain parameters on max. Bending and contact stresses [1].

B.Venkatesh [2010] designed a helical gear for marine application and analyzed it for different materials. The dimension has been taken based on the theoretical calculations. Finally the results from theoretical and FEM approaches were compared, and the value matches closely. Out of the selected materials, aluminum Alloy (ceramics) was found to be the best suited for marine application as it requires low weight component. Its use reduces the weight by 55-67 % also the bending and compressive stresses induced were less [2].

Yogesh C. Hamand [2011] showed an analysis on different stresses and deflections encountered by the sun gear tooth of planetary gearbox which was used in grabbing Crane. It includes the calculation of various forces and consequent bending and wear stresses, using WAS 4460 equations. As the work proceeds, it engages in developing 3-D model of the gear box using circular root fillet & trochoidal root fillet of gear tooth. The results obtained by the theoretical and software methods were in unison. The analysis reveals that the bending and shear stresses obtained by the trochoidal fillet stress were comparatively less than the circular fillet stress. But the wear stress generated in trochoidal fillet was higher, and the deflection produced was less. The rigorous analysis conclude that the trochoidal fillet gear were best suitable for higher number of teeth, while the circular fillet pinion were best suited for lesser number of teeth [3].

Sushil Kumar Tiwari[2012] presented an analysis on bending stress and contact stress of involute spur gear teeth in meshing. Bending stress and contact stress is the basic of stress analysis. It was difficult to get exact value of stress by using fundamental equation such as lewis formula for bending stress and Hertz equation for contact stress. In this paper detailed gear stress analysis has been done. [4].

Bharat Gupta [2012] conducted a contact stress analysis on spur gear, contact stress was generally the deciding factor for determining gear dimensions. In this paper, it was revealed that development of the hardness of the gear tooth profile can be improved to resist pitting failure, which was a process in which small particles were removed from the surface of the tooth due to high contact stress, present between mating teeth. It was also revealed that module is a very important parameter during designing of a gear and the maximum contact stress decreases with increasing module. So it was suggested that in applications where large power has to be transmitted, gears with higher module should be preferred [5].

Boddu Anil Kumar [2012] designed and analyzed helical gear for marine application. Designing part has been done using the CAD software by previously drafting the 2D drawing through calculations. Two analysis has been done on this helical gear, namely first the structural analysis and second the thermal analysis. Two different materials have been chosen, Nickel Chromium Alloy steel and Aluminum Alloy A360. Structural analysis has been carried out to validate the strength while the thermal analysis has been done to validate the thermal properties such as nodal temperature, thermal gradient and thermal flux [6].

V.Rajaprabakaran [2012] worked in the area of reducing fillet stress, by introducing some stress relieving holes. These holes were provided at different locations. The study shows that aero-fin shaped hole introduced along the stress flow direction yielded better results [7].

Pravin M. Kinge [2012] worked on improving the life of a gear, it was observed that the life of a gear was basically reduced due to the, the stress generated at the teeth edges, and these were generated due to the high stress concentration at the teeth edges. In order to relieve these stresses, three modifications, (1) The edged of the teeth were tapered by an angle 20˚, (2) making grove in the gear wheel and (3) making holes at the roots of the gear teeth, have been suggested in the design, and stresses were then calculated again. It was found out that the stress concentrated at the teeth edges, now got concentrated at the hole edges [8].

Shivang S. Jani [2013] modeled helical gear in the design software and then a FEM analysis has been conducted by specifying 10 specific points on the model. The design was found to be accurate and all the stresses, including friction stresses and total deformations were found to be in acceptable limit, it was further concluded that a gear optimization can be conducted by varying various parameters [9].

Vivek Karaveer [2013] conducted an analysis on modeling and finite element analysis of spur gear. It was seen that contact stress was a very important parameter in gear designing. In this analysis the material chosen was steel and grey cast iron. The analysis was then compared using Hertz equation. It was seen that the results obtained by FEM analysis and Hertz equation were comparable and difference was negligible [10].

M. S. Murthy [2013] dealt with the stress analysis techniques used by various researchers to find out and optimize various stresses produced. As there were many factors which affect the amount of stress produced, in this work, evaluation of stresses by changing some features such as helix angle and face width has been carried out [11].

A.Parthiban [2013] attempted to optimize the gear profile geometry in order to increase gear teeth strength, using CAD & CAE. It was seen that the gear with less than 17 teeth, had problem of undercutting during manufacturing, which minimizes gear strength at root. In this research work, authors suggested a unique method, which directs to use circular root instead of using standard trochoidal root fillet. This was further analyzed using CAE software. The analysis shows that the circular root fillet shows less bending stress as compared to standard trochoidal root fillet gear. It was also concluded that circular root fillet design was particularly favorable for lesser number of teeth and trochoidal fillet was best for more number of teeth [12].

Bhanu Pratap Pulla [2013] dealt with problem of undercutting and interference caused by deviations in ideal gear geometry as they cause serious harm to the gear tooth profile by digging one tooth profile over the other. A c-program is generated for creation of spur gear tooth profile and corrected spur gear tooth profile. These output files are converted to DXF file. And the models are then imported to analysis software. The analysis is done for various pressure angles, and it is found that the load carrying capacity increases with increase in pressure angle. Also the von-mises stresses are higher for higher pressure angle spur gear [13].

B.Venkatesh [2014] investigated the effect of parameters such as gear ratio, face width, helix angle and module on tangential force and dynamic tooth load of helical gear [14].

Jerin Sabu[2014] attempted to perform a finite element nonlinear contact analysis of Helical Gears. Maximum von-mises stress state of teeth flanks, teeth fillets and parts of helical gears during the teeth pair meshing period and deformation was calculated. The total deformation of gear teeth was found to be very less and which was acceptable [15].

Santosh S. Patil[2014] conducted an analysis on helical gear contact stress analysis under a static condition using a 3-D finite element method. Four helical gear pair sets have been prepared which were of 0, 5, 15, 25 helix angle. Contact stresses have been calculated using The Lagrange multiplier algorithm. The effect of friction was varied at the point of contact, so the problem generated was nonlinear and complicated. An average coefficient of friction from 0 to 0.3 has been considered to simplify the problem. it was concluded that the contact stresses decrease with helix angle for a constant coefficient of friction and for smaller helical angle gears, the increase in contact stress with the increase in coefficient of friction was lesser as compared to the gears with higher helical angle [16].

S. Jyothirmai [2014] conducted an analysis on finite element approach to bending, contact and fatigue stress distribution in helical gear system. The objective of this work was to conduct a comparative study on helical gear design and its performance based on various performance metrics through finite element as well as analytical approaches based on American Gear Manufacturing Association [AGMA]. The effect of major performance metrics of different helical gear tooth systems such as single, herringbone and crossed helical gear were studied through finite element approach [FEA] and compared with theoretical analysis of helical gear pair [17].

Nidal H. Abu-Hamdeh [2014] generated stress relieving features to decrease the root fillet stress in spur gear. A model was generated to calculate von mises stress at the root fillet of the gear without holes and was used as a reference model. These stresses were then compared with AGMA standard. These stresses were in equivalence to the previous determined stresses. two other models were then prepared, namely first model and second model to evaluate the effect of various hole parameters such as number, diameter, location, angle. The first model was performed by creating hole/holes in the gear body. The second model was performed by creating hole/holes in the face/profile of the gear. The results showed that the increasing the diameter size and the number of holes, increases the stress reduction in the root fillet stress [18].

A.Y Gidado [2014] provided a parametric designing of helical gear and then analyzed for bending and contact stresses using FEA. The model was analyzed for different values of face width, and it shows appreciable decrease in bending stress, with increase in face width [19].

Conclusion

The present study reveals that there are many ways to reduce bending and contact stress generation between mating teeth of gears. One way is to consider safety factor and calculation of uncertain parameters [1]. The selection of suitable material also heavily impact stress induced [2]. For sun gear tooth of planetary gearbox trochoidal fillet is more beneficial in order to reduce stress levels [3][12][18]. Detailed bending and contact stress is necessary to determine exact value of stresses [4]. Design parameters such as Module, Number of teeth, helix angle, face width are very important to keep stresses up to a normal range [5][6]. Some researchers also suggested to modify design parameters [7][8][10][17]. The coefficient of friction also plays vital role in generation of contact stresses [16]

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