A Study on Modelling& Finite Element Analysis of Flywheel Ring Gear & Starter Motor Pinion

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Abstract - Gears are one of the most important parts of Mechanical system are generally used to transmission power from one shaft to another, depending on application they are available with different type of tooth profiles. In all spur gears are the most preferred type of gear because of simplicity of use & manufacturing with high degree of transmission efficiency. In this paper an attempt is made to predict static Contact stresses, Bending stresses, load sharing for HCR & NCR for the given pair of spur gear by using FEA also wear of Ring gear & Pinion after completing Endurance test. The main concern is the tooth profile of both gears i.e. straight spur for Flywheel ring gear & involute spur for starter motor pinion, this system of gear pair will have different contact geometry then straight spur to straight spur and involute spur to involute spur. Some of the experimental results are also discussed in order to determine whether the system will meet the performance specification are not.

Keywords: Spur gear, FEA, Contact stresses, Bending stresses, Ring gear, Pinion, Starter motor, Gear tooth failure.

I. INTRODUCTION

A gear also called as cogwheel is the most important & critical element of power transmission system. Gear is a rotating cylindrical wheel having tooth cut on it, which meshes with another toothed part to transmit the power, in most cases with teeth on the one gear being of identical shape, and often also with that shape on the other gear in mesh. There are different types of gears like Spur, Helical, Wormand Bevel. Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form (they are usually of special form to achieve constant drive ratio, mainly involute), the edge ofeach tooth is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel shafts. As the most common type, spur gears are often used because they are the simplest to design & manufacture, less costly, efficient.

The starter motor:

The starter motor is necessary for internal-combustion engines, because the four stroke cycle requires that the pistons already to be in motion before the ignition phase or power stroke of the engine Cycle. This means that the engine must be ‘cranked’ over by an external force.

Basic Configuration and operation:- The modern starter motor is an electric motor with a solenoid switch, similar to a relay, bolted to its side. When low-current power from the lead-acid battery is applied to the solenoid usually through a key switch, it pulls out a small pinion gear on the starter motor’s shaft and meshes it with the ring gear on the flywheel of the engine. If the engine starts the key switch is released, the solenoid pulls the small gear back off the starter gear and the starter motor stops running. Modern starter motors have a special pinion gear and ‘free-wheel’ assembly that enables the pinion gear to automatically disengage from the ring gear when the engine starts. Larger, high power engines such as those used in heavy equipment sometimes have a smaller petrol powered engine attached to the side as a starter motor.The starting system consists of the battery, cables, starter motor, flywheel ring-gear, and the ignition switch. During starting, two actions occur. The pinion of the starter motor engages with the flywheel ring gear, and the starter motor then operates to ‘crank’ the engine. The starter motor is an electric motor mounted on the engine block, and operated from the battery. It is designed to have high turning effort at low speeds. The starter cables are the thickest on the vehicle, as a high current (80-100 amp.) must be delivered to thestarter motor, to turn the crankshaft from rest, and keep it turning until the engine fires, and runs on its own.

Reason for the Gear tooth failure:

The different modes of failure of gear tooth are bending failure, pitting & scoring, corrosive wear. In bending failure every gear tooth acts as a cantilever. If total repetitive dynamic load acting on the gear tooth is greater than the beam strength of the gear tooth, then the gear tooth will fail in bending. In pitting failure-it is surface fatigue failure which occurs due to many repetitions of Hertz contact stresses. The failure occurs when the surface contact stress are higher than the endurance limit of the material.Scoring-it is a stick slip phenomenon in which alternate sharing & welding takes place rapidly at highest spots. It is avoided by properly designing parameters such as speed, pressure & proper flow lubricant.Corrosive wear-the corrosion of the tooth surface is namely caused due to the presence of corrosive element such as additives present in the lubricating oils. To avoid these proper anticorrosive additives should be used.Bending stresses-among the several failure mechanisms for spur gears, failure due to bending stresses is very important when the loads are too large. In case of bending failure the gear tooth is considered as a cantilever beam under load. The ability of the tooth to resist tooth breakage as the root is often referred as the beam. The tooth load FN is supposed to act at the tip corner. Load FN acts along the line of action at pressure angle and when referred to pitch point at the intersection of the line of action and centre line of the tooth.

Contact stresses-contact mechanism is the study of the deformation of solids that touch each other at one or more points. The physical and mathematical formulation of the subject is built upon the mechanic of material & continuum mechanic and focuses on computations involving elastic, visco-elastic a plastic bodies in static or in dynamic condition. Hertzian contact stress refers to the localized stresses that developed as two curved surfaces come in contact and deforms slightly under the imposed loads. This amount of deformation is depends on the modulus of elasticity of the material in contact. It gives the contact stresses as a function of normal contact force, the radii of curvature of both bodies and the modulus of elasticity of both the bodies. In gear & bearing in operation, these contact stresses are cyclic in nature and over time lead to sub-surface fatigue cracks.

II. SYSTEM MODEL

In this study the system of gears used consists of 8 tooth pinion & 126 tooth ring gear is used. Both gears spur. Material used while carrying analysis is structural steel. This study mainly works on the behaviour of gear assembly, the starter motor pinion & flywheel ring gear. As like other gear assembly, tooth's of mating gears are always in constant mesh, but in case of our system the starter pinion will move and made contact with ring gear. As the contact increases from initial to maximum the stresses developed also varies with respect to time or increasing gear load.

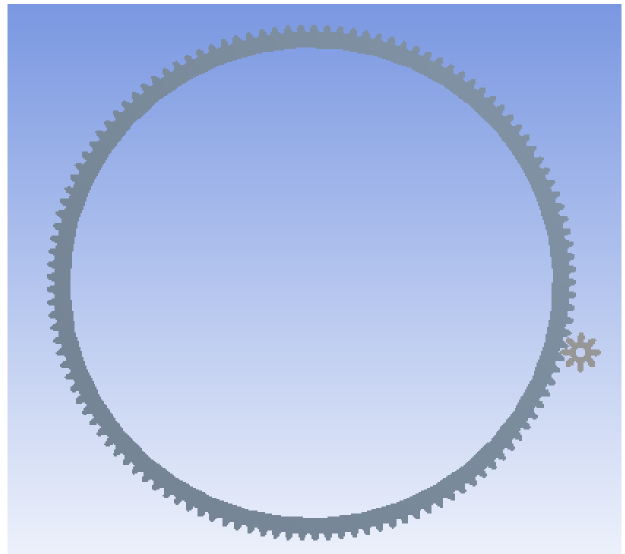

Fig. 2.1 Ring gear & Pinion

III. PREVIOUS WORK

Many of the Researchers nationally and internationally found gear contact analysis as a field of interest with wide scope of research; lot of work by many researchers are carried out in spur gear or helical gear contact analysis using finite element method. The gear stress analysis, the transmission errors, and the prediction of gear dynamic loads, and the optimal design for gear sets are always major concerns in gear design. Some of the papers from distinct researchers are reviewed here in order to look upon their work in the field of Finite element Analysis of Gear Pair.

Quasi static finite element analysis was carried out for NCR & HCR gears with fixed module, centre distance & gear ratio. Here the increasing contact ratio is obtained by increasing the addendum factor from 1.0 to 1.25 m. Hence a contact ratio of more than 2.0 was achieved for the same number of tooth. Two dimensional deformable body contact models for both HCR gear & NCR gears were created using the ANSYS-APDL loop program. Various parameters such as load sharing ratio, bending stress & contact stress were evaluated and compared over the path of contact. The maximum bending stress for a HCR gear is 18% less & contact stress is 19% less than of a NCR gear for the pair of same module & fixed center distance. Hence the load carrying capacity of the HCR gear is 18% more than the NCR gear designed for the same weight, fixed module & same centre distance of gear pair [1]. In this paper researchers studied the contact stresses among the Spur gear pair &Helical gear pair, under static condition by using 3D finite element model. The Helical gear pair on which the analysis was carried out were 0° ,5°, 15°, 25° helical gear set. During analysis FE gear model was verified with Hertz/AGMA equation for zero coefficient of friction. The FE model of gear pair are compatible in evaluating the contact stresses & the results obtained are in good agreement with analytical calculations. For the spur gear pair the increase in contact stress with the increase in coefficient of friction was about 10% [2].This paper presents the stress analysis of mating tooth of spur gears to find maximum contact stress in the gear tooth. The results obtained from Finite Element Method are compared with theoretical Hertzian equation values. The spur gears are sketched, modelled& assembled in ANSYS 14.5 DesignModular. The results show that the difference between maximum contact stresses obtained from Hertz equation & Finite Element Analysis is very less and it is acceptable also the deformation patterns of steel & cast iron gears depict that the difference in their deformation is negligible[3].

As mentioned in the paper a pair of spur gear tooth in action is generally subjected to two types of cyclic stresses: bending stresses inducing bending fatigue & contact stress causing contact fatigue. Both this type of stresses may not attend their maximum values at same point of contact fatigue. These types of failures can be minimized by careful analysis of the problem during the design stage & creating proper tooth surface profile, in order to analyze spur gear pair a 3D deformable-body (model) of spur gear is developed and bending stress analysis will be performed as it affects transmission [4].

In this paper tooth failure of spur gear is examined. The spur gear with less than 17 numbers of tooth had the problem of undercutting during gear manufacturing process which minimizes the strength of gear at root. Circular root filled instead of the standard trochoidal root filled is introduced in spur gear & analyzed using ANSYS. From the study it is observed that the circular root filled design is particularly suitable for lesser number of tooth in pinion &where as the trochoidal root filled design is suitable for higher number of tooth [5]. In this paper, the actual shape of trochoid is considered, whereas the fillet radius is assumed as a constant radius curve for calculating the geometry factor presented by AGMA. The FEA of final drive gear assembly of Military vehicle for both NCR & HCR is examined and the contact stresses are more than 25% less in HCR gears compared To NCR gears. The load carrying capacity of HCR gearing could be increased by at least 25% for the same weight & volume [6].The present paper concentrates on the gear fatigue wear reduction through micro-geometry modification method. An advanced non-linear finite element method has been successfully used to accurately simulate gear contact behaviour. The models have used true three dimensional gear tooth profiles with micro-geometry modifications under real load conditions. The shaft misalignment, deflection and assembly deflection effects on gear surface contact behaviour have been investigated. The optimized micro-geometry based on the analysis has been proposed to reduce surface contact fatigue failure. The model has been very successfully applied in automotive transmission gear surface fatigue wear reduction. The highly accurate gear micro-geometry modification method has improved the gear surface fatigue wear significantly. This method can also be applied to transmission system noise analysis in term of transmission error reduction[7].

This paper investigates finite element model for monitoring the stresses induced of tooth flank, tooth fillet during meshing of gears. The involute profile of helical gear has been modelled and the simulation is carried out for the bending and contact stresses and the same have been estimated. To estimate bending and contact stresses, 3D models are generated by modelling software CATIA V5 and simulation is done by finite element software package ANSYS 14.0. Analytical method of calculating gear bending stresses uses Lewis and AGMA bending equation. For contact stresses Hertz and AGMA contact equation are used. 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. In this work we got on three results as follow; Theoretical results (from Lewis equation and Hertz equation directly), AGMA results, ANSYS results and all results are closer [8].The present work is aim of analytical design of girth gear by using AGMA standard; bending & contact stresses on the gear tooth are calculated. The validation of the stresses is done by using FEA (ANSYS). The values of the bending stress and contact stress determined using AGMA found to be in agreement with ANSYS results and corresponding error observed is less than 5%. Girth gears are large ring gears which are normally fitted to the outside of the mills or kilns to provide the primary rotational drive. The two things that form the test of the gear design are surface durability (pitting) and tooth bending strength. A girth gear can be single or double pinion driven [9]. The major objective of this project is to find the region of the surface distortion due to wear at vicinity of the pitch line. Generally for medium power transmission spur gears with involute profile is used. In transmitting the power, the gears are subjected to number of stresses and the failure of the gear is mainly caused due to bending and pitting. The former can be avoided by providing high strength material i.e. material having high static strength but the pitting failure can be avoided only by proper surface hardening of the gear teeth. Most of the gear failures occur mainly due to contact failures. Pitting occurs at the pitch point on the surface of the tooth. The stresses developed are called as Contact stresses. One more observation during this work is that σx varies distinctively about pitch line as if it is junction between two stress regions [10].

IV. CONCLUSION

While studying literatures it was observed that, FEA is a good option for conducting gear contact analysis. Many of the researchers found results of FEA are in good agreement with the manually calculated results for contact stresses and bending stresses. The set of gears used are of same module & pressure angle. Material properties plays very important role in order to analyze structural deformation. ANSYS can be used for conducting gear contact analysis. Hertz/AGMA equation can be used to calculate contact stresses as well as Lewi's/AGMA equation can be used to find Bending stresses.

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