# A Review- Design and Analysis of Effect of Change of Contact Ratio on Contact Fatigue Stress of Spur Gear

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***Abstract***-*The dynamic analysis of the gears has become important part due to the pressing need for high speed and heavy load carrying machinery. A high contact ratio spur gear pair reduces the variation of tooth stiffness and thus to reduce vibration and noise. In spite of many studies in the past, the engineers and researchers have to give more attention to an investigation of contact and bending stress characteristic of spur gears. This is because of the advances in the engineering technology. The paper presents the review of design and analysis on the effect of change of contact ratio on fatigue stress of spur gear.*

***Keywords***-Bending stress, High Contact Ratio, Spur Gear

## I. INTRODUCTION

Gears are widely used in almost each type of machineries in the industry. Along with bolts, nuts and screws; they are a common element in machines and will be needed frequently by machine designers to realize their designs in almost all fields of mechanical applications. Ever since the first gear was conceived over 3000 years ago, they have become an integral component in all manner of tools and machineries.

### A. Spur gear

Spur Gears are the most common means of transmitting power in the modern mechanical engineering world. They vary from tiny size used in the watches to the large gears used in marine speed reducers; bridge lifting mechanism and railroad turn table drivers. They form vital elements of main and ancillary mechanism in many machines such as automobiles, tractors, metal cutting machine tools, rolling mills, hoisting and transmitting machinery and marine engines etc.

The four major failure modes in gear systems are tooth bending fatigue, contact fatigue, surface wear, and scoring. The pitting of gear teeth flanks and tooth breakage in the tooth root are the two kinds of teeth damage can occur on gears under repeated loading due to fatigue. Tooth breakage is clearly the worst damage case since the gear could have seriously hampered operating condition or even be destroyed. Because of this, the stress in the tooth should always be carefully studied in all practical gear. The fatigue life of components subjected to sinusoidal loading can be estimated by using cumulative damage theories. Due to the complexity in geometry and loading on the structure, the finite element method is preferably adopted.

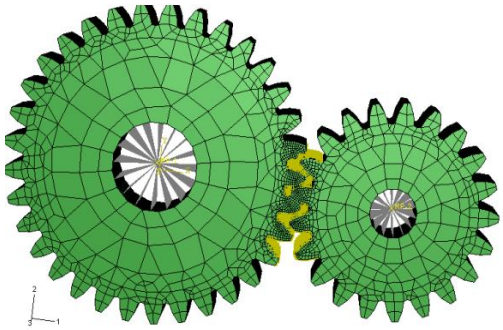

Figure I Spur gear pair

### 1. Advantages of spur gear

1. Spur gears have high power transmission efficiency.
2. They are compact and easy to install.
3. They offer constant velocity ratio.
4. No slip occurs.
5. Spur gears are highly reliable.
6. They can be used to transmit large amount of power (of the order of 50,000 kW).

### 2. Disadvantages of spur gear

1. Spur gear drives are costly when compared to belt drives.
2. They have a limited center distance. This is because in a spur gear drive, the gears should be meshed and they should be in direct contact with each other.
3. It is noisy at high speeds.
4. They cannot be used for long distance power transmission.
5. A large amount of stress is experienced by a gear.

### B.Contact Ratio

Contact ratio is defined as ratio of length of arc of contact to circular pitch. When two gear teeth mesh, the meshing zone is usually limited between the intersecting radii of addendum of the respective gears as shown in Figure 1.5. From the figure it can be seen that the initial tooth contact occurs at point a and final tooth contact occurs at b. when. from points a and b the tooth profiles are drawn, they will intersect the pitch circle at points A and B respectively. The radial distance AP is called the arc of approach qa, and the radial distance PB is called the arc of recesses qr and the sum of these being the arc of action qt.

When the arc of action qt and the circular pitch p of a mating gear pair is equal. Then there is always only one pair of teeth in contact and their clearance occupies the space between the arcs AB.

Contact ratio is defined as the average number of pairs of teeth in contact under static conditions, and with no errors and tooth profile modifications. The term high contact ratio (HCR) means the gearing that has at least two pairs of teeth in contact at all times i.e. contact ratio is 2 or more. The percentage change in mesh stiffness for HCR meshes is lower than low contact ratio (LCR) meshes, so high-quality HCR gear meshes have lower mesh induced vibration and noise than LCR gear meshes.

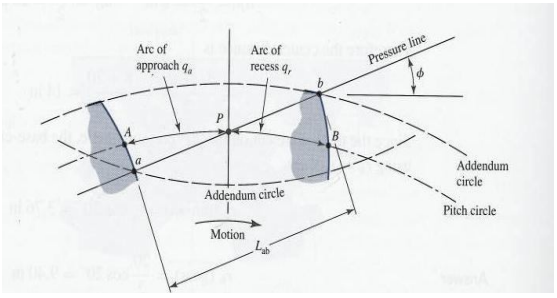


Figure II Contact ratio

The main goal in advanced gear transmission design is to increased life and reliability and reduced weight of a gear. For achieving these goals, a high contact ratio gears (HCRG) provides an effective means. At least two pairs of teeth in contact at all times in case of HCRG, , whereas in standard low contact ratio gears (LCRG), alternate between one and two pairs are in contact. This gives higher power-to-weight ratio for longer life and greater reliability because the transmitted load is shared between two or more pairs of teeth; the individual tooth load and stresses were less for HCRG compare to LCRG designs. HCRG are expected to be dynamically more sensitive to tooth profile. Dynamic loads and stresses are important in gear performance. High dynamic loads will increase gear noise and the risk of surface failure, and large value of dynamic stress at the tooth root can lead to premature tooth fatigue and fracture. To determine the load sharing between the two and three pairs in contact, dynamic analysis is required.

## II. LITERATURE

D. RAJESH KHANNA et. al. (2015) had investigated the characteristics of a gear system which includes contact stresses, bending stresses, and the transmission errors of gears in mesh.They proposed the two-dimensional, three-dimensional methods to estimate the tooth contact stress and the root bending stresses. To determine the accuracy of the present method for the bending stresses, they built three and two-dimensional models both. They compared the results with the different numbers of teeth. And found that FEA models are good enough for stress analysis.

Utkarsh. M. Desai et.al. (2015) has been investigated and found in certain applications the performance of the spur gear is not satisfactory and therefore, to improve the performance of the spur gears, it is required to explore some alternate materials. They worked on a metallic gear of Alloy Steel and is replaced by the composite gear of 30% Glass filled Poly-ether-ether- Ketone (PEEK). To study the free vibration behavior of both materials, the Finite Element modal for spur gear was formulated. From the analysis, they observed that the natural frequency obtained from the mathematical analysis was good agreement with the results of a finite element modal analysis. Overall, it was observed from their analysis of current work that the spur gear of alloy steel (nickel chrome steel) can be replaced by composite thermoplastic GF 30 PEEK material due to aforesaid properties.

Deviprajwal. S. Shetty et. al. (2016) was investigated spur gears in power transmission. The efficiency of the gears are very high compared to the other power transmission systems such as belts, chains, or pulleys and are thus used in wide variety of application ranging from small domestic items such as watches and toys to large-scale industrial applications such as turbines and propellers. Thus that stresses in the gears had to be analyzed under operating conditions in order to prevent its failure. They compared the results of ANSYS and theoretical results, it was found to be nearly equal, and the percentage difference is found to be 1.99%. They observed that ANSYS workbench is a reliable source for bending stress analysis. And also the bending stress near the root of the gear tooth decreases as an increase in the value of face width for both steel and Aluminum as a gear material. By investigating they found that Aluminum as gear material provides reliability because of its high strength to weight ratio.

Sujit R. Gavhane et. al. (2014) worked on Gear drive. The static contact and bending stress analysis were performed, while trying to design spur gears to resist bending failure and pitting of the teeth, as both affect transmission error. Their aim was to determine bending stresses in spur gear and reduction of these stresses using stress relieving features. During analysis, deformation was noted. They studied the stress relieving features for spur gear with single hole stress relieving technique by using FEA.

Zheng Li et. al. (2013) studied the frictional effects on gear tooth contact analysis. The situation of a frictional shear stress of gear teeth and the relevant frictional effects on bending stresses was investigated. And also, transmission error in gear meshing. For understanding gear contact behavior accurately, the adequate consideration of frictional effects was essential. Using finite element method, an analysis of tooth frictional effect on gear performance in spur gear was presented. They developed a Non-linear finite element model for gear tooth contact with rolling/sliding. Identified contact zones for multiple tooth pairs and derived the associated integration situation. They have discussed phenomena of gained results to understand the particular static and dynamic frictional effects on gear tooth contact analysis. With both static and dynamic boundary conditions the potentially significant contribution of tooth frictional shear stress particularly in the case of gear tooth contact analysis were presented.

Mahendran et. al. (2014) had design the spur gear with weight reduction and stress distribution for cast steel and composite materials. They worked on the impact analysis for cast steel and composite materials. And also consider torque loading for cast steel and composite materials.

They found that, the stress induced, deformation and weight of the composite spur gear is less as compared to the cast steel spur gear. So, Composite materials are capable of using in automobile vehicle gear boxes up to 1.5KN in the application of Tata super ace model instead of existing cast steel gears with better results. They gives some suggestion after completing their work:

- Various composite materials can be applied instead of currently used materials.
- The input conditions can be varied to parameters like pressure, temperature etc.

Harshal P. Rahate et. al. (2015) had worked on gear teeth normally fail when load is increased above a certain limit. Therefore it is required to explore alternate material for gear manufacturing. Composite materials provide adequate strength with weight reduction and they have emerged out as a better replacement for metallic gears. The contact stress in the mating gear is the key parameter in gear design. They worked to represent contact stress analysis of steel gear and composite gear using Hertz equation and by Finite Element Analysis using Ansys 16.0 Workbench. They compared their results of both theoretical method and FEA shows a good degree of agreement with each other.

By Hertz equation, the theoretical maximum contact stress is calculated. Also, the FE analysis of spur gear was done to determine the maximum contact stress by ANSYS 16.0. It was found that the results from both Hertz equation and Finite Element Analysis are comparable. The results were within the difference of 5%. Also, they observed that stress reduced by nearly 25% due to the use of composite material.

C.M. Meenakshi et. al. (2012) has investigation on study the various stress state of spur gear. The tangential and radial forces which acts on various point upon that basis we can analyze by applying the forces. Bending stress and contact stress on the tooth of spur gear drive is found by using Ansys software. Gears are machine elements used to transmit power between rotating shaft by means of engagement of projection called teeth. In the wooden mechanical world, gears are most common means of transmitting power.

They worked on the theoretical stresses of both bending and contact stress is found manually and then analyzed in ANSYS software. They compare their results with manual and found that results were approximate or closer to it. Hence they concluded that ANSYS Software could be used for other analyzing purpose also.

From the above literature it is observed that, the dynamic analysis of the gears has become important part due to the pressing need of high speed and heavy load carrying machinery. A high contact ratio spur gear pair reduces the variation of tooth stiffness and thus to reduce vibration and noise. It also improves structural efficiency, reliability and power to weight ratio. With increased requirements of high speed, heavy load and light weight in gear design, the dynamic load is required to determine among two or three pairs in contact. In this work, an analytical method is discussed for calculation of the load sharing among meshing teeth pairs. They determined variations of dynamic load during mesh cycle. Variable stiffness's which are required for dynamic load calculations are found using analytical expressions.

This information may be useful in further analysis of High Contact Ratio Spur Gear drives

## III. OBJECTIVE

The objectives of present work are stated below

1. To understand the working of high contact ratio gears.
2. Finding out the load sharing between gear teeth.
3. To calculate stiffness variation with pinion roll angle.
4. Finding out the dynamic load variation with respect to operational speed.
5. To determine the principal stresses variation with respect to operational speed

## IV. METHODOLOGY

In recent years, there have been considerable developments in direct computer-aided design (CAD)/computer aided engineering (CAE) data interchange. As a result engineers can now undertake a wide range of design, analysis, and modelling, on their respective research areas.

Many research methods use detailed finite element methods to predict, but without the prediction being fully integrated within advanced optimization procedures, as they require complete automatic FE solutions. To get input parameters for simplified analytical dynamic models, the other research methods use finite- element simulations. Hence considering these factors, the accuracy and robustness of the procedures used have a scope to enhance and thereby achieving a higher accuracy of results.

## V. CONCLUSION

The present work lecturer review on analytical method and Numerical method for calculation of the tooth load sharing in high contact ratio spur gear pairs at any point in mesh cycle. With respect to pinion roll angle, it gives the stiffness variation of the driving gear, driven gear and mesh. For dynamic load analysis of high contact ratio spur gear system, a torsional vibration based model will be used. This will gives the effect of operational speed on a magnitude of the dynamic load and the principal stresses acting on pinion tooth. Effect of operational speed on the location of the maximum dynamic load will be predicted.

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