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A review of gear power transmission optimization by using genetic algorithm

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Abstract - **This Review Paper gives the information about Bending and Contact Stress Analysis of Helical Gear. Thus, this review paper mainly focus on the ANSYS, MATLAB finite element methods and AGMA standards for computation of bending and contact stress on a root of helical gear. In this paper the bending stress and contact stress of the gear tooth are examined and are to be one of the main contributors for the failure of the gear in a gear set. Thus, the analysis of stresses has become popular as an area of research on gears to minimize or to reduce the failures and for optimal design of gears. Authors have use various Approaches and means to conclude their main objective of finding out the contact stresses and gear failure causes in static condition using Finite Element Analysis, AGMA Standards MATLAB. This review paper contains theoretical, numerical and analytical methods for the helical gear pair analysis.**

Keywords- **Helical gear; ANSYS, MATLAB; AGMA Standards; Creo; FEA analysis; Bending strength; Helix angle; Pressure angle.**

I. INTRODUCTION

1. General

Gear design is a complex phenomenon requiring consideration of several items such as gear geometry, material heat treatment, manufacturing, etc., to satisfy. Functional requirement, of high strength, high accuracy, low noise, and compactness of the drive. Traditionally, gear designers have been concerned with requirements of strength, noise, life, and accuracy of kinematic transmission. The recent focus of research however is the optimal design of compact gear pairs (gear boxes) for minimum weight and space requirements Designing a new product consists of several parameters, which differ according to the depth of design, input data, design strategy, procedures, and results.

Mechanical design includes an optimization process in which designers always consider certain objectives such as strength, deflection, weight, wear, corrosion depending on the requirements. Among these objectives the weight of a new product is one of the best considerable design parameter. The problem of minimum volume design of simple gear trains has been a subject of considerable interest, since many high-performance power transmission applications (e.g., automotive, aerospace, machine tools, etc.) require low weight. Gears plays an important role in transmit the necessary power for the proper function of the machines.

The use of power is desirable at various angles to perform the various tasks like lifting, digging, cutting and pulling etc. This work describes the importance of helical gear in machinery and optimization of center distance using algorithm. The helical gears are employed to transmit motion between parallel shafts. These gears can also be used for transmitting motion between non-parallel, non-intersecting shafts.

2. Advantages of Gear Drives

Advantages of gear drives over other transmission means are:

- They give positive drives and constancy of speed ratio without any slippage.
- The drive is very compact due to short centre distances used in such drives.
- High efficiency, reliable service and simple operation.
- Maintenance is inexpensive and if properly lubricated and operated, gear drives have the longest service life as compared to other mechanical drives.
- Gear drives can be used where precise timing is desired.
- Gear drives can drive much heavier loads than other drives due to their unlimited sizes.

Gear drives can be used for wide range of transmitted power, i.e., from one-tenths of a KW to tens of thousands of KW.

3. Disadvantages of gear drives

Advantages of gear drives over other transmission means are:

- The manufacturing is complex. Special tools and equipment are needed to manufacture them.
- Due to errors and inaccuracy in their manufacturing, the drive may become noisy accompanied by vibrations at high speeds.
- They are not suitable for large centre distances because the drive will become bulky.

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4. Helical Gears

Helical gears are similar to spur gears except that their teeth are cut at an angle to the hole (axis) rather than straight and parallel to the axis like they are in the teeth of a spur gear. Helical gears are manufactured as both right and left-handed gears. The teeth of a left-handed helical gear lean to the left when the gear is placed on a flat surface. The teeth of a right-handed helical gear lean to the right when placed on a flat surface. In spur gears Fig.1.1 (a), the teeth are parallel to the axis whereas in helical gears Fig.1.1 (b) the teeth are inclined to the axis. Both the gears are transmitting power between two parallel shafts. [19] At any time, the load on helical gears is distributed over several teeth, resulting in reduced wear. When two helical gears are engaged as, the helix angle has to be the same on each gear, but one gear must have a right-hand helix and the other a left-hand helix. In helical gear the line contact is diagonal across the face of the tooth.

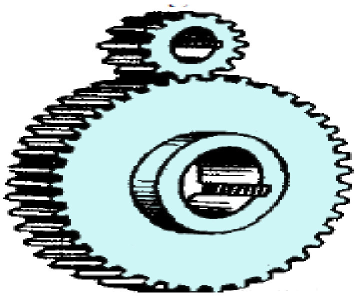

Fig.1 (a) spur gear

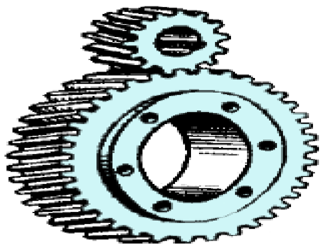

Fig.1 (b) helical gear

Hence gradual engagement of the teeth and the smooth transfer of load from one tooth to another occur. Helical gears are capable of providing smoother and quieter operations at the same time transmit heavy loads. They are useful for high speed and high power applications, quiet at high speeds. Helical gears operate with less noise and vibration than spur gears. At any time, the load on helical gears is distributed over several teeth, resulting in reduced wear. Due to their angular cut, teeth meshing results in thrust loads along the gear shaft. This action requires thrust bearings to absorb the thrust load and maintain gear alignment. They are widely used in automobile.

II.REVIEW OF PAST RESEARCH

ParidhiRai et al (2018) minimized the volume of helical gear pair by including profile shaft coefficients as design variables along with module, face width and number of teeth using RCGA. Transverse load factor, face load factor, form factor, stress factor and zone factor are affected by profile shift and hence profile shift influences the design optimization result for helical gear pair. Tooth contact and bending strength are the two constraints used in the optimization procedure. It has been found that volume with profile shift is smaller compared to that of without profile shift. For further validation of RCGA results, commercially used software KISSsoft has been used.

Daniel Miler (2018) conducting a multi-objective optimization of gear pair parameters with a goal of reducing the transmission volume and power losses. Gearing efficiency primarily depends on the normal load, sliding velocities, and the friction coefficient. Gearing efficiency was calculated analytically, using the approximate load distribution formulae and efficiency formulation developed by Schlenk. The resulting formula was included in the genetic algorithm as an objective. To verify it, results were compared to the ones obtained by other authors. Optimization variables consisted of the gear module, the face width, the pinion and wheel profile shift coefficients and the number of teeth of the pinion. Solutions have shown that the trade-off between volume and efficiency is obligatory and a combi- nation of the lower gear module, the lower face width, the higher profile shift coefficients and the higher number of teeth of the pinion yield good results regarding both objectives.

Ashish V Kadu and Sanjay S Deshmukh (2015) experimented that the transmission error in the actual gear system which arises because of an irregular tool geometry or imperfect geometry or imperfect mounting the characteristic of the involutes spur gear are analyzed by using finite element method. The contact stresses are examined by using 2D FEM Model. And the bending stresses in the tooth root are examined by using 3D FEM Model. The conventional method of calculating gear contact stress using Hertz's theory for verification by 2D FEM analyzer using ANSYS, the stiffness relationship between two contact area is usually established using a spring place between source and target surfaces for the contact generation between two gears. The stresses are compared with theoretical result. The static transmission error and analysis of load sharing method using displacement vector and the effect of this error in the actual transmission power of mesh gear.

Deva Ganesh et al. (2015) studied that the meshing between two gears contact stresses are evolved, which are determined by using analyzing software called ANSYS. Finding stresses has become most popular in research on gears to minimize the vibrations, bending stresses and also reducing the mass percentage in gears. These stresses are used to find the optimum design in the gears which reduces the chances of failure. The model is generated by using Catia and ANSYS is used for numerical analysis. The analytical study is based on Hertz's equation. Study is conducted by varying the geometrical profile of the teeth and to find the change in contact stresses between gears. It is therefore observed that more contact stresses are obtained in modified gears. Both the results calculated using ANSYS and compared according to the given moment of inertia.

Sarfraz Ali N. Quadri and Dhananjay R. Dolas (2015) experimented an attempt to summarize about stresses developed in a mating spur gear which has involute teeth. A pair of spur gears are taken from a lathe gear box and progressed onward to calculate stresses. Conventionally the analysis is carried out analytically using Lewis formulae and then Finite Element Analysis is used for the same. Some stress relieving features have been incorporated in the teeth to know their effect on the stress concentrations. A finite element model of teeth is considered for analysis and geometrical features of various sizes are introduced at various locations and their effect is analyzed.

Mohammad Jebran Khan et al. (2015) experimented that the gears or toothed wheels form a positive drive for power transmission system in precision machines wherein a definite velocity ratio is needed. Despite having high cost, complicated manufacturing, need of precise alignment of shafts and lubrication, the gear drives are preferred over other power transmission drives. One of the important reasons of preference being that of efficiency which is very high in gear drives, even up to 99 percent in case of spur gears. Spur gears are the simplest of the gear drives having teeth cut parallel to the axis of the shaft. The contact stress analysis of Stainless Steel spur gears by theoretical method using Hertz equations and by Finite Element Analysis using FEA software ANSYS workbench. The spur gear is sketched and modelled in ANSYS design modeler and the contact stress analysis is done in mechanical ANSYS multiphysics. When compared, the results of both theoretical method and FEA show a good degree of agreement with each other.

Manoj Singh et al. (2015) studied that contact stress analysis between 2 gear teeth was thought of in several contact positions representing a try of pairing gears throughout rotation. The contact stress within the pairing gears is that the key parameter geared style. The strain analysis of pairing teeth of gear to seek out maximum contact stress within the gear teeth. The results obtained from Finite component Analysis (FEA) are compared with theoretical nuclear physicist equation values. The most objective of the study is to attenuate stresses at maximum stress targeted space. Style of gear is improved by up the standard of fabric, improving surface hardness by heat treatment, surface finishing ways. aside from this stress conjointly happens during its actual operating. Therefore it's necessary to attenuate the stresses. These stresses are reduced by introducing stress relief options at the stress zone.

Bhatt ParthJitendrabhai (2015) studied that the gears are one of the most critical components in mechanical power transmission systems. The bending and surface strength of the gear tooth are considered to be one of the main contributors for the failure of the gear in gear set. The three dimensional solid model can be generated in Pro-e. This model is imported in Ansys and then contact stress and bending stress can be calculated in Ansys for different face width and helix angle. Contact stress and bending stress can also be calculated by hertz, lewis and AGMA equation. Bending stress can be occurring in the root of gear and contact stress can be occur between meshing of two gear. Finally these two methods bending and contact stress results both are compared with each other for different face width and helix angle different material can also be tried for weight and cost optimization. And also to increase corrosion resistance which might be cause of failure.

NagarajuGummadi and Rama Thirumurugan (2015) investigated that the gear failure are due to fillet and contact stresses. Even though analytical methods are available to determine these, load sharing is not considered in these methods .Also the hertzian equations used to determine the contact stress are found to produce accurate results only at the pitch point. So, by using Finite Element Method, these stresses can be determined with reasonable accuracy. The aim of the current work is contact stress analysis of normal contact ratio gears considering load sharing effect. Contact element method is used for this analysis and the effect of parameters like number of teeth, gear ratio, pressure angle and correction factor on contact stress variation at different points along the line of contact is studied. The FEM analysis shows that with increase in number of teeth, gear ratio and pressure angle, there is a decrease in the maximum value of contact stress.

Krishanu Gupta and Sushovan Chatterjee (2015) studied that the comparison studies of the static stresses for spur gear with different pressure angles. The analyzed results of a symmetric type involute profiled spur gear pair at different pressure angles are compared. Gears are one of the most important and crucial component in a mechanical power transmission unit and also in most of the industrial rotating machineries. Generally, a spur gear pair in action undergoes two types of stresses: the bending stress and the contact stress. In this paper, both these stresses on the gear tooth pair are analyzed using the finite element analysis and are compared. The stresses on the gear tooth are first analyzed using a finite element software and then those results are validated using the conventional formulae for finding stresses in gear tooth.

S.K.Suresh Kumar and S.Navaneethan (2015) studied that the gear contact stress problem has been great point of interest for many years, but still an extensive research is required to understand the various parameters affecting this stress. Among such parameters, helix angle is one which has played a crucial role in variation of contact stress. Numerous studies have been carried out on spur gear for contact stress variation. Hence, the present work is an attempt to study the contact stresses among the helical gear pairs, of different materials such as Steel, Cast iron, Aluminum under static conditions, by using a 3D finite element method. The helical gear pairs on which the analysis is carried are 10, 15, 20, 25 degree helical gear sets. The helical gear contact stress is evaluated using FEA. The FEA results have been further compared with the analytical calculations. The analytical calculations are based upon AGMA equations, which are modified to include helix angle. This approach can be applied to gear design efficiently.

K.Shilpa et al. (2015) investigated that the characteristics of an involute gear system including contact stresses, bending stresses, and the transmission errors of gears in mesh. Gearing is one of the most critical components in mechanical power transmission systems. Transmission error is considered to be one of the main contributors to noise and vibration in a gear set. Transmission error measurement has become popular as an area of research on gears and is possible method for quality control. Current methods of calculating gear contact stresses use Hertz's equations, which were originally derived for contact between two cylinders. To enable the investigation of contact problems with FEM, the stiffness relationship between the two contact areas is usually established through a spring placed between the two contacting areas. This work investigates the characteristics of an Involute helical gear system mainly focused on bending stresses using solid works simulation. The analytical study is based on Lewis formula. It 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 width. Along with results of helical gear, spur gear results calculated and compared.

Putti Srinivasa Rao et al. (2015) studied that the contact stress in the mating gears is the key parameter in gear design. Deformation of the gear is also another key parameter which is to be considered. Gears generally fail when the working stress exceeds the maximum stress. The complex design problem of spur gear which requires fine software skill for modeling and also for analyzing. The project aims at the minimization of both contact stress as well as deformation to arrive at the best possible combination of driver and driven gear. In this process of spur gears mating, 3 different materials were selected and the software programme was performed for 9 different combinations to get the best result possible. The results of the two dimensional FEM analysis from ANSYS are presented. These stresses were compared with the theoretical Hertz's equation values. Both results agree very well. This indicates that the FEM model is accurate.

Sabah Khan (2015) studied that the gears are one of the most critical components in mechanical power transmission systems. Transmission error is considered to be one of the main contributors to noise and vibration in a gear set. Transmission error measurement has become popular as an area of research. To estimate transmission error in a gear system, the characteristics of involute gears were analysed using ANSYS. The contact stresses were examined using 2-D FEM models. The bending stresses in the tooth root were examined using a 3-D FEM model.

Faisal.S. Hussain et al. (2014) studied the failure and causes of spur gear in this work only parallel axis spur gear reduction unit which is the type, probably encountered most often in general practice, and has been considered. A review of relevant literature in the areas of optimized design of spur gear indicates that compact design of spur gears involves a complicated algebraic analysis. A series of iterations is normally required to arrive at a practical combination of pinion teeth and module from their theoretical values.

Alkunte Suhas Suryakant et al. (2014) studied that the gears generally fail when the working stress exceeds the maximum permissible stress. Contact stress analysis between two spur gear teeth was considered in different contact positions representing a pair of mating gears during rotation. These stresses are proportional to the amount of power transmitted while the design could offer favourable or adverse conditions for generation of the same. This dissertation work would identify the magnitude of the stresses for a given configuration of a gear transmitting power while trying to find ways for reducing weight of the gear. The philosophy for driving this work is the lightness of the gear for a given purpose while keeping intact its functionality. The process constraints for manufacturing the gear also need to be considered while recommending alternative/s. Ease of incorporating the new feature for weight reduction over the existing process of manufacturing and the magnitude of volume of mass (or weight) reduced could be considered as the key parameters for assessment for this work.

Prakash Kumar Sen et al. (2014) studied 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.

A.SathyanarayanaAchari et al. (2014) studied that the bending stress at the root of the helical gear tooth and surface contact stresses are computed by using theoretical method as well as FEA. To estimate the bending stress at the tooth root Lewis beam strength method was applied. NX CAD modelling software package is used to create the 3D solid model of helical gear pairs. NX Nastran software package is used to analyze the gear tooth root bending stress. Contact stresses are calculated by AGMA standards. In this also NX CAD modeling software package is used to generate helical gear tooth contact models. NX Nastran software package is used to analyze the surface contact stress.

J. Venkatesh and Murthy (2014) studied the analysis of stresses has become popular as an area of research on gears to minimize or to reduce the failures and for optimal design of gears In this paper bending and contact stresses are calculated by using analytical method as well as Finite element analysis. To estimate bending stress modified Lewis beam strength method is used. Pro-e solid modeling software is used to generate the 3-D solid model of helical gear. Ansys software package is used to analyze the bending stress. Contact stresses are calculated by using modified AGMA contact stress method. In this also Pro-e solid modeling software is used to generate contact gear tooth model. Ansys software package is used to analyze the contact stress. Finally these two methods bending and contact stress results are compared with each other.

JerinSabu et al. (2014) investigated that the helical gears are currently used increasingly as a power transmitting gear due to their relatively smooth and silent operation, large load carrying capacity and their operation at higher speeds. The development of the finite element model for the helical gear pair for monitoring the deformation and stress state of teeth flanks, teeth fillets and parts of helical gears during the tooth pair meshing period. For the investigation of contact problems with finite element method, the stiffness relationship between the two contact areas is usually established through a spring placed between the two contacting areas. This can be achieved by inserting a contact element placed in between the two areas where contact occurs. Initially helical gear pairs are modelled in SolidWorks and then import the IGES file to the ANSYS environment. Thereafter in ANSYS Workbench, nonlinear contact analysis is done. The stresses generated on gear teeth flanks, teeth fillets and parts of helical gears during the tooth pair meshing period are obtained.

A. SathyanarayanaAchar et al. (2014) studied the bending stress at the root of the helical gear tooth and surface contact stresses are computed by using theoretical method as well as FEA. To estimate the bending stress at the tooth root Lewis beam strength method was applied. NX CAD 8.5 modeling software package is used to create the 3D solid model of helical gear pairs. NX Nastran 8.5 software package is used to analyze the gear tooth root bending stress. Contact stresses are calculated by AGMA standards. In this also NX CAD 8.5 modeling software package is used to generate helical gear tooth contact models. NX Nastran 8.5 software package is used to analyze the surface contact stress. Ultimately, these two methods, tooth root bending stress and contact stress results are compared with respect to each other.

Sridhar Goud. B et al. (2014) experimented the main reason of the failure in the gear is bending stresses and vibrations also to be taken into account. But the stresses are occurred due to the contact between two gears while power transmission process is started. Due to meshing between two gears contact stresses are evolved, which are determined by using analyzing software called ANSYS. Finding stresses has become most popular in research on gears to minimize the vibrations, bending stresses and also reducing the mass percentage in gears. These stresses are used to find the optimum design in the gears which reduces the chances of failure. The model is generated by using CATIA and ANSYS is used for numerical analysis. The analytical study is based on Hertz's equation. Study is conducted by varying the geometrical profile of the teeth and to find the change in contact stresses between gears. It is therefore observed that more contact stresses are obtained in modified gears. Both the results calculated using ANSYS and compared according to the given moment of inertia.

AbhijitMahadevSankpal and M. M. Mirza (2014) experimented that the Contact stress refers to the localized stresses that develop as two curved surfaces come in contact and deform slightly under the imposed loads. Also due to contact stresses wear takes place at gear tooth. Wear is nothing but progressive removal of metal from the surface. Consequently tooth thins down and gets weakened. Pitting is a surface fatigue failure of the gear tooth. It occurs due to misalignment; wrong viscosity selection of the lubricant used, and contact stress exceeding the surface fatigue strength of the material. Material in the fatigue region gets removed and a pit is formed. The contact stresses find out by FEM method and experimental method by using the polariscope. And compare the FEM result with experimental result.

Sujit R. Gavhane and S.B.Naik (2014) studied that the gear analyses are multidisciplinary, including calculations related to the tooth stresses and to tribological failures such as like wear or scoring. In this thesis, static contact and bending stress analyses were performed, while trying to design spur gears to resist bending failure and pitting of the teeth, as both affect transmission error. As computers have become more and more powerful, people have tended to use numerical approaches to develop theoretical models to predict the effect. This has improved gear analyses and computer simulations. Numerical methods can potentially provide more accurate solutions since they normally require much less restrictive assumptions. The model and the solution methods, however, must be chosen carefully to ensure that the results are accurate and that the computational time is reasonable.

RajmalSuwalal Jain et al. (2014) experimented that the static contact and bending stress analyses shall be performed, while trying to design spur gears to resist bending failure and pitting of the teeth, as both affect transmission error. The finite element method is very often used to analyze the stress state of an elastic body with complicated geometry, such as a gear. the finite element models and solution methods needed for the accurate calculation of two dimensional spur gear contact stresses and gear bending stresses would be determined. Then, the contact and bending stresses calculated using ANSYS should be compared to the results obtained. The purpose is to develop a model to study and predict the transmission error model including the contact stresses and the torsional mesh stiffness of gears in mesh using the ANSYS software package based on numerical method. The aim is to reduce the vibrations and thereby reduce the amount of noise generated.

P. Marimuthu and G. Muthuveerappan (2014) attempted for a reasonably accurate estimation of optimum profile shifts based on pinion and gear tooth fillet strength for a load at critical loading point considering the load sharing between the gear pair on asymmetric normal and high contact ratio asymmetric spur gear through direct design.

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KetanTamboli (2014) attempted using Particle Swarm Optimization (PSO). The results achieved are satisfactory and helps designer to employ for minimum material and cost by fulfilling the strength and performance requirements.

Raghava Krishna Sameer.B and V.Srikanth (2013) studied one of the main reason of the failure in the gear is bending stresses and vibrations also to be taken into account. But the stresses are occurred due to the contact between two gears while power transmission process is started. Due to meshing between two gears contact stresses are evolved, which are determined by using analysing software called ANSYS. Finding stresses has become most popular in research on gears to minimize the vibrations, bending stresses and also reducing the mass percentage in gears. These stresses are used to find the optimum design in the gears which reduces the chances of failure. The model is generated by using CATIA V5 and ANSYS is used for numerical analysis. The analytical study is based on Hertz's equation.

Yi-Cheng Chen and Chung-BiauTsay (2013) investigated the contact stress and bending stress of a helical gear set with localized bearing contact, by means of finite element analysis (FEA). The proposed helical gear set comprises an involute pinion and a double crowned gear. Mathematical models of the complete tooth geometry of the pinion and the gear have been derived based on the theory of gearing. Accordingly, a mesh-generation program was also developed for finite element stress analysis. The gear stress distribution is investigated using the commercial FEA package.

VishwjeetV.Ambade et al. (2013) studied the analysis of bending stress and contact stress of involute spur gear teeth in meshing. There are several kinds of stresses present in loaded and rotating gear teeth. Bending stress and contact stress (Hertz stress) calculation is the basic of stress analysis. It is difficult to get correct answer on gear tooth stress by implying fundamental stress equation, such as Lewis formula for bending stress and Hertz equation for contact stress. This paper shows the theoretical and numerical approach to calculate bending and contact stress. The results were further compared with ANSYS result to validate.

Dhavale A.S. and AbhayUtpat (2013) studied when gear is subjected to load, high stresses developed at the root of the teeth, Due to these high stresses, possibility of fatigue failure at the root of teeth of spur gear increases. There is higher chance of fatigue failure at these locations. So to avoid fatigue failure of the gear, the stresses should be minimized at maximum stress concentrated area. Design of spur gear can be improved by improving the quality of material, improving surface hardness by heat treatment, surface finishing methods. Apart from this stress also occurs during its actual working. Hence, it is important to minimize the stresses. These stresses can be minimized by introducing stress relief features at stress zone. Many simulation packages are available for checking the different values of stresses. Simulation is doesn't give exact results but gives a brief idea where stresses are induced. Hence, experimental stress analysis method can also be adopted for studying stresses.

Govind T Sarkar et al. (2013) investigated that the bending and surface stresses of gear tooth are major factor for failure of gear. Pitting is a surface fatigue failure due to repetitions of high contact stresses. The 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 modeled 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 for different helical angle, face width are generated by modeling software and simulation is done by finite element software packages. Analytical method of calculating gear bending stresses uses AGMA bending equation and for contact stress AGMA contact equation is used. It is important to develop appropriate models of contact element and to get equivalent result using Ansys and compare the result with standard AGMA stress.

Pushpendra Kumar Mishra and Murthy (2013) studied that the complex design problem of helical gear requires superior software skills for modelling and analysis. The problem can be resolved using MATLAB Simulink environment which provides equivalent results to the AGMA and also with ANSYS. Helical gear modelled on Pro engineer Pro-e software and stress analysis part is done on ANSYS software. The results are compared with both AGMA and FEM procedures.

V.Rajaprabakaran and R.Ashokraj (2013) studied that the gear are commonly used for transmitting power. They develop high stress concentration at the root and the point of contact. The repeated stressing on the fillets causes the fatigue failure of gear tooth. The main objective is to add different shaped holes to reduce stress concentration. A finite element model of Spur gear with a segment of three teeth is considered for analysis and stress concentration reducing holes of various sizes are introduced on gear teeth at various locations. Analysis revealed that aero-fin shaped hole introduced along the stress flow direction yielded better results.

VivekKaraveer et al. (2013) studied the contact stress in the mating gears is the key parameter in gear design. 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 (FEA) are compared with theoretical Hertzian equation values. For the analysis, steel and grey cast iron are used as the materials of spur gear. The spur gears are sketched, modeled and assembled in ANSYS software. As Finite Element Method (FEM) is the easy and accurate technique for stress analysis, FEA is done in finite element software ANSYS software. Also deformation for steel and grey cast iron is obtained as efficiency of the gear depends on its deformation. The results show that the difference between maximum contact stresses obtained from Hertz equation and Finite Element Analysis is very less and it is acceptable. The deformation patterns of steel and grey cast iron gears depict that the difference in their deformation is negligible.

Sumit Sharma et al. (2013) studied that the gears have wide variety of applications. They form the most important component in a power transmission system. The gears generally fail when tooth stress exceeds the safe limit. Therefore, it is essential to determine the maximum stress that a gear tooth is subjected to, under a specified loading. Analysis of gears is carried out so that these can be prevented from failure. When failure occurs, they are expensive not only in terms of the cost of replacement or repair but also the cost associated with the downtime of the system of which they are a part. In order to analyze the exact failure point and the stress levels at which gear is failing, the modeling and stress analysis of the gearbox has been done in Pro-E & ANSYS respectively, taking various constraints and boundary conditions.

RatnadeepsinhM. Jadeja et al. (2013) experimented that the bevel gears are widely used because of their suitability towards transferring power between nonparallel shafts at almost any angle or speed. The American Gear Manufacturing Association (AGMA) has developed standards for the design, analysis, and manufacture of bevel gears. The bending stress equation for bevel gear teeth is obtained from the Lewis bending stress equation for a beam and bending stress value derived for the spiral bevel gear, straight teeth bevel gear and zerol bevel gear. For above mentioned gear comparison between analytical value and value obtain by the ANSYS Workbench.

AniskhanPathan et al. (2012) studied that a spur gear pair dynamic model for the gear dynamic contact loading, dynamic contact stress state and dynamic contact strain state analysis is presented. A dynamic model of the gear set with two degrees of freedom is used. The transmission is analyzed using the nonlinear finite elements method where a novel approach for interpreting the results of the stress and strain state using stress and/or strain tensor invariants is developed. For a more general approach, the software for the finite element analysis of the gear set as a whole is developed, using the open source finite elements framework.

C.Veeranjaneyulu and U. HariBabu (2012) studied the mechanical design and analysis on assembly of gears in gearbox when they transmit power at different speeds i.e- 2500 rpm, 5000 rpm and 7500 rpm. Analysis is also conducted by varying the materials for gears, Cast Iron, Cast Steels and Aluminum Alloy. Presently used materials for gears and gear shafts are Cast Iron, Cast steel. In this paper to replace the materials with Aluminum material for reducing weight of the product. Stress, displacement is analyzed by considering weight reduction in the gearbox at higher speed. The analysis is done in Cosmos software. It’s a product of Solidworks. All the parts of differential are designed under static condition and modeled. Modeling and assembly is done in Solidworks. The detailed drawings of all parts are to be furnished.

Ivana Atanasovska et al. (2012) investigated the dynamic behaviour of helical gears with new standpoint for calculation of influence variables: mesh teeth stiffness, contact lines lengths and load distribution during mesh period. Nonlinear contact Finite Element Analysis and the new iteration procedure are used for calculation of meshed teeth deformations, stiffness and contact loads. The normal load distribution calculated with this procedure is used for evaluation of nonlinear dynamic analytical model of helical gears motion. Described investigation is especially important for gear pairs with high value of transmission ratio, often used in large transport machines. The presented models and results can be used for helical gears modeling when standard procedures don’t cover the requirements.

Sushil Kumar Tiwari and Upendra Kumar Joshi (2012) studied that the analysis of Bending stress and Contact stress of Involute spur gear teeth in meshing. There are several kinds of stresses present in loaded and rotating gear teeth. Bending stress and contact stress (Hertz stress) calculation is the basis of stress analysis. It is difficult to get correct answer on gear tooth stress by implying fundamental stress equation, such as Lewis formula for bending stress and Hertz equation for contact stress. The detailed gear stressing is the key . The design of an effective and reliable gearing system is include its ability to withstand RBS (Root Bending Stress) and SCS (Surface Contact Stress). Various research methods such as Theoretical, Numerical and Experimental are done. But

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use theoretical and numerical methods because Experimental testing can be expensive. In it 3D model of gear and finite element analysis to conduct RBS and SCS calculation for mating involute spur gears. A pair of involute spur gear without tooth modification and transmission error is defined in a CAD system and FEA is done by using finite element software ANSYS. Obtained FEA results is comparable with theoretical and AGMA standard. It is found that Lewis formula and Hertz equation is used for quick stress calculation for gear, whereas the AGMA standards and FEM is used for detailed gear stress calculation for a pair of involute spur gear

Y. Sandeep kumar et al. (2012) experimented that gears are one of the most critical components in mechanical power transmission system. Spur gears are mostly used in the applications varying from domestic items to heavy engineering applications. The contact stress and tooth stresses due to transmission depends on some parameters. In this paper the effect of tip radius, tooth width is considered and how the contact stress results vary with these parameters is studied. The Gear design is optimized based on FE analysis. The stresses were calculated using the Lewis equation and then compared with the FE model. The Bending stresses in the tooth root and at mating region were examined using 3D FE model.

CemalDolicanin et al. (2011) studied that a gear transmission dynamic model for the gear dynamic contact loading, dynamic contact stress state and dynamic contact strain state analysis is presented. A dynamic model of the transmission with four degrees of freedom is used. The transmission is analyzed using nonlinear finite elements contact formulation, using a novel software modules developed by the author used for the generalized analysis of the geared transmissions in the environment of the open source finite elements framework.

M. S. Hebba et al. (2009) studied the possibilities of using the stress redistribution techniques by introducing the stress relieving features in the stressed zone to the advantage of reduction of root fillet stress in spur gear. This also ensures interchangeability of existing gear systems. In this work, combination of circular and elliptical stress relieving features are used and better results are obtained than using circular stress relieving features alone which are used by earlier researchers. A finite element model with a segment of three teeth is considered for analysis and stress relieving features of various sizes are introduced on gear teeth at various locations. Analysis revealed that, combination of elliptical and circular stress relieving features at specific, locations are beneficial than single circular, single elliptical, two circular or two elliptical stress relieving feature.

III.SUMMARY OF PAST RESEARCH

The beam strength of helical gears is an important criterion for its designing as it also decides the force and power to be transmitted. If optimization of various influencing factors like contact ratio, gear ratio, helix angle, face width, module, pressure angle is done considering their combined effects then it will certainly enhance the effectiveness and performance of the helical gear. GA can also solve the objective functions and constraints that are not stated as explicit function of design variables that are hard to be solved by classical methods. Since genetic algorithm method of optimization is easy, effective and time-saving, it must be used by the researchers to optimize various engineering designs. Also we can conclude that the use of GA Toolbox given in MATLAB is easy to use as well as effective for such design optimization problems.

IV. OBJECTIVES OF PRESENT WORK

In this work a helical gear pair design optimization problem is solved. It is a multi-variable, complex non-linear problem with derived objective function and constraints.

- The main objective is to minimize the volume of the gear.
- The design parameters considered are module, face width, number of teeth on drive and driven and helix angle. MATLAB solvers fmincon and GA will be used.
- Simulation results will be analysed and compared to ParidhiRai et al. 2018.industries in manufacturing of vehicles and marine ships.

1. Applications of Helical Gear

Helical gears are used in various fields. Some of the examples are-

1. Most of the reputable industrial gear box suppliers suggest helical gears to work under heavy load efficiency and of course when we need silent operation such as automotive applications.
2. Fertilizer industries, printing industries, and earth moving industries
3. Steel, rolling mills, power and port industries
4. Textile industries, plastic industries, food industries, conveyors, elevators, blowers, compressors, oil industries and cutters.

V. HELICAL GEAR MATERIALS

Material of helical gear depends upon the application. Following are the some general materials used for helical gear manufacturing:- steel, cast iron, stainless steel, brass, aluminium, bronze etc. Cast iron is widely used due to good wearing properties, good mach inability and ease of producing complex shapes by casting method. Steel is used for high strength gears. Phosphorous bronze is used for worm gears to reduce wear.

1. Design Methodology

A heavy duty helical gear pair is considered. Data used are: power to be transmitted = 120 kW, gear ratio = 5.18, pressure angle = 20°, helix angle = 12°, material is case hardened steel (20MnCr5). Using Lewis equation, module is obtained as 14mm. DIN Standards [12, 13] and parameters for pinion, wheel and strength based factors are considered [8]. MATLAB solvers fmincon and GA are used for performing design optimization. In this procedure, module m_n (or x_1), face width, mm (b or x_2), gear teeth on drive and driven (Z_1 or x_3), (Z_2 or x_4) and helix angle, deg (β or x_5) are used as design variables.

Upper and lower bounds of design variables are: $14 \le m_n \le 15$, $50 \le b \le 250$, $25 \le Z_1 \le 56$, $130 \le Z_2 \le 290$, $4^o \le \beta \le 19.5^o$.

VI.CONCLUSION

In this work, a heavy duty helical gear pair is optimized. Objective functions and all constraints are well satisfied. Nature inspired algorithms GA and MATLAB solvers fmincon are successfully applied. The following are the important findings:

- Results obtained by genetic algorithm technique for all generations are almost same for our problem.
- By using GA value of decision variable is module (m_n) = 14 mm, face width (b) = 50 mm, No. of teeth on pinion (Z_1) = 25, No. of teeth on gear (Z_2) = 130 and Helix angle (β) = 4º. Value of objective function that is volume = 1.044×10^{10} mm^3.

VII. FUTURE SCOPE

Global market has brought increasing awareness to optimize gear design. Current trends in engineering globalization require results to comply with various normalized standards to determine their common fundamentals and those approaches needed to identify best practices in industries. This can lead to various benefits including reduction in redundancies, cost containment related to adjustments between manufacturers for missing part interchangeability and performance due to incompatibility of different standards.

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