

Design Optimization of a Spur Gear used in Lathe Machines -A Review Study

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Abstract— Spur gears are an important part of any mechanical engineering component. These are used in applications of power transmissions between two shafts where centre distance between shafts is very less. Gear drives provide higher efficiency than other type of power transmission drives. These are very sensitive in nature too hence a great degree of care must be taken in order to design gears. Current analysis focusses on comparative analysis of spur gears using different kinds of materials other than conventional material of mild steel so that its performance can be improved. In order to conduct the analysis six different materials Aluminium alloy, Gray Cast Iron, Carbon Fibre, E Glass, Epoxy Carbon & Epoxy E Glass have been used. All these materials have been tested on the basis of contact stress being generated. A CAD model of spur gear has been developed in CATIA V5-6 R2017 and Static Structural Analysis has been performed. This data has been compared with numerically solved data. After validation all the materials have been analysed in ANSYS 19.2.

Keywords: Spur Gear, Lathe Machines

I. INTRODUCTION

Gearing is one of the most critical components in a mechanical power transmission system, and in most industrial rotating machinery. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. In addition, the rapid shift in the industry from heavy industries such as shipbuilding to industries such as automobile manufacture and office automation tools will necessitate a refined application of gear technology.

Designing highly loaded spur gears for power transmission systems that are both strong and quiet requires analysis methods that can easily be implemented and also provide information on contact and bending stresses, along with transmission errors. The finite element method is capable of providing this information, but the time needed to create such a model is large. In order to reduce the modelling time, a pre-processor method that creates the geometry needed for a finite element analysis may be used, such as that provided by Pro/Engineer. Pro/Engineer can generate models of three-dimensional gears easily.

While composites have an already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvements in manufacturing technology alone is not enough to overcome the cost hurdle.

II. LITERATURE REVIEW

- 1) Husaini et al. [1] studied about Damage or failure frequently occurs on gearbox gears. If this occurs in the gearbox of tractors, this can be severe. This study aimed to determine the cause of the spur gear fracture through empirical and simulation studies. The hardness test was undertaken employing the Rockwell method where the fracture surface was observed using a scanning electron microscope (SEM) in order to identify crack initiation and the type of fracture. The stress intensity factor was next analysed using the finite element method (FEM). The results of the chemical composition testing indicated that the material used was according to the AISI 8620 standard containing an element of Carbon (C) of about 0.142 %. The hardness value of the gear was 109 HRB. The observation of the fracture surface showed a brittle fracture surface, suggesting that an impact load had occurred. The simulation results using the FEM also showed that the maximum stress intensity factor and KI value occurred at the centre of the tooth. The value of KI was shown to be larger than the fracture toughness and (KIC). Therefore, this result indicates that a crack will continue to propagate until final failure.
- 2) V.A. Gavali et al. [2] studied about gears while transmitting the power generates high stresses. at the mating positions over the teeth as they amend the rate of rotation of machine shaft. The axis of rotation for high-speed machinery is the optimal medium for low energy loss and high accuracy. Toothed spur gears are used to transmit the power with high velocity ratio. Various methods are used to find out contact stresses such as Hertz contact stresses, Lewis bending Equation, AGMA Equation. Most of the research work attempted on mathematical contact stress analysis and compared with finite element analysis. In few papers the work was focused on the stress redistribution technique by introducing the stress relieving features in the stressed zone for minimization of stresses in spur gear. The purpose of this dissertation work is to identify the magnitude of the stresses for a spur gear used in lathe machine for operations such as boring, facing. Various case studies are going to perform. For simulation we are going to use FEA tools such as Hypermesh, Abaqus. For validation we can go for experimental stress analysis i.e., photo elasticity method. Before going for FEA and Experimental we will go for analytical analysis. The contact stresses and deformations obtained by experimentally and compared with the results of FEA.
- 3) Fatmir Azemi et al. [3] studied about Gears are one of the most important 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 CAD software, in this case we have created model in Autodesk Inventor 2015. This model of the spur gears is imported in ANSYS software and then contact stress and bending stress can be calculated in ANSYS. The paper presents the results of calculation of pair spur-gears that it used in the gear-box reduction of the working wheel of the Excavator located in open-cast coal mines, and after that will be optimized the shape of the spur gear with usage of ANSYS software. To be more specific, how much material can be removed from the gear body without compromising the gear meshing properties? Consequently, the aim of this research is to reduce weight of the gears.

- 4) G.C. Mohan Kumar et al. [4] studied about Gear is the most critical component widely used in the transmission of motion and power between shafts. During motion, the gears are loaded, which develops critical bending stress at the root of the gear and also at the point of contact. The loading point "Highest Point Single Tooth Contact" (HPSTC) is the most critical in any gear. The present research work involves a reduction in the weight of gear by optimizing material inside the tooth. This work involves removing material by making holes inside the tooth at different locations with different sizes. The FEM analysis leads to optimizing the material utilization and is carried out using ANSYS APDL tool.
- 5) Putti Srinivasa Rao et al. [5] studied about 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 study in this paper shows that the complex design problem of spur gear which requires fine software skill for modelling and also for analysing. 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.
- 6) El-Sayed Aziz et al. [6] studied about A methodology for the analysis of load distribution and contact stress on gear teeth. which utilizes a combination of closed form solutions and two-dimensional finite element methods, within a constraint-based knowledge-based environment, is presented. Once the design parameters are specified, the complete process of generating the analysis model, starting from the determination of the coordinates of the tooth profile, the creation of a sector of the mating gear teeth, automatic mesh generation, boundary conditions and loading, is totally automated and transparent to the designer. The effects of non-standard geometry, load sharing on the contact zone, friction and root stresses are easily included in the model.

The Finite Element Method (FEM) based results compare favourably with those obtained from closed form solutions (AGMA equations and classical Hertzian contact solution). The advantage of the approach rests in the ability to modify any of the gear design parameters such as diametral pitch, tooth profile modification etc., in an automated manner along with obtaining a better estimation of the risks of failure of the gear design on hand. The procedure may be easily extended to other types of gearing systems.

- 7) Deepika Potghan et al. [7] studied about This paper deals with the reduction of contact stresses of the spur gear and pinion used in headstock of a lathe machine. its introducing stress relieving feature of different shapes i.e., circular hole, elliptical hole and aero fin hole. In this paper the stress analysis of mating gears of the spur gear with three different materials is done to determine the contact stresses generated in the gear teeth. In the previous paper the results obtained from Finite Element Analysis (FEA) using Ansys are compared with the values obtained from theoretical Hertzian equation. The materials of spur gear used for analysis are grey cast iron, high carbon steel and medium carbon steel. In this paper the stresses which were calculated has been reduced by introducing stress relieving feature of different shapes. It was found that Stress relieving feature having the shape of aero- fin yielded better results when compared to elliptical and circular holes.
- 8) Vrushali Wable et al. [8] studied about Gear is most effective part of transmission system due to efficiency and reliability. Gear is used for high load in machine tools. These gears are continuously operated under specified conditions. If gear failure occurs, it is due to pitting failure and scoring failure. In this paper, pitting failure has been studied for a gear. Modelling of gears in CATIA V5 is done by parametric formulation. The gear is analysed in ANSYS for deformation and max contact stress which causes pitting. Experimental Analysis is done using photo elastic method on photo elastic apparatus.
- 9) Prafulla M. Chor et al. [9] studied about the gears are used for a wide range of industrial applications. They have varied application starting from textile looms to aviation industries, automobile gear box and machine tool application to transmitting the power. Their function is to convert input provided by prime mover into an output with lower speed and corresponding higher torque. Spur gears are used to transmit the power up to velocity ratio is ten. This phase they induce high stress at the point of contact. A pair of teeth in action is generally subjected to contact stresses causing fatigue failure of gear tooth. The main purpose of this study is to reduce the contact stress of gear by increasing the module of gear. One Spur gear train is selected for analysis. The Contact stress of existing gear train is calculated and compared with fatigue strengths of gear material. If this stress on gears is higher than fatigue strengths mean gears are failed due to fatigue. To reduce the contact stress by increasing the module of gear. The contact stress is calculated by Hertz's Equation and Strain gauge

- is used for the experimental investigation of the stress field.
- 10) Xiaohe Deng et al. [10] studied about A design method for the geometric shape and modification of asymmetric spur gear. this geometric shape and modification of the gear can be obtained directly according to the rack-cutter profile. In the geometric design process of the gear, a rack-cutter with different pressure angles and fillet radius in the driving side and coast side was selected, and the generated asymmetric spur gear profiles also had different pressure angles and fillets accordingly. In the modification design of the gear, the pressure angle modification of rack-cutter was conducted firstly and then the corresponding modified involute gear profile was obtained. The geometric model of spur gears was developed using computer-aided design, and the meshing process was analysed using finite element simulation method. Furthermore, the transmission error and load sharing ratio of unmodified and modified asymmetric spur gears were investigated. Research results showed that the proposed gear design method was feasible and desired spur gear can be obtained through one-time rapid machining by the method. Asymmetric spur gear with better transmission characteristic can be obtained via involute modification.
 - 11) Miss. Kachare Savita et al. [11] studied about the spur gear design. A designer of modern gear drive system must have to remember that the main objective of gear drive is to transmit higher power with comparatively smaller overall dimensions of the driving system which can be constructed with minimum possible manufacturing cost, runs reasonably free of noise and vibration and which requires little maintenance. In this paper single stage spur gear train and helical gear train with an idler gear are designed by American Gear Manufacturing Association (AGMA) standard. An idler gear is placed between two gearwheels to obtained the same direction of rotation. AGMA stress equation is used to determine the tooth bending strength and surface contact strength. As a result, dimensions of gears are finding out and comparative study is carried out to select the optimum design of gear train for a given input parameter.
 - 12) Ms. Nilescha U. Patil et al. [12] studied about Gears are machine elements used to transmit motion and power between rotating shafts it means progressive engagements of projections. Gears have wide variety of applications. Their application varies from watches to very large mechanical units like the lifting devices and automotive. Engineering components made of composite materials find increasing applications ranging from space craft to small instruments. It is possible that gears will predominate as the most effective means of transmitting power in future machines due to their high degree of reliability and compactness. The main objective of the present work is to investigate Finite Element Analysis of the spur gear pair for different material in ANSYS software. In this paper A review has been taken for case-I purpose is to design the spur gear and study the weight reduction and stress distribution for cast steel and composite materials and results are observed. And in case-II Static analysis is performed to determine the deformation and Von-mises stresses. Analysis is done by considering different materials for gears like Structural Steel, Gray Cast Iron, Aluminium Alloy and Epoxy E Glass UD, and results are compared.
 - 13) Fatih Karpat et al. [13] studied about Gears are one of the most crucial parts of power transmission systems in various industrial applications. Recently, there emerged a need to design gear drivers due to the rising performance requirements of various power transmission applications, such as higher load-carrying capacity, higher strength, longer working life, lower cost, and higher velocity. Due to their excellent properties, gears with asymmetric teeth have been designed to obtain better performance in applications. As the rotation speed of the gear transmission increases, the dynamic Behaviour of the gears has become a subject of growing interest. The most important contributing factor of dynamic Behaviour is the stiffness of the teeth, which changes constantly throughout the operation. The calculation of gear stiffness is important for determining the load distribution between the gear teeth when two sets of teeth are in contact. The primary objective of this article is to develop a new approach to calculate gear mesh stiffness for asymmetric gears. With this aim in mind, single tooth stiffness was calculated in the first stage of the study using a finite element method. This study presents crucial results to gear researchers for understanding spur gears with involute asymmetric teeth, and the results will provide researchers with input data for dynamic analysis.
 - 14) Sameer Chakravarthy N C et al. [14] studied about the gear fitted in the gearbox Armoured tracked vehicle. It is vulnerable to considerable fatigue damage over its life period due to the dynamic excitations caused by the terrain undulations, the rotating wheel and track assemblies. For this purpose, initially static analysis of the model was carried out to validate the model and the boundary conditions correctness. Further Modal analysis is carried out to determine the dynamic characteristics of the gear model. The random load time history is transformed in to frequency domain using Fast Fourier transform to obtain load Power Spectral Density (PSD). Then the stress PSD response is obtained at critical node from the random vibration analysis. Once the spectrum of stress variation is obtained given input to the fatigue analysis and fatigue life is determined by FE package ANSYS 11.0.
 - 15) P. B. Pawar et al. [15] studied about The Spur gears are simplest and widely used in power transmission. In recent years it is required to operate machines at varying load and speed. Gear teeth normally fail when load is increased above certain limit. Therefore, it is required to explore alternate materials for gear manufacturing. Composite materials provide adequate strength with weight reduction and they have emerged as a better alternative for replacing metallic gears. In this work metallic gears of steel alloy and Aluminium Silicon carbide composite have been manufactured. Composites provide much improved mechanical properties such as better strength to weight ratio, more hardness, and hence

less chances of failure. So, this work is concerned with replacing metallic gear with composite material so as to improve performance of machine and to have longer working life. Efforts have also been carried out for modelling and finite element analysis of gears using ANSYS 14.0. Composite gears have been manufactured by stir casting, which is economical method. Composite gears offer improved properties over steel alloys and these can be used as better alternative for replacing metallic gears.

III. CONCLUSIONS

One can clearly analyse from the reviewing the literature already available that a lot of analysis work has been done for spur gears. Analysis has primarily been focused on optimizing the design of spur gears using different types of materials. Mostly composite materials have been preferred for optimization of spur gears but aluminium and its alloy may also provide better results. One other important aspect of analysis in case of spur gear is that all the analysis has mainly focused on contact stress or bending stress as the major component on which the design optimization is primarily based.

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