

A Review of Gear Parameters Optimization

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Abstract— Gearing is one of the most effective methods for transmitting power and rotary motion from the source to its application with or without change of speed or direction. Gears are mostly used to transmit torque and angular velocity from one shaft to another shaft. The less efficiency of gear box of a machine tool is a serious problem as it increases maintenance cost and also affects the reputation of a firm. Hence its life has to be increased and should be made more reliable. Optimization plays an important role in gear design as reducing the weight or volume of a gear set will increase its service life and improve the bearing capacity. The method of optimum design is effective in the field of gear research to determine the optimum gear parameters for satisfactory design. In gear design, number of parameters is involved. The gear design also requires an iterative approach to optimize the gear parameters. The alternative for the above problem is to design and optimization of a worm gear box which reduced maintenance and improved reliability, lack of lubrication requirements, precise peak torque transmission, inherent overload protection, physically isolated input and output shafts, misalignment tolerance, and low acoustic noise and vibration etc. And also it is multi-objective function with constraints is very difficult to optimize using conventional optimization techniques, used non-traditional optimization technique called Genetic algorithm. Genetic Algorithm is used for determining the best possible combination of gear parameters. A review of relevant literature in the areas of optimized design of gear indicates that compact design of gears involves a complicated algebraic analysis

Keywords — Gears, Spur Gear, Spiral Bevel Gears, Hypoid Gears, gear design.

Introduction

Gears are compact, positive-engagement, power transmission elements that determine the speed, torque, and direction of rotation of driven machine elements. Gear types may be grouped into five main categories - Spur, Helical, Bevel, Hypoid, and Worm. Typically, shaft orientation, efficiency, and speed determine which of these types should be used for a particular application.

Gears have wide variety of applications. They form the most important component in a power

transmission system. Advances in engineering technology in recent years have brought demands for gear teeth, which can operate at ever increasing load capacities and speeds. The gears generally fail when tooth stress exceeds the safe limit. Therefore, it is essential to explore the alternate Gear material. The important considerations while selecting a Gears material are the ability of the Gear material to withstand high frictional temperature and less abrasive wear. Weight, manufacturability and cost are also important factors those are need to be considered during the design phase. Moreover, the Gear must have enough thermal storage capacity to prevent distortion or cracking from thermal stress until the heat can be dissipated. It must have well anti fade characteristics i.e. their effectiveness should not decrease with constant, prolonged application and should have well anti wear properties.

The design of gears is a highly complicated task, and the need to develop light weight, quiet and more reliable designs has resulted in a variety of changes in the design process. Identifying the best design using graphical methods becomes tedious once the number of design variables exceeds two. Therefore, a more general and systematic approach to gear design is desirable.

Eliminating lubricant in geared systems is both cost-saving and environmentally sound, but does pose some technical challenges. Metal-to-metal contact of tooth surfaces sliding and rolling against each other under contact pressure causes high tooth temperature that may result in material microstructure changes. Tooth surfaces can severely wear away and even deform plastically. Tooth-sliding velocity and contact pressure can be reduced by changing the gear design

All over the world, more and more gears are manufactured by injection moulding with plastic, sintering using metallic powders or through shaped grinding of the steel or by the gashing method. Therefore, several restrictions can be omitted which occur when the gears are produced by the hob method or conventional gear grinding methods. New possibilities open up for the optimization of the gear with regard to operating noise, meshing and strength characteristics. With the support of suitable software, the calculation and optimization of such gears can be done without any problems. That opens new horizons to improve gears.

The following tendencies will be more pronounced in the future:

Metals will be increasingly substituted by plastics
significant reductions in gear noise and vibration
Increase of the performance density (smaller models for same performance)

Use of special tooth forms (non-involute toothing)

Spur gears are the most common type of gear they have straight teeth and are mounted on parallel shafts. The main reason for the popularity of spur gears is their simplicity in design, easy manufacturer and maintenance. However due to their design spur gears create large stress on the gear teeth. The development and use of optimization models is well established.

A worm is an example of a screw, one of the six simple machines. A gearbox designed using a worm and worm-wheel will be considerably smaller than one made from plain spur gears and has its drive axes at 90° to each other. Worm gear configurations in which the gear cannot drive the worm are said to be self-locking. Whether a worm and gear will be self-locking depends on the lead angle, the pressure angle, and the coefficient of friction; however, it is approximately correct to say that a worm and gear will be self-locking if the tangent of the lead angle is less than the coefficient of friction.

The worm and worm gear drive is never 100% efficient as there is always some power loss due to the friction (rubbing action) between the worm and worm gear. The factors have an impact on the friction and therefore, the efficiency of a drive includes Backlash, Lubrication, Speed of worm, Material of worm and gear, Load, Finish of surface on worm thread, Accuracy of cutting worm and gear and Lead angle of worm. Worm and Worm Gearbox are used in the places like Double Disc Surface Grinding Machine, Presses Rolling mills, Conveying engineering, mining industry machines.

Product development has changed from the traditional serial process of design, followed by prototype testing and manufacturing but to more on computer aids. Developments in Computer aided engineering has taken at a rapid pace have really influenced the chain of processes between the initial design and the final realization of a product. Ability of CAE software's on product designing, 3d visualization, analysis, simulation has impacted a lot on time and cost saving to the industry. This transformation has had a vast influence on manufacturing as well, providing process improvement that lead to higher quality and lower costs. The procedure needed to develop gear for a new product can require months of trial-and-error work. In view of increasing global competition for lower priced products, bevel gears are a prime target for the next generation of computerization. This review article will provide some fundamental information pertaining to gear development, procedure, techniques and optimization of Gear to

achieve maximum quality while substantially lowering development costs.

I. REVIEW OF LITERATURE

A. Spur Gear

In this paper Faisal S et al (2014) explained the parallel axis spur gear reduction unit which is the type, probably encountered most often in general practice. Optimized design of spur gear indicates that compact design of spur gears involves a complicated algebraic analysis. The author describes the development of such a design methodology and diagnostic tool for determining the modes of failure for spur gear and also the causes of the failures. The ray diagrams are incorporated to make the design more feasible with respect to the transmission ratio and number of teeth used in gearbox. The mode of failure curve in a design space shifts quite appreciably as torque increases. Further the author explains the mode of failures curves is not showing any change in the behavioural pattern when the pressure angle is changed and the large pressure angle gears have smaller value of pinion teeth. This clearly indicates that the lower number of teeth rather than the higher module which reduces the size of gear sets [1]. Jian Chen et al (2014) discusses about the feature of involute gear. According to the design principle of involute gear cutter, the index able gear insert with three cutting edges is designed. The milling FEM of index able gear insert is built in Deform 3D software, the FEA milling is analysed with different relief angle and the best relief angle is 6°. Considering cutting force and processing efficiency, the optimal cutting speed is 186.83mm/min and cutting depth is 2.5mm, which the relief angle of index able gear insert is 6° [2]. R.Thirumurugan and G.Muthuveerappan (2011) calculated maximum contact and fillet stress for normal and high contact ratio gear. The research is based on load contact ratio implementing finite element method and performed for single point load model and multipoint contact model. The effect of various gear parameters such as pressure angle, teeth number, gear ratio, tooth size and addendum on the load sharing ratio and corresponding stress was investigated. Calculation of maximum fillet and contact stress in the case of normal contact ratio gear and high contact ratio gear using the load sharing ratio was performed [3].

R.P.Sekar and G.Muthuveerappan (2014) explained the maximum stress on the gear and the pinion at the fillet section is unequal. By removing the maximum fillet stress the load carrying capacity of the gear can be increased. The performance of the gear can be improved by designing the gear with uniform fillet stress which is the replacement of unbalanced fillet stress. Changing the tooth thickness of basic racks from non-standard tooth thickness to standard one,

uniform fillet strength can be achieved [4]. Marimuthu, G. Muthuveerappan (2014) analysed the effect of the module, gear teeth and addendum height on the load sharing and corresponding stress. In order to calculate stress due to applied load at highest pressure angle, they developed a multi-point contact model for finite element analysis. For the parametric study, they developed ANSYS parametric design language code. It was seen that in the application of load at the critical loading point, an increase in addendum height increases the bending stress. On the contrary, Increase in module and number of teeth favourably decreases the bending stress [5]. Marunic (2012) explains the deformation in the middle web of thin rimmed involute spur gear in mesh with solid spur gear is expressed in the form of displacement as non-dimensional form is analysed. It is concluded that the comparison of maximum rim and web displacements shows that rim deforms considerably more than the web. This result additionally spurred to the necessity of approach that fully respects the actual gear structure and the contribution of every part that the gear teeth are supported [6]. Yallamti Murali Mohan and T.Seshaiah (2013) have studied the optimization of spur gear using genetic algorithm. The design variables for spur gear set are module, face width and number of teeth on the pinion, minimizing the centre distance, weight and tooth deflection of gears are taken as the objective function and subjected to constraints such as bending stress and contact stress. The proposed algorithm does not require gradient information of the objective function, which makes it very attractive. The results of proposed algorithm have been compared to those of the traditional techniques, such as, graphical technique, geometric programming, etc for solving the same problem and proposed traditional techniques [7]. Carlos H. Wink and Nandkishor S. Mantri (2012) explained about the gear design optimization. The predicted tooth contact temperature using LDP and the temperature estimated from micro hardness and material tempering curve is obtained for an existing gear set which is tested at high speed and without lubrication. The gear design is then optimized using both the RMC and LDP programs. The main reason for the reduction in contact temperature of the optimized design is due to the slip-to-roll ratio reduction, which is proportional to the reduction in temperature. The low contact temperature of the optimized design can significantly contribute to prevent tooth surface damage under no-lubricant operating conditions; this will be confirmed through dynamometer endurance testing [8].

B. Spiral Bevel Gears

Karlis Paulins et al (2014) developed spiral bevel gear with improved design of gear blanks with optimised tooth ends. It is possible to optimise

rectangular-generated, spiral bevel pinion/gear pairs with constant tooth height and a common pitch cone apex. The work successfully achieved the recalculation of the gear blanks, without any changes in the flank geometry or tooth-cutting process. When the mating pinion is designed without a complementary front cone, it is pointless to design the gear with a complementary back cone. More suitable geometry for modern machining and checking of blanks, due to the inclusion of chamfer-type surfaces in the basic design. Scientifically justified simplification of the gear blank geometry is directly related with the decrease of manufacturing time and related production costs. Taking into account scale and number of the spiral bevel gears produced today for consumer needs, such optimization would provide enormous economic benefits related not only to the reduction of the actual production costs but also to considerable increase of the life span of the gear transmissions [9]. Jihui Liang, 2lili Xin (2013) explained the dynamic simulation of spiral bevel gears. Mechanical properties of spiral bevel gear have significant influence on the whole mechanical structure and play an important role in the system optimization, strength check, fault diagnosis and fault prediction. The gear tooth meshing and dynamic load is an important issue in the gear research field. The precise modelling of spiral bevel gear is based on SOLIDWORKS software and virtual prototype of gear meshing parameterization is realized through ADAMS. By introducing Hertz contacting theory into simulation module and impose contacting force actively between main reducer and driven gear the simulation can be done. The result is in accordance with theoretical calculating results and simulation further verifies that stiffness excitation and meshing impulse excitation could produce cyclical fluctuation. This method could serve as reliable basis for strength check, optimization, vibration and noise analysis of spiral bevel gear transmission system [10]. Christian Brechera et al (2016) showed the potential of optimization for face-milled bevel gears. The comparison of the measured and the simulated TE showed that the FE-based tooth contact analysis ZaKo3D is capable of giving a good agreement between simulations and testing. The requirement is that the scatter of the topography is known and, if necessary, considered in the simulation. Therefore, the method is applied for an exemplary gear set. Two variants are investigated, a ground target topography is calculated and as well a variant with a scatter in the topography deviations. The topography scatter is derived from a possible lapping process, but can be also applied on purpose in the grinding process. By applying the micro geometry scatter from tooth to tooth, the results of the TE calculation show that the amplitudes of the tooth mesh frequencies decrease. In parallel, the amplitudes of the frequencies in between the tooth mesh

frequencies are rising. The TE of the ground reference shows a tonal distribution. The averaged order spectrum of the variant with the topography scatter shows increased background noise but the tooth mesh orders are clearly reduced. The results of the speed ramp simulations show that by applying a scatter of the topography on the flank, the amplitudes of the TE can be reduced [11]. Xiang Tieming et al (2015) did the free modal analysis for spiral gear wheel based on Lanczos method. In order to obtain the spiral bevel gear wheel natural frequencies and mode shapes in the unconstrained state for the purpose of dynamic characteristics study. In order to verify the effectiveness of the finite element analysis results, the experiment modal test based on the impulse force hammer percussion transient single-point excitation and multi-point response analysis method has been done. The maximum difference value of natural frequency between experimental modal test result and finite element modal analysis results is 29.86 Hz, the maximum error rate is 0.41%, which confirmed the result of finite element method is effective and reliable. The three-dimensional solid model of spiral bevel gear wheel is established in the UG NX environment, and the finite element model of spiral bevel gear wheel is built after the definition of material property parameters and grid meshing on the ANSYS Workbench platform. The free modal analysis of spiral bevel gear wheel has been done by using the Lanczos method for iterative calculation, the real first 4 orders of natural frequencies of experimental test for spiral bevel gear wheel are 2787.48 Hz, 3522.95 Hz, 7146.12 Hz, 7260.76 Hz respectively by free modal experimental test. The relative error rate of extraction for natural frequencies by using finite element modal analysis based on the Lanczos method [12].

C. Straight Bevel Gear

Saman Khalilpourazary et al (2011) designed the straight bevel gear by forging process method. In the present work, hot precision forging process of the straight bevel gear is simulated numerically using finite volume method and computer-aided design/computer-aided engineering technology. The required force for the forging process, as well as the final shape of the bevel gear, is determined through numerical estimation. The simulation results are confirmed through the comparison with the experimental data available in DIN standards. The finite volume method is both fast and accurate since the material flow calculations are performed on an under formed finite volume mesh, and it is robust since re-meshing techniques are completely eliminated. The forging process consists of two pre-form dies and a final die. The forming loads obtained from the simulations are compared with their experimental counterparts available in DIN standards, thereby good agreements are achieved.

After the simulation results are confirmed, the high-quality straight bevel gears are manufactured. It is concluded that this method can be effectively used to identify and rectify the potential defects such as laps and under-fill of die cavities before part production begins and hence reduce the overall time and cost of the manufacture (13).

D. Worm Gear

Rushil H. Sevak and Saurin Sheth (2014) suggested that before making gearbox, verification of its work, performance, efficiency, which effects gearbox performance, is necessary. DOE techniques are used to achieve desired design of gearbox for control of temperature and noise levels. The following parameters such as input speed, back lash, axial play of pinion, output shaft and oil viscosity are very crucial for the gearbox noise and the oil temperature. By optimizing input parameter the life of the gearbox can be increase [14]. Wen qingming et al (2010) discovered the shortage of the traditional "modification" theory, and then a research method of new modification principle is brought forward. Accordingly, the principle of curvature modification is established and the effect of the curvature modification theory is also analysed. From research and analysis, the curvature modification principle solves the long time unsolved problem in the modification of toroidal worm-gearing. The new toroidal worm gearing modified on the principle of curvature modification have higher carrying capacity and transmission efficiency than the traditional toroidal worm-gearing. From the experiment higher bearing ability and transmission efficiency can be achieved [15]. All references should be cited appropriately in the text. When citing, use the convention on the number of authors and the year; for an example, (Wilson, 2002), (Wilson & Smith, 2002), (Wilson et al., 2007), etc. For citing from books, try to include the page number whenever possible; Wilson (2002, p.15), for an example. Follow the appropriate referencing style and list alphabetically at the end. Please try to use accurate information on references, as it helps reviewers and readers. It is authors' responsibility to facilitate the Journal Editors to maintain the quality of the blind review process. Prakash D Patel and J.M.Patel (2012) studied the influence of a variety of operating conditions on the power losses and efficiency of an automotive manual transmission through experimental investigation. The experimental methodology is developed to measure power losses of a manual transmission under both loaded and unloaded conditions while all operating parameters are controlled tightly. A set of fixtures and instruments are designed and implemented for a five-speed manual transmission system of a front-wheel-drive passenger vehicle. Experimental parametric studies were performed to quantify the influence of operating conditions including load, oil

viscosity and oil volume on load-dependent (mechanical) and load-independent (spin) power losses of the transmission. Analysis of the power loss data revealed that all three of these parameters influenced the components of the transmission power loss significantly, and specific conclusions were drawn in order to aid attempts to increase overall transmission efficiency [16]. Bernd-Robert Höhn et al (2010) studied different methods which influence the power loss reduction. No load losses can be reduced at low temperatures and part load conditions when using low viscosity oils with a high viscosity index and low oil immersion depth of the components. This in turn influences the cooling properties in the gear and bearing meshes. Overall reduction of the gearbox losses in average of 50 % is technically feasible. There is a comparison of the no load losses of different bearing types, for same load capacity $C = 20$ kN. The lowest no load losses of radial bearings are expected for cylindrical roller bearings. They also have low values of taper roller bearings which are valid for unloaded bearing arrangements [17].

E. Hypoid Gears

Achtmann J et al (2003) investigated the relationship between the contact pattern and the so-called modified motions. The two coefficients of the linear terms of modified roll and helical motion is employed for formulating an optimization problem aimed at having the contact pattern match the target one. Although this method is quite systematic, the heavy computational burden required to model the response surface practically limits the number of design parameters [18]. Simon V (2005) investigated the direct dependence of each of four tool parameters on the contact properties, and then selected the compromise values of such parameters corresponding to a decrease in both the maximum contact pressure and the peak-to-peak transmission error. Further investigation involving all the parameters of a modern computer numerically controlled CNC hypoid generator would entail a prohibitive amount of calculation, especially if cross-dependencies are considered [19].

F. Hall Effect Gear

In this work, the author analysed the optimization of Hall Effect gear tooth speed sensors. From the experiments results of sensor optimization, it shows that the sensing gap/distance of Hall Effect Gear Tooth sensors can be improved by using differential magnetic field detection. In this case the sensing gap of single output sensors is 2.5 times of that by using peak magnetic field detection. For dual output sensors the sensing gap/distance depends not only on the magnetic field detection method but also on the distance between the two Hall ICs. The duty cycle of Hall Effect gear tooth sensors depends on the geometric duty cycle and tooth shape of the target

wheel and the magnetic field detection method. The phase drift of dual output sensors can be determined by the mathematical model more accurately if the sensors are made according to differential magnetic field detection and by using a smaller distance between the two Hall GTSICs.

G. Harmonic Gear

Bo Zeng et al (2012) studied the optimization of Harmonic gear by Genetic Algorithm. According to the optimization design results, it illustrates effectiveness of hybrid genetic algorithm to deal with engineering problems. At the same time, this method can provide theoretical foundation for the optimization of harmonic gear [20].

H. Helical Gear

Dipesh Patel R. G et al (2015) studied the optimization of the bending strength of Helical gear is to be maximized for fixed center distance and fixed weight of gearbox, and also fulfilling the certain necessary requirements. Due to the complexity of the problem, it is complicated and time consuming to optimize. MATLAB is used for determining the best possible combination of gear parameters and comparison of this result is made with ANSYS results. When in optimized design the bending stresses the gears are within the permissible limit. Hence the design is safe against the bending fatigue failure and surface fatigue failure. And also he concluded that the overall bending stress in the optimized gear design is reduced by 22.28 % compared to existing design. The center distance between input and output shaft is reduced by 12.72 %. And the material volume increase by 0.97%, hence the weight of gearbox is increase by 0.97%, but it is negligible. Genetic algorithm is important tool for optimization of complex problem [21]. Wei Feng and Lin Hua (2011) have explained the optimization method for the helical gear precision forging. It is proposed based on the finite element method (FEM) and Taguchi method with multi-objective design. The maximum forging force and the die-fill quality are considered as the optimal objectives. The optimal parameters combination is obtained through S/N analysis and the analysis of variance (ANOVA). The significant forming parameters affecting the helical gear warm forging process such as deformation temperature, friction coefficient, and punch velocity can be easily recognized by performing the experiments which are designed based on the orthogonal array of the Taguchi method. Deformation temperature and friction coefficient affect the helical gear warm forging process greatly regardless of case 1 to 3, they contribute about 86% together, while punch velocity does not affect the helical gear warm forging process too much, it only contributes

about 5%, and interaction between deformation temperature and punch velocity has little effect on the helical gear warm forging process. For a given helical gear forming process, the optimal combination of process parameters can be determined through the modified Taguchi method to obtain the minimum values of the maximum forging force F_{max} and the minimum distance D_{min} . The optimal process parameters were confirmed with confirmatory experiments [22]. Ping WANG et al (2010) studied the weight reduction design of gear drive based on parameter and structural optimization. The drive ratio and gear parameters are determined based on the multi objective optimum design with minimizing the SGV and the EMI synchronously. Reducing the EMI is of significance for the drive motor to save energy. For gears requiring former design, structural topology optimization can be adopted to further reduce the moment of inertia and the gear weight, thus further reduce the EMI in the drive system. The conceptual design of the gear former is proposed by topology optimization, and the reasonability of structural topology optimization of the gear can be determined by structural static and dynamic analysis using FEM. The loading mode for structural topology optimization of the gear, dynamic analysis and experiments of gear drive system of WRD still require further study [23]. Gregory Hyatta et al (2014) reviewed the strategies with the gear production. It is obvious that 5-axis and turn-mill CNC machines can support a wider range of gear cutting solutions then dedicated and single-purpose gear cutting machines. This agility is attractive for various business models and it does not need compromises in quality and productivity. In fact we have observed that in some cases the agile machines offer even higher productivity, and higher quality levels. As a result the selection of capital equipment for gear production must be based on thorough investigation of application-specific solutions if agility is to be pursued without compromise in productivity or quality [24].

III. CONCLUSION & FUTURE SCOPE

From the literature it seems that the input speed, back lash, axial play of pinion and output shaft, oil viscosity are very crucial for the gearbox noise and temperature of oil. Also models will be developed to predict oil temperature and noise in context by input parameters. By optimizing input parameters, life of the gearbox will be increase. After study of many research papers and market survey, should improve the torque improvement, lead angle improvement, reducing backlash and proper bearing and lubricant selection which influences the gearbox life and efficiency. As compared to the conventional

methods which use a single design point, Genetic Algorithm use a population of points and gives the global results when compared to the classical method of optimization. Further work could be directed in the direction of optimization of gear parameters using genetic algorithm producing high quality and cost effective products.

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