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Research Article

A Review on Optimum Profile Modification of Spur Gear

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Abstract

This paper represents a review on modification of spur gear design using different optimization technique. Gearing is most important for mechanical power transmission system. Gear design involves choosing of specific design, specific character, specific material, analysis of force and mechanical properties. The main purpose of spur gear design is to reduce transmission error and improves efficiency of power transmission system. Optimization is used to get optimal design parameters to maximize the power transmitting capacity of mechanical system.

***Keywords**: Spur gear, Optimization, Transmission error, optimal design, etc.*

1. Introduction

Gears are machine elements used for mechanical power transmission system. In actual practical there is always error occurred in transmission which is known as transmission error. Due to transmission error noise is radiated from gear. Many authors are studying the different ways to reduce the transmission error to get maximum power transmission efficiency of mechanical system. One of the methods for reducing transmission error is profile modification of gears. Profile modification of spur gear can be done by three ways. Following are three ways for profile modification

(1) macro-geometry modification
(2) micro-geometry modification and
(3) Surface finishing.

Macro-geometry modification consists of getting optimum number of teeth, diameters, pressure angle, backlash and clearance. Many authors studied the effect of the average number of teeth in contact for both spur and helical gear vibrations.

Micro-geometric modifications consist of removing material from the gear teeth flanks for reducing teeth deflection under specific load hence transmission error is minimized for specific torque. In short intentional removal of material for getting optimum profile for specific load means micro-geometric modification.

Another way for reducing transmission error is surface finishing and strict manufacturing tolerance which also result in reduction of gear vibrations. Manufacturing profile errors are considered as a possible source of unwanted vibration. Indeed, teeth quality such as surface roughness, surfaces finishing and tolerance can play a significant role: their improvement can lead to a reduction of radiated noise. Macro-geometric modifications involve important changes of gear pair as well as the other members of the gear train hence these changes are expensive and these changes only possible in first stage of gear design. High-quality surface finishing and strict tolerances also result in high manufacturing costs as well as their effect on vibrations is very small. Therefore, the micro-geometric optimization is getting high attention.

2. Basic terms of spur gear

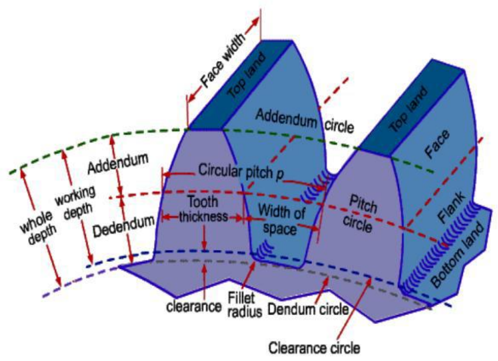

Fig.1 Involute Spur gear

Pitch surface: The surface of the imaginary rolling cylinder that the toothed gear may be considered to replace.

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Pitch circle: A right section of the pitch surface.
Addendum circle: A circle bounding the ends of the teeth, in a right section of the gear.
Root (or dedendum) circle: The circle bounding the spaces between the teeth, in a right section of the gear.
Addendum: The radial distance between the pitch circle and the addendum circle.
Dedendum: The radial distance between the pitch circle and the root circle.
Clearance: The difference between the dedendum of one gear and the addendum of the mating gear.
Face of a tooth: That part of the tooth surface lying outside the pitch surface.
Flank of a tooth: The part of the tooth surface lying inside the pitch surface.
Circular thickness (also called the tooth thickness) : The thickness of the tooth measured on the pitch circle. It is the length of an arc and not the length of a straight line.

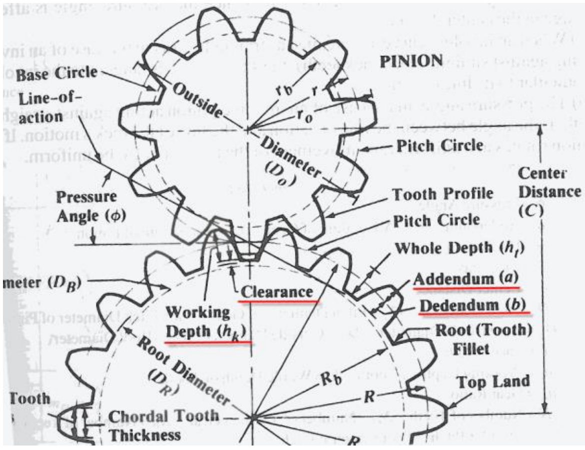

Fig 2. Working Gear Nomenclature

Tooth space: The distance between adjacent teeth measured on the pitch circle.
Backlash: The difference between the circle thickness of one gear and the tooth space of the mating gear.
Backlash =*Space* width – Tooth thickness
Circular pitch p: The width of a tooth and a space, measured on the pitch circle.
Diametral pitch P: The number of teeth of a gear per inch of its pitch diameter. A toothed gear must have an integral number of teeth. The circular pitch, therefore, equals the pitch circumference divided by the number of teeth. The diametral pitch is, by definition, the number of teeth divided by the pitch diameter.
Module m: Pitch diameter divided by number of teeth. The pitch diameter is usually specified in inches or millimeters; in the former case the module is the inverse of diametral pitch.
Fillet : The small radius that connects the profile of a tooth to the root circle.
Pinion: The smaller of any pair of mating gears. The larger of the pair is called simply the gear.
Velocity ratio: The ratio of the number of revolutions of the driving (or input) gear to the number of revolutions of the driven (or output) gear, in a unit of time.
Pitch point: The point of tangency of the pitch circles of a pair of mating gears.
Common tangent: The line tangent to the pitch circle at the pitch point.
Base circle: An imaginary circle used in involute gearing to generate the involutes that form the tooth profiles.

3. Need of work

The main purpose of gear tooth profile is transmission of power using gear tooth action from one shaft to another. There is always fluctuation in transmission of power due to relative position of gear pair. Hence lot of research is going on to get optimum profile of spur gear pair to reduce transmission error and to get maximum power transmission efficiency.

Reduction of dynamic force and noise of gear system is an important concern in gear design. Tooth profile modification is one of the most popular and effective methods for minimizing of the dynamic vibration and noise.

4. Literature Survey

Faggioni *et al*. presented a global optimization method for gear vibration reduction using profile modifications. He developed a nonlinear dynamic model for the study of the vibration behaviour and validated the model from previous literature. The objective function of his studies was minimization of static transmission error or minimization of amplitude of vibration. He developed Random-Simplex optimization algorithm to find the optimal profile of spur gear pair to reduce the vibration for maximum range of operating condition. The optimum reliability is calculated by using Monte Carlo simulation. The result of his studies shows good efficiency of transmission system as well as reliable performance. He presented the application of High Contact ratio (HCR) gear and applies the above algorithm to get optimal parameters of gear pair which results into extremely good performance.

Bonori *et al.*used Genetic Algorithm (GA) for getting optimizes spur gear pairs for the reduction of vibration and noise. Between the three types of profile modification he used micro-geometric modifications which consist of getting optimum values of tip and root relief. He used minimization of static transmission error as objective function of genetic algorithm for reduction of vibration and noise. He used nonlinear finite element approach for calculating STE. The effectiveness of approach he checked by actual test. Result of his studies shows that with the help of genetic algorithm global optimum values of design parameters can get which results into reduction of vibration and noise.

Ghosh *et al*. studied the how the gear tooth profile modification affects the level of vibration using pair of spur gear. Level of vibration measured by different metrics such as dynamic mesh force, dynamic tooth force, bearing force along line of action and off line of action directions. For solving optimization problem for getting optimal tooth profile he used two methods

1) Graphical method,
2) Semi- analytical method.

He shows that if vibration is caused by profile error then using optimization technique it can reduced at effective amount.

Korta *et al*. used application of response surface method for optimization of gear. He also used micro-geometry modification parameters for tooth profile modification as design variables. He used three different techniques such as

1) Gaussian Process (stochastic),
2) Shepard k-Nearest (nonparametric deterministic) and
3) Polynomial (parametric deterministic).

He used above methods on pair of identical spur gears in which objective function of optimization problem of tooth profile modification is minimization of peak-to-peak transmission error and maximization of contact stress along the meshing cycle. He used constraint for the above problem as tooth bending force. Using above optimization method he able to find optimal parameters of micro-geometric modification of tooth profile.

Niels L. Pedersen used profile modification for reduction of bending stress. According to him bending stress is important factor in gear design because bending stress is responsible for geometrical shape changes. Hence objective function of his optimization problem is reduction of bending stress in spur gears. Pedersen suggest that using asymmetric gear teeth and by shape optimization bending stress can be reduced significantly. He also suggested that for maximum stress reduction tool of manufacturing of gear should designed depending on the no. of teeth.

Sankar *et al*. used profile modification for a purpose of increasing tooth strength of spur gear. He used root fillet as design variable that is he used root fillet as design parameter for increasing tooth strength. He suggested for a gear with less than 17 numbers of teeth circular root fillet should be used instead of the standard trochoidal root fillet in spur gear. He used ANSYS version 11.0 software for analysing the effect of different type of fillet used and concluded that for spur gear with less than 17 number of teeth circular root filet is better. He compare the result of modified gear with standard gear and concluded that for lesser no teeth circular root fillet is better while for having more than 17 number of teeth trochoidal root fillet is more suitable.

Barbieri *et al* also used profile modification for reduction of gear noise. He used two different ways for reduction of gear noise based on reduction of Static Transmission Error (STE) and Dynamic Transmission Error (DTE). For computation of dynamic properties of system he developed simple lumped parameter model and proposed a genetic algorithm for finding the optimal parameters of spur gear. He also studied the effect of manufacturing error on dynamic performance of spur gear.

Singh *et al* used macro-geometric modification of spur gear for the minimization of centre distance between spur gear pair. He used number of teeth as design variable and gear ratio, contact ratio, tip interference, face width as design constraint. He used genetic algorithm for minimization of centre distance between gear pair as objective function and proved that genetic algorithm gives better result than traditional optimization method.

Gologlu *et al* used genetic algorithm for getting minimum volume of gear trains. He used number of teeth and face width as design variable and bending strength, contact stress, face width etc. as design constraint.

Mendi *et al* used profile modification for multi objective function such as minimization of gear volume and minimization of Shaft volume. He used macro-geometric modification parameters such as number of teeth, face width, shaft diameter and shaft length as design variables and used genetic algorithm for getting the optimal values of above parametres.

Rao *et al* used profile modification for getting minimum value of weight of spur gear pair. He used face width, diameter and number of teeth as design variable that is he used macro-geometric modification of gear for the purpose of minimization of weight of gear pair. He used two different optimization algorithms such as particle swarm optimization and simulated annealing algorithm for getting optimal gear design parameter.

Gupta *et al* proposes gear modification for minimization of centre distance between gear pair. She used module and number of teeth as design parameters and bending stress and surface stress as design constraint. She also used genetic algorithm for getting optimal values of design parameters.

Thompson *et al* presented optimal design of spur gear for multiple objectives such as minimum volume of gear train and lo weight of gear system. He used traditional optimization method which is quasi-newton method for achieving above objective.

Conclusions

This paper gives short overview profile modification of spur gear and effect of profile modification on transmission of mechanical power system. This study shows necessity of optimization for getting optimal design variable of spur gear so that efficiency of mechanical power transmission system improved considerably. In short this review concludes that optimal profile of spur gear reduces transmission error and also results in reduction of vibration.

References

Faggioni, M., Pellicano, F., Andrisano, A. O., Bertacchi,G., 2011, Dynamic Optimization of Spur Gears*, Mechanism and Machine theory* 46, 544-557

Bonori, G., Barbieri, M., Pellicano, F., 2008, OptimumProfile Modifications of Spur Gears by Meansof Genetic Algorithms*, Journal of Sound and Vibration*,313, pp. 603-616.

S.S. Ghosh, G. Chakraborty., 2016, On optimal tooth profile modification for reduction of vibration and noise in spur gear pairs, *Journal of Mechanism and Machine Theory*, 105, pp. 145-163.

Jakub A. Korta, Domenico Mundo., 2017,Multi-objective micro-geometry optimization of gear tooth supported by response surface methodology, Mechanism and Machine Theory 109, 278–295.

Niels L. Pedersen, 2010, Improving bending stress in spur gears using asymmetric gears andshape optimization, *Mechanism and Machine Theory*, 45, pp. 1707–1720.

ShanmugasundaramSankar, MaasanamuthuSundar Raj, Muthusamy Nataraj., 2010, Profile Modification for Increasing the Tooth Strength in Spur Gear Using CAD, Engineering, 2, pp. 740-749.

Marco Barbieri, 2008, optimization methods for spur gear dynamics, *ENOC*, Saint Petersburg, Russia.

Ashtoshkumarsingh, Hitendra Pal Gangawar, RakeshSaxena, AnandiMisra, 2012, Optimization of Internal spur gear design using Genetic algorithm, MIT *International Journal of Mechanical Engineering*, vol. 2, pp. (22-30)

CevdetGologlu, MetinZeyveli, 2009, A genetic approach to automate preliminary design of gear drives, *Computers & Industrial Engineering* 57, 1043–1051.

FarukMendi, Tamer Bas_kal, KurtulusBoran, FatihEmreBoran, 2010, Optimization of module, shaft diameter and rolling bearing for spur gear through genetic algorithm, *Expert Systems with Applications* 37, 8058–8064.

V. Savsani, R.V. Rao, D.P. Vakharia, 2010, Optimal weight design of a gear train using particle swarm optimization and simulated annealing algorithms, *Mechanism and Machine Theory 45*, 531–541.

Anjali Gupta, 2014, Design Optimization of the Spur Gear Set, *IJERT*, pp. 2278-0181.

David F. Thompson, Shubhagm Gupta, Amit Shukla, 2000, Trade of analysis in minimum volume design of multi-stage spur gear reduction units, *Mechanism and Machine Theory 35*, 609-627.