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A Review of Gear optimization Methods

Kaushal Barot[1], Ronak Barot[2]

[1]Department of Mechanical Engineering, Parul University, India
[2]Goverment I.T.I, Patan, India

Abstract: ***Gears are the important components of almost every machines used in industrial environment for that Searching for best gear is a very hard problem and Optimization theory is one of the oldest branches of Mathematics. Gear optimization can be divided into two categories, namely, single gear pair or Gear train optimization. The problem of gear pairs or gear design optimization is difficult to solve because it involves multiple objectives and large number of variables. Therefore a reliable and robust optimization technique will be helpful in obtaining optimal solution for the problems. This review is intended to showcase variety of methods used to find the exact solution of elementary problems. Finding an alternative with the most cost effective or highest achievable performance under the given constraints by maximizing desired factors and minimizing undesired ones.***

Keywords: Gear, Optimization, Multiple objectives, Robust, Optimal solution

1. Introduction

Gears are used in most types of machinery and vehicles for the transmission of power. The design of gears is highly complicated involving the satisfaction of many constraints such as strength, pitting resistance, bending stress, scoring wear, and interference etc. The concentration is focused on gears which are used to transmit motion between shafts because of the reason that out of the various methods of power transmission, the toothed gear transmission stands unique due to its high efficiency, reliable service, transmit large power, compact layout and simple operation.

Planetary gears for power transmission system in which for vibration behavior optimization we use global optimization and brute force method to get optimal profile influence [1] .For detection of gear-bearing fault in single stage spur gear box using Artificial neural network in which MATLAB is used for feature extraction and neural network is used in diagnosis [2]. Helical gear which is used in automobile, cranes, power plants, sugar mills etc and optimal design of heavy duty gear pair using particle swarm optimization for minimum volume energy and cost effective system [3]. Spiral bevel gears with optimized tooth-end geometry in which improved design of gear blank with optimized tooth ends for which recalculations has been done for strength improvements [4]. Gear pair design optimization using GA, FEA and MITC calc analytical tool for maximize power, efficiency and minimize the overall weight and center distance considered [5].

2. Facts Available in Different Articles

2.1 Vibration behavior optimization of planetary gear set

Planetary gear system, have been widely used in power transmission systems owing to their advantages such as high torque to weight ratios, large speed reductions in compact volumes, availability of multiple speed reduction ratios, high reliability and high efficiency. Examples of application of planetary gears are automotive transmissions, tractors, helicopters, and aircraft engines. The profile modification of planetary gears is influenced for reducing noise and vibration problems. Brute Force is a power met hod to optimize the profile modification. Brute force methods are often seen as reference methods for calculating the number of states, or the number of calculations necessary to find the optimum with a probability of 100%.Hence,it can be used for the estimation of the effort to solve a problem. Planetary gear vibrations produce dynamic loads, cause reduction in the structural life time and generate noise. In this study, Planetary gear vibrations has modified using modifying the mesh stiffness in sun- planet and planet-ring by brute force method that caused this planetary gear set work with less chaotic vibrations[1].

2.2 Fault Detection in spur gear pair using ANN

Gears and bearings are important components of almost every machines used in industrial environment. Hence detection of defect in any of these must be detected in advance to avoid catastrophic failure. This paper aims to address the effect of bearing defect on gear vibration signature and effect gear defect on bearing vibration signature. Also its purpose is to make vibration analysis of single stage spur gear box, when both gear and bearing are defective. A condition monitoring set up is designed for analyzing the defect in outer race of bearing and damaged tooth of gear. MATLAB is used for feature extraction and neural network is used for diagnosis. In the literature, many authors have analyzed defects in bearings and gears separately. But it is found that the real situation may be more complex. The work presents a laboratory investigation carried out through an experimental set-up for the study of combined gear –bearing fault. This paper proposes a novel approach of damage detection in which defects in multiple components are analyzed using vibration signal [2].

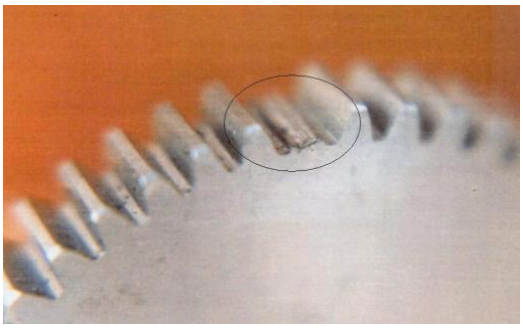

Figure 1: Gear with one tooth missing

2.3 Vibration behavior optimization of planetary gear set

A helical gear pair of a heavy duty gear reducer is considered for the objective of minimum volume, since the most power transmission systems require low weight energy efficient and cost effective system elements. The various factors for sizing and strength of gears are computed for gear geometry parameters using DIN standard. The formulation of the constrained non-linear multi-variable optimization problem with derived objective function and constraints is presented. The solution is attempted using Particle Swarm Optimization (PSO).

$$V = \frac{\pi}{4}\frac{m_n^2 b}{\cos^2\beta}\left(Z_1^2 + Z_2^2\right) \quad (1)$$

The results achieved are satisfactory and helps designer to employ for minimum material and cost by fulfilling the strength and performance requirements.

2.4 Spiral bevel gears with optimized tool geometry

Industrially-manufactured, spiral bevel gears with complementary tooth-end surfaces as a rule have reduced tooth thickness and subsequently reduced strength at the tooth ends. The weakened tooth ends of octoid gearing are generally produced by machining, inevitably resulting in a certain lengthwise dimensional discrepancy and slight profile difference. This in turn very often leads to systematic breakage of teeth. Serious, systematic damage occurs irrespective of the transmission tightness of the outer or inner tooth ends. Gear manufacturers currently use several solutions to avoid such breakages, including artificial inclination near to the teeth or deliberately reducing the back or outer cone angle and increasing the front or root cone angle. This paper outlines an improved design of gear blanks, with optimized tooth ends. Our research concluded that it is possible to optimize rectangular-generated, spiral bevel pinion/gear pairs with constant tooth height and a common pitch cone apex. We can successfully achieve this through recalculation of the gear blanks, without any changes in the flank geometry or tooth-cutting process. Thus the gear pair with optimized tooth ends can be cut without interference to the customary tooth-cutting process. To prove the concept, an example of the recalculation is provided. These improvements result in increased tooth strength, simplification of the gear blank geometry and more suitable geometry for modern machining, as well as a smaller outer diameter of the gear.

These conclusions are having significant impact to the practical work and could be directly applied into the industrial manufacturing and especially in field of the tailor-made repair works of the spiral bevel gears. 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.

2.5 Gear pair design and optimization by Genetic algorithm and FEA

Multiple, often conflicting objectives arise naturally in most real-world optimization. Gear is a mechanical device that transfers the rotating motion and power from one part of a machine to another. Searching for best gear is a very hard problem. Gear optimization can be divided into two categories, namely, single gear pair or Gear train optimization. The problem of gear pairs design optimization is difficult to solve because it involves multiple objectives and large number of variables. Therefore a reliable and robust optimization technique will be helpful in obtaining optimal solution for the problems. In this paper an attempt has been made to optimize spur gear pair design using Genetic Algorithm (GA) and analytical tool MITCalc. A combined objective function which maximizes the Power, Efficiency and minimizes the overall Weight, Centre distance has been considered in this model. Finite Element Analysis (FEA) was carried out and results were compared with the allowable limit.

3. Result and Discussion

As far as planetary gears for power transmission system in which for vibration behavior optimization we use global optimization and brute force method to get optimal profile influence. For detection of gear-bearing fault in single stage spur gear box using ANN in which MATLAB is used for feature extraction and neural network is used in diagnosis. Helical gear which is used in automobile, cranes, power plants, sugar mills etc. Optimal design of heavy duty gear pair using particle swarm optimization for minimum volume energy and cost effective system. Spiral bevel gears with optimized tooth-end geometry in which improved design of gear blank with optimized tooth ends for which recalculations has been done for strength improvements. Gear pair design optimization using GA, FEA and MITC calc analytical tool for maximize power, efficiency and minimize the overall weight and center distance considered. Means to utilize various techniques for error minimization to improve the overall effectiveness of the objective function and enhance the utilization capacity of gear system.

4. Conclusion

The RMS (root mean square) diagrams of sun and 1st planet in horizontal, vertical and rotational translations.RMS diagram of sun rotation and 1st planet. The optimal radiuses and amplitudes were achieved by optimizing peak to peak of transmission errors in sun- planet and planet-gear mesh using brute force method.

Table 1: Comparison of conventional and GA results

Variables	Conventional Calculations	GA Results
Module(mm)	3	3.000000
Face Width (mm)	10	10.001736
No. of teeth on pinion	18	18.000000
Centre Distance(mm)	114	113.400028
Gear Weight(N)	19.94	18.184130
Deflection	0.000032	0.000015

Experimental vibration studies with locally defective deep groove ball bearings, missing tooth gears and combined gear-bearing defect have been carried out and reported in this paper by applying radial loading on the gear-bearing test rig. Based on the studies reported herein, the following conclusions have been drawn: (i) it is observed from above analysis of seeded faults that the set up prepared for analyzing the combined defects in gear bearing system is working satisfactorily. (ii) With defective bearing, the higher vibration peaks at gear mesh frequency and its harmonics with side bands are observed, compared to good condition. (iii) With defective gear, the higher vibration peaks at bearing defect frequencies are observed, compared to good condition. (iv) Overall vibration increases in presence of bearing defect, gear defect and combined gear- bearing defects in comparison to healthy condition of gear box. (v) Vibration signal statistical parameters, such as RMS, Standard deviation, Kurtosis, crest factor etc. values increases while the derived parameters like p21, p23 decreases with increase in defects in gear-bearing system. (vi)The ANN based defect classifier using the above mentioned statistical parameters as neurons are effective in defect identification. vii) This is a novel thing that the multiple defects in a gear-bearing system can also be detected using trained neural network.

The helical gear pair for heavy duty application is optimized for minimum volume to have light weight, energy efficient and cost effective with improved performance. The application of PSO gives optimum volume. The work can be further extended for ulti objective and use of other evolutionary methods.

These conclusions are having significant impact to the practical work and could be directly applied into the industrial manufacturing and especially in field of the tailor-made repair works of the spiral bevel gears. 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.

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