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Weight Optimization of the Gear Train – A Review

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Abstract: Gear trains are used to transmit the power in various industrial applications. For gear train, various conflicting and dependent parameters needs to be, analyzed during its design and manufacturing. The study of conflicting dependent parameters with various optimization tools is presented in this paper as review. Total number of research papers studied are thirty-six which are further grouped in five categories like design method used, software used etc. The design parameters are considered for optimization are face width, moduleand number of teeth on pinion and gear etc. The exhaustive literature review reviled that genetic algorithm is the most commonly used optimization technique for designing industrial gear train.

Keywords: gear train, optimization, GA, PSO, SA.

I. INTRODUCTION

Gear trains are used to transmit power in various industrial and defense applications. The weight is the important criteria in the mobile applications affecting cost. While designing the gear train, various conflicting dependent parameters need to be studied so that they should not affect the required optimized dimensions. In the conventional method, the design is based on the bending strength and wear strength of the gear tooth which determines the parameters of the gear. It satisfies only one condition at a time. For this, the various classical and modern optimization methods are used. The optimization is an act of obtaining best results under given circumstances. There are number of optimization methods available for different types of problems. In this paper the literature is collected on various optimization tools of gear train as in divided in various sections which are further described.

II. GEAR TRAIN DESIGN PROCEDURE/METHODS

Wang et al [12] have presented, the mathematical formulation and an algorithmic procedure to solve multiple-objective gear design problem. The results were compared by them with previous research. Thompson et al [6] have presented a generalized optimal design formulation. The methodology is applied to the design of two-stage and three-stage spur gear reduction unit, subject to identical loading conditions and design criteria. The approach serves to extend traditional design procedures by demonstrating the tradeoff between surface fatigue life and minimum volume using a basic multiobjective optimization procedure. Chong et al [27] proposed a new generalized design methodology. A 4 step algorithm to automate the preliminary design of multistage gear drives. The final step of the algorithm uses simulated annealing (SA) algorithm. Mantriota et al [36] presents a methodology for computing the mechanical efficiency of Epicyclic Gear Trains. This capability was to takes into account load for dependent power losses and inertia effect. It also describes an apparatus used for the experimental validation of the proposed methodology. Swantner et al [1]presented a method for automating the design of gear trains. The search process combines topological changes, discrete variable choices and continuous variable optimization. Also presents details on the rules that generate feasible gear trains, the evaluation routines used in determining the objective functions and constraints, and the interaction among the three search methods are shown by them. Baglioni et al [23] have done the work on the efficiency of the gear by varying the addendum size of pinion for operating condition, addendum modification coefficient and transmission ratio.

III. OPTIMIZATION TOOLS USED FOR OF GEAR TRAIN

Li et al [4] developed a simple and practical model by establishing the batch module 'integration by FEA and optimum design' was established to search for contact nodes and elements and to automatically define the contact surface for contact analysis. Pennestri et al [8]have presented the systematic technique for the dynamic equation of the epicyclic gear train. Huang et al [11] have developed iterative physical programming approach for multiobjective optimization of three stage spur gear reduction unit. Mundo[7] has done the work on the planetary gear train with non circular gear geometries. It is illustrated by giving the example of bicycle with these model applied shows that the efforts of pedaling has been minimized. Faggioni[17] has presented global optimization method focused on gear vibration reduction by means of profile modification. Marjanvic et al [19] presented a practical approach to the optimization of spur gear train and developed GTO software. Their results shows that the volume of spur gear train is reduced by 22.5% and GTO

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software have short computing time. Staph [10] has developed a computer program to design external spur gears with normal and high contact ratio. The program is used to study the effect of change in parameters on several performance factors. The results show that the gear with high contact gear ratio with increase in addendum will have lower bending and compressive stress and increased friction heat and flash temperature.

IV. EVOLUTIONARY TECHNIQUES USED

Srinivas et al [20] have described nondominated sorting genetic algorithm (NSGA), the results shows that the NSGA can be used to find multiple parato optimal solutions for multiobjective optimization problem. Bing et al [31] have done the optimization with the mathematical model using fuzzy andgenetic algorithm. They employed it to design of transmission system. The result of optimization showed that objective function optimum is 10.44% lessthan the former. Savsani et al [30] have presented two methods PSO and SA to find optimum design parameters of spur gear train for minimum weight. The results were compared to previous work and results show that the weight reductions for 2 cases are 11% and 4.3% respectively. Chen et al [35] presented the SA algorithm to find optimum combination of design parameter the results compared with GA and shown 11.2% weight reduction. Jain [25]demonstrated the use of multiobjective evolutionary algorithm capable of finding multiple nondominated solutions. The efficiency of NSGA-II was demonstrated using example. Yan [21] has done the work on the optimization using intelligent algorithm ANN with GA for helical cylindrical gear reducer. The performance was better than original GA and traditional methods. Sanghvi et al [22] have optimized and load carrying capacity using MATLAB toolbox, GA and NSGA-II. The problem is treated as multiobjective problem in NSGA-II and results shows that the volume decreased by the 13.08% and load carrying capacity increased by 1%. Tamboli et al. [15] has presented the study on the optimal design of heavy duty helical gear pair using PSO technique for the minimum weight. Various factors of size and strength of gears are computed for gear geometry parameter using DIN standard. Dalian et al [32] havedone diagnosis on SVM by using Artificial Bee Colony (ABC) algorithm. The recognition rates for the gear box faults were improved by ABC, GA and PSO. The results show that the ABC algorithm performance better.

V. GANETIC ALGORITHM

GA is a global search optimization technique. Yokota et al. [29] used the constraints of bending strength, torsional strength of the shaft and gear dimensions for nonlinear integer programming (NIP) problem formulation. Authors claim that the weight of gears decreased by 48.8% and space area increased by 33.6%. Marcelin[13] has proposed a computer aided design with penalty selection method to optimize on e stage gear pair how GA was an effective method is shown by two examples. The volume is minimized by reducing the center distance between gear pair, transmission and gear ratio. In his another study Marcelin[14]has shown a different numerical approach based on GA and NN is presented. The selection of the optimum gear parameter like module, shaft diameter and rolling bearing for spur gear has been carried out using GA. Goluglu et al [2] have automated the preliminary design of gear drive by minimizing the volume. GA is applied with static and dynamic penalty function as objective function to handle the design constraints the results were compared to the deterministic design procedure developed and showing 98% of the success. Mendi et al [9] optimized the gear components, gear box shaft and rolling bearing with smallest volume which can carry the system load effectively. The result shows that the volume obtained by GA is 1.47% lower than AM. Barbieri et al [16] have presented the a corrigendum, a dynamic model is updated keeping in account the derivation by means of an error function the new dynamic model results shows that the profile modification are effective.Mohan et al [33] have shown the use of GA for solving the optimization problem of spur gear in his study. With the use of three deferent materials namely CI, C45 AND alloy steel (15Ni2Cr1).

VI. USE OF SOFTWARE

Tsai et al [18] have done a multi tooth contact analysis using FEM for calculating static transmission errors of plastic spur gears of plastic spur gear. The modification of existing method is proposed for plastic gears and verified the same by FEM. Houck et al [5] presents GA implementation in MATLAB for function optimization the uses of GA toolbox as well as codes were introduced in the paper. Lin et al [28] have presented the approach for the mesh generation of gear drives at any meshing position and an automatic modeling program for tooth mesh analysis was developed it was also used to simulate the gear behavior under dynamic loading conditions. Guo et al [3] describes the GA and its complete programming in MATLAB for the optimization of gear train. Padmanabhan et al [26] have made attempt to optimize the design using GA and analytical tool MITcalc. FEA was carried out and results were compared to allowable limit of material which was 6.525 less than the theoretical value. Xiao-qin et al [34] have done the work on automatic optimization design for gear reducer is realized By Visual Basic programming mixed with MATLAB, design efficiency and quality greatly improved. Genetic algorithm and genetic toolbox of MATLAB is used when calculating, with the advantages of simple programming, good reliability and high efficiency. Golabi[24] has done the work on the one, two and three stage gear box. MATLAB tool and practical graphs are used to present the optimization results. The results were compared with the previous work and it's found that the reduction in weight was 7.8% and 7.2% for respective two cases.

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VII. CONCLUSION

The gear trains are optimized by various methods. The conventional methods have shown laborious work required. The origin of new evolutionary optimization methods used in gear train optimization methods shows considerable savings in materials and weight due to reduced weights. Also the improved life of the optimized gear train shows that evolutionary optimization technique can be effectively used for gear train optimization.

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