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Multi Objective Optimization for Spur Gear design Using Sheep Flocks Heredity Model Algorithm

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Abstract. In a perspective of stable industrial development to manufacture added consistent and economical industrial product, gears are ever more focus to requirements in terms of power capability, efficiency and compactness etc. In order to increase the performance factors of gears such as transmission capacity, efficiency, gear life, etc. is a difficult criteria for a design engineers as these are all progress in a conflicting behavior. This paper deals with the multi-objective optimization of spur gear drive design with two contradictory objective functions such as maximization of power transmission and minimization of volume of the gear drive. These objectives are approached by an optimization technique based on a Sheep Flocks Heredity Model Algorithm (SFHM) with design constraints like stress, center distance etc. A spur gear problem is solved with traditional trial method and results are compared with proposed algorithm.

Introduction

Gears may be defined as a class of mechanical elements, which are used for transmitting controlled relative motion between shafts. Buiga and Popa [1] proposed an optimal design mass minimization problem of a single-stage helical gear unit, complete with the sizing of shafts, gearing and housing using genetic algorithm (GA). Yallamti and Seshaiah [2] have developed optimization of spur gear set for its center distance, weight and tooth deflections using genetic algorithm. Nenad Marjanovic et al [3] developed a selection based matrix mathematical model to solve optimization spur gear problem for minimum weight. Padmanabhan et al [4] proposed modified Artificial Immune System algorithm for a helical gear design with multi objectives. Chang Wei Wu et al [5] designed a compact manual gear train of a tractor with minimum quality and minimum center distance of the gear train is obtained by using particle swarm optimization algorithm.

Optimization Algorithms helps in the designing to obtain the best solution for the complex problem. An evolutionary algorithm is the optimum algorithm used to reduce the complicity of the design. G. Ramya and M. Chandrasekaran [6] proposed a Shuffled Frog Leaping Algorithm and Sheep Flock Heredity Model Algorithm for minimizing the maximum completion time based on job scheduling and minimization of labor costs based on employee workload. M. Chandrasekaran et al [7,8] developed a multi objective optimization for n-job, m-machine job shop scheduling problems using Sheep Flocks Heredity Model Algorithm.

The present work is carried out on spur gear design problem with conflicting objectives as to increase the transmission power output and to reduce the volume of the gear drive by considering compressive stress, bending stress, center distance and module as constraints with Sheep Flock Heredity Model Algorithm.

Gear Drive Optimization

A two objective functions by which optimality of gear drive design are include as Maximization of Power transmitted (f_1) and Minimization of volume of gear drive (f_2) design constraints should be considered in the design of gear drive like bending stress, compressive stress, module and centre distance etc. The design variables such as power, module, gear thickness and number of teeth are influencing the design objectives.

A Spur Gear drive problem

In this paper, a spur gear drive problem is considered as, 'Design a single speed spur gear drive to transmit 18 kW at 1200 rpm. Gear ratio is 3.5. The gears are made of C45 steel'.

The complete optimized problem of spur gear drive in terms of design variables Power (P), Module (m), Gear thickness (b) and Number of teeth on Pinion (Z_1) for the above problem with C45 material, after simplification is,

$$\text{Maximize } f_1 = P \quad \text{where, } P^{(L)} \leq P \leq P^{(U)} \tag{1}$$

$$\text{Minimize } f_2 = 10.411 \times b \times (mZ_1)^2 \tag{2}$$

Subject to,

$$m Z_1 \, b^{0.5} P^{-0.5} \geq 317.16 \tag{3}$$

$$m^2 (Z_1 + 8) \, b \, P^{-1} \geq 607.92 \tag{4}$$

$$m Z_1 P^{-0.333} \geq 53.65 \tag{5}$$

$$m^3 (Z_1+8)^{0.333} P^{-0.333} \geq 31.45 \tag{6}$$

$$Z_i \, \varepsilon \, I, \text{ for } i = 14, 16,18,20,22,24,26,28 \tag{7}$$

The equations (1) represent the maximization of Power and equation (2) for minimization of gear drive volume. The above gear drive objectives should satisfies with the design constraints of allowable bending stress, allowable compressive stress, minimum module and minimum centre distance etc. the below equations (3), (4), (5) and (6) has been adopted from [10]. In this gear design, four different parameters are as objectives, i.e., power and volume. Since these two objectives are on different scales, these factors are to be normalized to the same scale. The normalized and combined objective function (COF) is,

$$COF = \left[\left(\frac{power}{max.power} xNW_1 \right) + \left(\frac{min.weight}{weight} xNW_2 \right) \right] \tag{8}$$

Where NW_1, $NW_2 = 0.25$

Sheep Flocks Heredity Model Algorithm

Sheep flock Heredity algorithm was developed by Koichi Nara et al [9]. Normally, sheep in an each flock are living within their own flock under the control of shepherds. The genetic inheritance only occurs within the flock group and the each sheep with high fitness characteristics to their environment breed in the flock. Let us assume that two sheep flocks were occasionally mixed in a moment when shepherds looked aside. Then the certain moment, the shepherd of corresponding flock group runs into the mixed flock, and separates the sheep as before. However, shepherds cannot distinguish their sheep originally they owned because their appearance of all flock group of sheep are same and unique. Therefore, one flock from each sheep group is inevitably mixed with the other flocks in different group. The characteristics of the sheep in the neighboring flocks can be inherent to the sheep in other flocks in this occasion. The flock of the sheep, which has better fitness characteristics to the field environment, breeds most. In sheep flocks heredity model algorithm special string structure called hierarchical genetic operations like crossover level operations and mutation level operations are introduced [6].

Steps in Sheep Flocks Heredity Model Algorithm

- Initial the required population randomly with control string of [P, b, Z_1, m, f_1, f_2].
- For each control string (chromosome), evaluate the COF (fitness function).
- Perform the control variables (sub chromosomes) level crossover and mutation.
- After selecting the best chromosome from the population based on COF, do the chromosome level crossover and mutation.
- Recalculate the COF for each chromosome in the population and sort them.
- Select best strings for the next new population with size of the old population and this completes one generation process.
- Repeat from step 2, until a termination criterion is met, visualize the best string.

Results and Discussion

The Sheep Flocks Heredity Model Algorithm was with design parameters (P, m, b and z_1) boundary values as inputs. The spur gear design problem is solved by using C45 as gear material. The Gear material properties of Gear drive is tabulated in Table 1.

Table 1. C45 Gear Material Properties

Material	Bending Stress (σ_b) N/mm^2	Compressive Stress (σ_c) N/mm^2	Young's Modulus (E)N/mm^2
C-45	140	500	2.1×10^5

After number of iteration performed by SFHM, for the C45 gear material for the specified spur gear design problem, the optimized results were tabulated in Table 2 in compared with existing trail method.

Table 2.Comparasion of Gear drive opimized results by SFHM

Parameters / Material	Traditional Trial Method	SFHM
Power (P) kW	18.00	19.25
Module (m) mm	4.00	4.00
Gear Thickness (b) mm	40.00	31.50
No. of teeth on pinion (Z_1)	20	18
Volume of Gear drive (mm^3)	2665216	1700075

Fig. 1. Comparison of Power

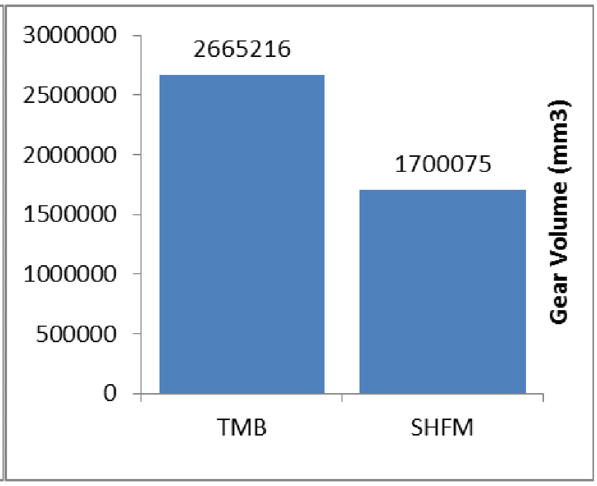

Fig. 2. Comparison of Weight

By varying all design parameters such as power transmission, gear thickness, number of teeth on pinion and gear module, SFHM performs well and shows a huge reduction in gear drive volume. For specified spur drive problem, around 36.2% reduction of gear volume in comparison with the trial design method. Also resulting in more than 6.9% of increase of power in compared with existing design method.

Conclusion

A good engineering design has to reduce the most significant result and to exploit the main significant desirable result. Optimization algorithms are more flexible and ever-increasing in field engineering design problems, technically because of the availability and affordability of today's technical world. A population based algorithms offers well-organized ways of creating and comparing a novel design solution in order to complete an optimal design. This paper proposed Sheep Flocks Heredity Model Algorithm to solve spur dear design problem. In this work, a gear drive design was taken with two different objectives and results were obtained by SFHM shows considerable reduction in gear drive volume in compared with trail method. Also shows better results over power transmission. The above algorithm can be employment in design of various mechanical components.

References

[1]Ovidiu Buiga, Claudiu-Ovidiu Popa, Optimal Mass Design Of A Single-Stage Helical Gear Unit With Genetic Algorithms, Proceedings Of The Romanian Academy, 13 (2012) 243–250.

[2] Yallamti Murali Mohan ,T.Seshaiah, Spur Gear Optimization By Using Genetic Algorithm,International Journal of Engineering Research and Applications, 2 (2012), 311-318.

[3]Nenad Marjanovic, Biserka Isailovic,Vesna Marjanovic,Zoran Milojevic, Mirko Blagojevic and Milorad Bojic, A practical approach to the optimization of gear trains with spur gears Mechanism and Machine Theory, 53 (2012) 1–16.

[4]Padmanabhan.S, M.Chandrasekaran, P.Asokan and V. Srinivasa Raman, Optimal Solution for Gear Drive Design Using Population Based Algorithm, Intl Journal of Review of Mechanical Engineering, 5 (2013) 802-806.

[5]Chang Wei Wu, Yong Hai Wu, Cong Bin Ma, Cheng, Wang Optimization Design of Gear Train Based on Particle Swarm Optimization Algorithm, Applied Mechanics and Materials, 373-375 (2013) 1072- 1075.

[6]G. Ramya and M. Chandrasekaran , Solving Job Shop Scheduling Problem Based on Employee Availability Constraint,Applied Mechanics and Materials, 376 (2013) 197-206.

[7]M. Chandrasekaran, P. Asokan, S. Kumanan, S. Umamaheswari, C.S.P.Rao, Multi Objective Optimization for Job shop scheduling Using Sheep Flocks Heredity Model Algorithm", International Journal of Manufacturing Science and Technology , 9 (2007) 47-54.

[8]Chandrasekaran,M., P.Asokan, S.Kumanan and T.Balamurugan, Sheep Flocks Heredity Model Algorithm for Solving Job Shop Scheduling Problems International Journal of Applied Management and Technology,4 (2006) 79-100.

[9]Koichi Nara, Tomomi Takeyama &Hyunchul Kim , A New Evolutionary Algorithm Based on Sheep Flocks Heredity Model and Its Application to Scheduling Problem. IEEE Transactions, 6 (1999) 503-508.

[10] Design Data Book, Faculty of Mechanical Engineering, PSG College of Technology, India, 2008.

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