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DESIGN OPTIMIZATION OF HELICAL GEAR USING SHEEP FLOCKS HEREDITY MODEL ALGORITHM

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ABSTRACT

An optimal design for an engineering optimization problem involves various decision variables and constraints. In engineering applications, objectives under consideration conflict with each other, and optimizing a meticulous solution with respect to a single objective can result in objectionable results with respect to the other objectives. A practical solution to a multi-objective problem is to examine a set of solutions, each of which satisfies the objectives at a satisfactory level without being conquered by any other solution. In this paper, Sheep Flocks Heredity Model Algorithm (SFHM) used to optimize the helical gear drive with combined objective function which maximizes the power and minimizes the overall weight has been considered. The performance of the proposed algorithms is validated and results are compared.

Keywords: design optimization, gear design, helical gear, sheep flocks heredity model algorithm.

INTRODUCTION

Mechanical engineering design can be defined as the preference of materials and geometry, which satisfies, specified functional requirements of that design. A good design has to reduce the most significant difficult result and to exploit the main significant desirable result. Optimization algorithms are more flexible and ever-increasing in field engineering design problems, rightfully because of the availability and affordability of today's technical world. A population based heuristic algorithm offers well-organized ways of creating and comparing a novel design solution in order to complete an optimal design. Gears, as a class of mechanical mechanism, are used to transmit relative motion between two shafts. The design of gears is critical for smooth functioning of any mechanism, automobile and machinery. Gear drive design starts with the need of optimizing the gear width, module and number of teeth etc., it creates huge challenges to designer.

Quancai Li *et al* [1] developed a multi-objective for gear transmission with design variables and choice restrictive constraints. Majid and Esmaile [2] evaluated an engineering optimization problem with continuous design variables with two New Harmony search heuristic algorithms.

Ya Feng Li *et al* [3], a design of three-stage wind turbine gear box was optimized with genetic algorithm with more optimized result. Savsani *et al* [4] developed the particle swarm optimization and simulated annealing heuristic algorithms to minimize the weight of a spur gear train. Chong and Lee [5] showed a two-stage gear train and the simple planetary gear train for a minimization volume with genetic algorithm and discussed that genetic algorithm is better than the conventional algorithms. Padmanabhan. S *et al* [6] used modified artificial immune system algorithm to optimize the design of helical gear pair with combined objective function to maximize the Power, Efficiency and minimize Weight, Centre distance. 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.
This paper is proposed design optimization of helical gear pair with contradictory objectives as to increase the transmission power and to reduce the weight of the gear drive by considering compressive stress, bending stress, center distance and module as constraints with Sheep Flock Heredity Model Algorithm.

Helical gear design optimization

The Helical gear drive design consists of determining the design variable such as module, gear thickness and number of teeth in order to optimize the design. A number of objective functions by which optimality of gear drive design are include: Maximization of Power transmitted (f_1) and Minimization of Weight (f_2). Several design constraints should be considered in the design of gear drive like bending stress, compressive stress, module and centre distance etc.

Gear drive problem

In this paper, gear design problem are taken as, a pair of helical gears to transmit 38 kW at 1500 r.p.m. The transmission ratio is 5 and the material for gear drive Alloy Steel. The helix angle is 15º and pressure angle is 20º. The material properties of gear drive are tabulated in Table-1.

Table-1. Gear material properties.

Material	Density (ρ) kg/mm^3	Bending stress (σ_b) N/mm^2	Compressive stress (σ_c) N/mm^2	Young's Modulus (E) N/mm^2
Alloy Steel	8.84×10^{-6}	400	1100	2.15×10^5

The complete design optimization problem of helical gear drive in terms of design variables Power (P), Module (m_n), Gear thickness (b) and Number of teeth on Pinion (Z_1) for the above problem is,

Maximize $f_1 = P$ where, $P^{(L)} \le P \le P^{(U}$ (1)

Minimize $f_2 = 193.406 \times 10^{-6} \times b \times (m_n Z_1)^2$ (2)

Subject to,

$m_n Z_1 \ b^{0.5} \ P^{-0.5} \ge 56.8$ (3)

$(Z_1 + 4) \ m_n^2 \ b \ P^{-1} \ge 57.2579$ (4)

$m_n Z_1 P^{-0.333} \ge 15.12$ (5)

$m_n^3 (Z_1+4) P^{-1} \ge 5.79$ (6)

Equations (3), (4), (5) and (6) are represents allowable bending stress, allowable compressive stress, minimum module and minimum centre distance respectively has been adopted from [10]. Power and Weight are two different scale, these factors are to be normalized to the same scale. The normalized and combined objective function (COF) is,

$$COF=\left[\left(\frac{power}{max.power}xNW_1\right)+\left(\frac{min.weight}{weight}xNW_2\right)\right] \quad (7)$$

Where NW_1, $NW_2 = 0.5$

Sheep Flocks Heredity Model algorithm

Sheep flock Heredity algorithm was developed by Koichi Nara *et al* [9]. Sheep in an each one herd are existing inside their group under the control of shepherds. The genetic inheritance just happens inside the group and the each sheep with high fitness character to their surroundings breed in the flock. When two sheep flocks were rarely mixed in a instant when shepherds looked aside. At that point the certain time, the shepherd of relating group gathering runs into the blended run, and differentiates the sheep as some time recently. On the other hand, shepherds can't recognize their sheep initially they claimed in light of the fact that their appearance of all group gathering of sheep are same and one of a kind. Therefore, one flock from each sheep group is predictably mixed with the other flocks in different group. The qualities of the sheep in the neighboring groups could be natural to the sheep in different rushes in this event. 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 [7].

Flow of Sheep Flocks Heredity Model algorithm

Initial the required population randomly with control string of [P, m_n, b, Z_1, 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 DISCUSSIONS

The Sheep Flocks Heredity Model Algorithm was developed with design parameters (P, m_n, b and Z_1) boundary values as inputs. After iteration of SFHM with alloy steel gear material for the specified helical gear driver, the optimized results were tabulated in Table-2 in compared with existing trail design method.

Table-2. Comparasion of Helical Gear drive results by SFHM.

Parameters / Material	Traditional trial method	SFHM
Power (P) kW	38.00	38.82
Module (m) mm	5.00	5.00
Gear Thickness (b) mm	50.00	41.25
No. of teeth on pinion (Z_1)	18	18
Weight (Kg)	78.36	64.65

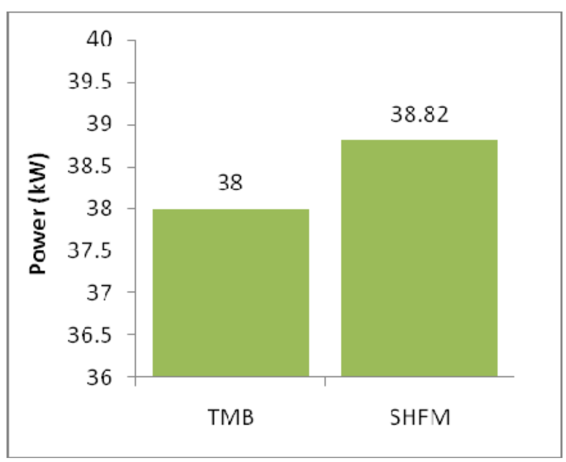

Figure-1. Comparison of power.

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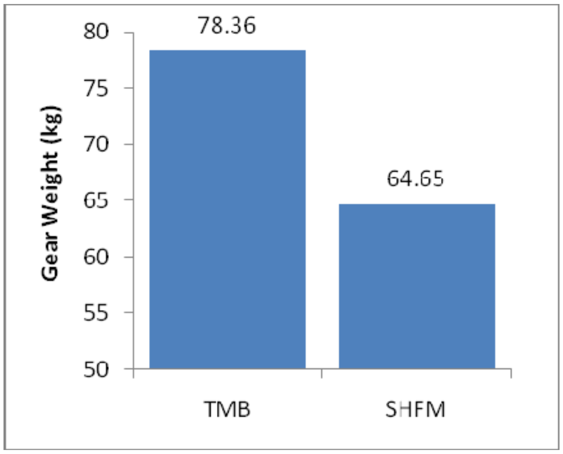

Figure-2. Comparison of weight.

By varying all design parameters such as power, gear thickness, number of teeth on pinion and gear module, SFHM performs well and shows a huge reduction in gear weight. For the helical gear drive problem, around 17.5% reduction of gear volume in comparison with the existing trail design method. Also resulting in more than 2.15% of increase of power in compared with existing trail design method.

CONCLUSIONS

The majority of an engineering design involves extensive calculations and a number of non linear, non-differentiable and multi variables objective functions. It is extremely impracticable to solve by mechanical optimal techniques. Evolutionary algorithm like SFHM can be powerfully applied for best solutions in an engineering design. Sheep Flocks Heredity Model Algorithm shows the substantial decrease in weight of gear drive with above gear materials, which is directly proportional to cost of the gear drive. The amount of material consumed is reduced due to reduction in weight of the gear drive and also its shows considerable increase in power with respect to all materials in compare with conventional design. As a future work, this algorithm can be used evaluated the range of engineering design application like multispeed gear box, epicyclic gear train and springs etc.

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