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Optimum Design for Conflicting Objective of a Composite Helical Spring by Multi Optimization Technique (Particle Swarm Optimization)

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ABSTRACT

The quality of suspension helical spring is very important to the stability and safety of automobile. Taking the automobile suspension helical spring as the research object, by using Pareto optimization theory and particle swarm optimization algorithm, the paper establishes a multi-objective optimization model of automobile suspension helical spring which is based on the Matlab optimization design platform. The purpose is to seek for the optimal structure design proposal which is under the objective of maximum stiffness and minimum mass of spring. The Pareto optimal solution set is obtained.

I. INTRODUCTION

During the driving process of automobile, the suspension spring bears the action of high frequency fluctuating load and impulsive load, and operates as buffering and shock absorber. So, the quality of suspension spring plays a crucial role in the stability and security of automobile. Helical spring has good flexibility, and can absorb great mass of mechanical energy. It is widely used as automobile suspension spring, especially in the suspension of lightweight car and medium bus. Currently, the application research of multi-objective optimization algorithm is a one of the hottest topics. Compared with evolutionary algorithm, particle swarm optimization (PSO) has many merits such as fewer parameters, simpler algorithm and faster convergence. It is broadly applied in multi-objective optimization research and engineering practice. By using Pareto optimization theory and particle swarm optimization algorithm, based on the Matlab optimization design platform, the paper establishes a multi-objective optimization model of automobile suspension helical spring. The purpose is to seek for the optimal structure design proposal which is under the objective of maximum natural frequency and minimum quality of spring. The Pareto optimal solution set is obtained. Gobby and Mastinu applied multi objective programming to the design of helical spring , in particular to composites springs with a hollow circular core . Given the technical specification in terms of stiffness, maximum deflection, etc., the method allows defining the spring geometrical and mechanical parameters so as to obtain the best compromise between conflicting goals. Constraints can be added on local and global stability , resonance frequency , etc. A mathematical model was developed and validated[1]. Yokota et al. formulated an optimal weight design problem for helical metallic spring with constraints on the allowable shearing stress, no of active coils and coil mean diameter. Formulated as an integer programming problem with nonlinear constraints, it was solved by genetic algorithm[2]. Multi objective optimization was also applied to the optimal design of composite helical spring by Lecarpentier[3] and Ratle et al.[4]. In an investigation by Charlebois et al.[5] the mechanical properties of braided composites were measured angles .Note that Harte and Fleck[6,7] characterized the mechanical properties of tubular braided composites in tension , compression and shear. More recently Zebdi[8] characterized experimentally tubular and helical composites helical springs. All these investigations have provided valuable information on the design of composite on helical spring which is the purpose of this investigation . Heyan Li did modelling and parametric study on drag torque of wet clutch. Here equivalent radius was considered where in the flow rate and drag torque can be evaluated.Y.Takagi has worked on the numerical and physical experiments on drag torque in a wet clutch. Three-dimensional hydrodynamic numerical simulations were carried out, and the drag torque was measured experimentally for a single wet clutch pack. At low rotation speeds, the oil flow was of single-phase, and the drag torque was linearly proportional to the rotation speed. Manoj Kumar Kodaganti Venu has worked on the wet clutch modelling techniques and design optimization of clutches in an automatic transmission. Light was shed on the losses that occurred in these multi plate wet clutches when they are disengaged and the design optimization of clutches in a six speed transmission based on these losses. Note that Harte and Fleck characterized the mechanical properties of tubular braided composites in tension , compression and shear. More recently Zebdi characterized experimentally tubular and helical composites helical springs. All these investigations have provided valuable information on the design of composite on helical spring which is the purpose of this investigation. Rania Hassan compared particle swarm optimization and genetic algorithm. The performance comparison of the GA and PSO is implemented using a set of benchmark test problems. Katiyar worked on genetic algorithm and the particle swarm optimization. Mathematical problems were taken for comparison of results. Particle swarm optimization was similar to the genetic algorithm in the sense that both are population-based search algorithms but optimized results depended on constraint‘s complexity. Cheng Guo, Xiaoyong Yang briefly introduced genetic algorithm and provided its complete programming in detail by MATLAB 7.0. This study provided the complete original codes in MATLAB which can be directly run through MATLAB 7.0.

II. THEORITICAL ANALYSIS

Design equations referred from IS codes and books, will be used for designing spring made from solid circular wire/rod. These design equations are again referred to formulate the design equations for spring made from hollow circular wire/rod.

III. SCOPE OF THE WORK

In this work, dimensions of the springs made from solid as well as hollow circular wire of same material and for same problem are determined analytically. These model tested by particle swarm optimization. After tests, various parameters like mass, stiffness induced etc. will be compared.

IV. PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization is a heuristic global optimization method and also an optimization algorithm, which is based on swarm intelligence. It comes from the research on the bird and fish flock movement behavior. The algorithm is widely used and rapidly developed for its easy implementation and few particles required to be tuned. The main idea of the principle of PSO is presented; the advantages and the shortcomings are summarized. Particle swarm optimization (PSO) is a kind of stochastic optimization algorithm based on Swarm Intelligence. Inspired by the research results of Artificial Life, Kennedy and Eberhart put forward PSO, and attracted great attention in the fields of optimization and evolutionary computing immediately. At present, PSO has been widely used in function optimization, neural network training, fuzzy systems control and other application fields. The results of theoretical research and practical application show that PSO has such merits as fast convergence, high-quality solution and good robustness in function optimization of multi dimension space and dynamic objective optimization. The basic idea of PSO is derived from the research of simplified social model of bird flock and the simulation of their behavior. Individuals of the group will be moved to good area based on the fitness of environment. It does not use the evolutionary operator to each individual, but takes it as a mass less and size less particle of searching space, flying with a certain speed and direction. Through learning and adaptation to the environment, it can adjust the speed and direction of the next flight dynamically based on the flying experience of individuals and groups. In the particle swarm algorithm, the position of each particle in the problem solution space is likened to a solution to a problem (Note: the solution mentioned here is a solution of the original space, rather than a solution of target space). When particles move to a new position, it creates a different solution. The solution can be evaluated by fitness function, which gives the quantitative evaluation to the usefulness of the solution. Because each particle moves in the solution space, its speed and direction will change along the direction of each dimension. When the particles traverse the entire solution space, it will the problem will be obtained.

V. FLOW CHART OF PSO

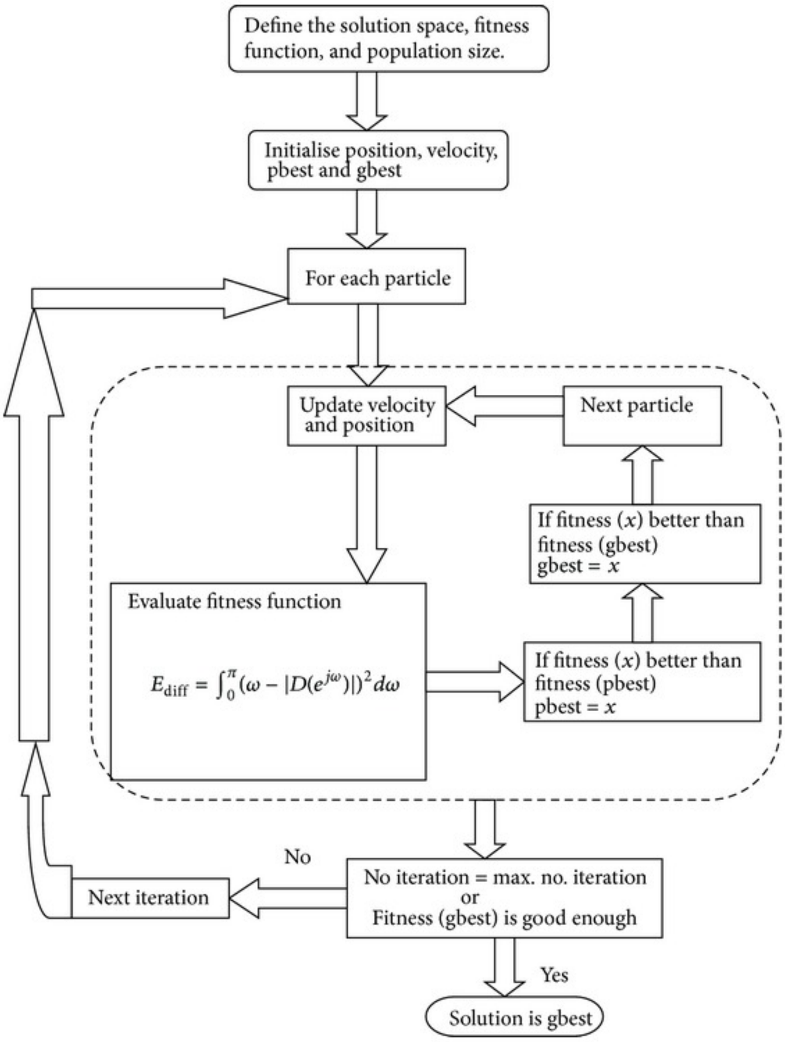

Figure Flow Diagram

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VI. CONFLICTIVE OBJECTIVE

Minimization of mass

Spring mass (g)

$$m = \rho\pi D\left(\frac{N}{\cos\alpha} + N_i\right)\pi\frac{(d_{ext}^2 - d_o^2)}{4}$$

Maximization of stiffness

Spring stiffness (k)

$$K = \frac{G(d_{ext}^4 - d_o^4)}{8ND^3}$$

VII. CONCLUSION

Main objective of the work is to validate the applicability of the weight optimization technique in which spring is designed with hollow circular wire. Failure of helical compression spring occurs in torsion. In case of torsion, the section having larger moment of inertia will have greater torsional strength. Thus weight can be reduced by designing the spring with hollow circular wire instead of solid circular wire. Thus this technique of weight optimization for helical compression spring can be effectively implemented with assumption that both springs are made from the same material, have the same spring rate i.e. stiffness, undergo the same maximum load, sustain the same maximum shear stress

VIII. FUTURE SCOPE

Work The authors will also hybridize PSO with other single solution heuristics for comparison with PSOTS. Currently, PSO-SA or Particle Swarm Optimization – Simulated Annealing is applied on the same set of test problems. Results of the study

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will be compared with the results of PSO-TS and the results of previous studies mentioned in this paper.

IX. THE MAIN DESIGN EQUATIONS

1. Hollow wire thickness(mm)

$$e = \frac{(d_{ext} - d_o)}{2}$$

2. Spring index

$$c = \frac{D}{d_{ext}}$$

3. Stiffness (Spring constant) (N/mm)

$$K = \frac{G(d_{ext}^4 - d_o^4)}{8ND^3}$$

4. Load (N)

$$P = K\delta$$

5. Wahl's correction factor

$$k = \frac{4C - 1}{4C - 4} + \frac{.615}{C}$$

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