Weight Minimization of a Speed Reducer Using Prey Predator Algorithm

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ABSTRACT

This article describes how a speed reducer is a mechanical device which is very useful to reduce speed in different machineries. The use of gears to adjust a speed is an old practice, however the formulation of the problem as an optimization problem and solving it using different approaches begun in early 1970’s. The problem is a constrained, nonlinear and nonconvex problem. That makes it challenging to handle it by deterministic approaches. Hence, different metaheuristic and hybrid methods have been proposed and used. Furthermore, due to the challenging behaviour of the problem, it has been used as a benchmark problem to test and compare new algorithms. In this article, a brief review of the problem, its application and the advances in solving the problem will be presented. A metaheuristic algorithm called prey predator algorithm will then be used to solve the problem. Prey-predator algorithm has been found to be effective with an easy way to control the exploration and exploitation search behaviour. Simulation-based comparison with previous results shows that indeed the algorithm produces a promising result. Hence, this study showed that applying prey predator algorithm for speed reducer production is a reasonable idea.

KEYWORDS

Engineering Optimization, Prey Predator Algorithm, Speed Reducer, Swarm Intelligence Applications

1. INTRODUCTION

The applications and uses of optimization techniques become very important and crucial for different engineering applications. For a mathematically formulated decision making problem, different methods can be used as a solution approach. These methods can be classified as deterministic and non-deterministic methods. A deterministic method refers to methods which are based on mathematical arguments to obtain an optimal solution, for example simplex algorithm, whereas, non-deterministic methods are methods which try to approximate the optimal solution within a reasonable run time. Metaheuristic algorithms are non-deterministic approaches which become very common in different application from a wide range of disciplines. One of the major reasons for that, is that their effectiveness to deal with complex and also high dimensional problems. Even though these algorithms do not guarantee to produce an optimal solution, they are found to give an acceptable solution within a

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reasonable time. Generally, there are two classes of these algorithms, namely evolutionary computing and swarm intelligence.

Engineering design has been one of the application areas where metaheuristic algorithms become very applicable. Designing a speed reducer is one of the interesting engineering problems, researchers try to address since early 1980’s. It is a gear box of a mechanical system, where it is applicable in a wide range of applications where reducing a speed is needed. These include turbine generators, motor or machine tools, airplanes and the likes. The speed reducer is enclosed in a rigid housing so that it can be lubricated, protected from moisture and dust with an enough space for cooling. The design of a speed reducer with an optimum minimized weight without affecting all the needed functioning has been one of the challenging problem, hence it is taken as a challenging benchmark for optimization methods. In this paper, a detailed discussion on the problem, along with proposing a solution approach based on a swarm intelligence algorithm called prey predator algorithm and possible future works will be discussed.

Prey predator algorithm is a swarm based metaheuristic algorithm inspired by the interaction of a predator and its prey (Hamadneh, Tilahun, Sathasivam, & Ong, 2013; Tilahun, & Ong, 2015). It works by exploring the solution space by categorizing the solutions into three categories as predator, best prey and ordinary prey. By increasing the number of best prey and predators, recent studies suggested that the degree of exploration and exploitation of prey predator algorithm can easily be tuned (Tilahun et al., 2016). In addition, the algorithm has been extended to a new version where adaptive step length is used (Tilahun, & Melesse, 2015; Tilahun, & Ngnotchouye, 2016). It has been found to be promising when compared to other algorithms (Tilahun et al., 2015; Tilahun et al., 2012; Tilahun et al., 2013). The algorithm has been tested in different application and found to be effective (Hamadneh et al., 2013; Tilahun et al., 2016a, 2016b; Tilahun, Gosshu, & Ngnotchouye, 2017; Tilahun, 2012; Tilahun, 2013; Bahmani-Firouzi, Shariinia, Azizipanah-Abarghooei, & Niknam, 2015; Dai, Liu, & Chai, 2015).

Hence, the major objectives of this paper are 1) to discuss the advances made in solving the well-known weight minimization of speed reducer problem, 2) to propose the effective use of the swarm intelligence algorithm which becomes very useful in different applications to solve the problem and 3) to explore and highlight research directions in the area relevant to weight minimization of a speed reducer from an optimization point of view.

The manuscript is organized as follows. In the following section e brief discussion on a speed reducer and previous relevant works will be discussed followed by the optimization model formulation of the problem in Section 3. Section 4 focuses on the solution approach followed by a simulation based comparison and discussion in Section 5. There will be a conclusion in Section 6.

2. A SPEED REDUCER

A Speed reducer is a mechanical device very common in different machines with the objective of converting the speed to increase the torque with the aim of increasing the efficiency on the work of the machine. It consists of a gear or series of gears combined in such a manner to increase the torque of an engine. Basically, the torque of an engine increases in direct proportion to the reduction of the engines rotations per minute. If you decrease the rotation without slowing down the engine, you increase the force generated. The basic idea of a speed reducer using gears is an old idea whereas formulating it as a mathematical optimization problem to determine the minimum weight of the device with a given assumptions and expectations is quite new, proposed in early 1970’s (Golinski, 1970). Currently, there are several types and brands of a speed reducer. One of the common type is shown in Figure 1.

In the literature, there are a number of variants of the problem with minor difference in the assumptions. In this paper, we consider the two versions of the problem. The first class is as proposed in Chihsiang and Papalambros (1996) whereas the second is as presented in Golinski (1970).
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