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Application of metaheuristic algorithms in the dimensional synthesis of a hybrid rigid-flexible four-bar linkage for open-path generation

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Abstract

Hybrid rigid-flexible mechanisms are very current due to their good characteristics, but due to the complexity of the design process, they are less common than traditional ones, both in practice and in the literature. When designing hybrid mechanisms, the methods developed to design compliant mechanisms are most often practiced, while dimensional synthesis is applied sporadically. Therefore, this paper will focus on the problem of dimensional synthesis of a hybrid four-bar mechanism for open-path generation. The input link of the hybrid mechanism is flexible and represented as a fixed continuum rod of constant curvature. To solve the considered problem, four modern metaheuristic algorithms were applied: DE, MPA, SHADE-WOA and DE-MPA. The analysis of the efficiency of the applied algorithms was performed through four different examples of dimensional synthesis of the hybrid four-bar linkage for open-path generation. Similar to the case of the optimal synthesis of a traditional mechanism with rigid links, the application of metaheuristic algorithms in hybrid mechanisms achieved satisfactory results, which was confirmed by a corresponding comparative analysis.

Keywords

Hybrid mechanisms, dimensional synthesis, open-path generation, metaheuristic algorithms, optimization

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Introduction

The problem of the dimensional synthesis of mechanisms has always been interesting for researchers. The dimensional synthesis aims to design the geometric parameters of a mechanism whose coupler point should describe the motion that will follow the path defined by the appropriate number of prescribed points. At the same time, the deviation of the actual path from the desired one, which is defined by precision points, should be as small as possible. A large number of studies are focused on the dimensional synthesis of mechanisms with rigid links.[1–3] The reason for this is the fact that these mechanisms can be analyzed without considering forces and elastic deformations. In other words, kinematic analysis can be completely separated from dynamic analysis.

The development of modern industrial production was the motive for the creation and development of compliant mechanisms. The advantages of these mechanisms compared to traditional ones are that there is no clearance, wear, and friction, and they are more precise and lighter. The main disadvantage of compliant mechanisms is the limitation of deformation due to limited allowable strain. In addition, the design of these mechanisms is more complex compared to conventional ones, because elastic strain must be taken into account.

As a response to the shortcomings of compliant mechanisms, hybrid rigid-flexible mechanisms were developed. A hybrid rigid-flexible mechanism is a mechanism composed of both rigid and flexible links.[4] The joints of the rigid body and the elasticity of the rods enable the movement of the hybrid mechanism.

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