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Design and Analysis of a Three-dimensional Bridge-type Mechanism based on the Stiffness Distribution

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Highlights

1. A 3-D bridge type mechanism with ultra-large amplification ratio is proposed in this paper.

2. The concept based on the stiffness distribution design is used to improve the performance of the 3-D bridge type mechanism with combined flexure hinges.

3. A new evaluation index, relative amplification rate is proposed to evaluate the displacement loss of the amplifier.

4. A reinforced beam approach is employed to further downsize the structure of the amplifier.

Abstract

A 3-D bridge-type mechanism is designed and analyzed in this paper. Compared with the previous design, the mechanism proposed in this paper, among other advantages that the conventional bridge-type mechanisms have e.g., compact size, simple design and symmetric structure etc, features a high amplification ratio. To evaluate the displacement loss of the amplifier, as a new evaluation index, the relative amplification rate, is proposed in this paper. An analytical model for the amplification ratio and the relative amplification rate is established based on the screw theory. Several bridge-type mechanisms combined with four frequently used flexure hinges are analyzed based on the consideration of stiffness distribution, which are compared via the aforementioned analytical model. Based on the comparison, the numerical results show that the proposed bridge-type mechanism reaches the optimal performance in terms of the amplification ratio and the relative amplification rate when the V-shaped hinge and the filleted leaf hinge are employed in bridge 1 and bridge 2 respectively. Finally, the performance of the amplifier with amplification ratio of 41 and relative amplification rate of 0.93 is confirmed by FEA simulation and experiments.

Keywords: Flexure hinges; Bridge type mechanism; Amplification ratio; Stiffness distribution

1. Introduction

Compliant mechanisms are frequently used in high precision engineering [1-3], in which piezoelectric stack is a widely employed actuator [4, 5] due to its outstanding features, e.g., high stiffness, high resolution and large blocking force. However, in general, the stroke of the piezoelectric stack is only about 0.1%~0.2% of the length of the piezoelectric materials [6, 7], which is difficult to satisfy the application when a large workspace is needed. To solve this problem, many kinds of displacement amplifiers are proposed and developed.

Generally, the amplifiers can be divided into three types based on the fundamental principle, i.e., the lever-type amplifier [8], the Scott-Russell amplifier [9] and the bridge-type amplifier [10, 11], as illustrated in Fig. 1. Compared with