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Compliant constant-force linear-motion mechanism

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ABSTRACT

A fully compliant constant-force mechanism that uses an initially angled parallel-guiding mechanism is proposed. A pseudo-rigid-body model (PRBM) of the mechanism is developed and validated using both finite element models and experimental prototype testing. The PRBM is used as a preliminary design tool to identify parameters that result in a constant-force mechanism. An adjustable version of the mechanism is also proposed and is used to assess the range of validity of the PRBM and highlights how the system response can be varied by changing the flexible beams inclination. A finite element based optimization is used to create a modified version of the mechanism that incorporates beam-end rotation effects and offers greater performance. Potential applications for the mechanism are discussed and it is demonstrated as a component of a statically balanced system.

1. Introduction

A constant-force mechanism (CFM) has a constant reaction force over a range of displacements. These mechanisms have potential in applications where a certain amount of contact force is desired such as in electrical connectors [1,2] and automotive clutches [3,4]. CFM's can be used in exercise equipment to simulate free weights [5,6], in robot end-effector applications [7,8] and grippers for handling objects of various sizes [9]. Adjustable constant-force mechanisms have been achieved by combining bistable mechanisms with preloaded linear springs [10]. CFM's have also been combined with bistable mechanisms to provide overload protection in force regulation applications [11]. Applications for constant-force mechanisms range from devices such as snap fits [12] to micro-electromechanical systems [13,14].

Early constant-force mechanisms were constant-force tension springs which are also known as Negator springs [15]. These springs consist of a strip of spring steel in a tightly wound coil and are found in consumer items such as tape measures and pull-starts. Nathan proposed a rigid link constant-force generator which produces a constant unidirectional force for any position [16]. This basic mechanism is found in many gravitational force balancing applications such as desk lamps. Other rigid link-mechanisms which produce constant-force have also been developed [17]. Methods for the design, analysis, and application of compliant constant-force mechanisms continues to be a topic of research [18–23].

The compliant constant-force linear-motion mechanism proposed in this paper combines constant-force characteristics with a parallel guiding mechanism. This mechanism consists of an initially tilted parallel guiding mechanism on a sliding joint and a grounded connecting link as shown in Fig. 1.

By mirroring this mechanism along the ground link, a slider is no longer needed and the mechanism can achieve constant-force displacement without sliders or revolute joints, i.e. it is a fully compliant constant-force mechanism. This mechanism

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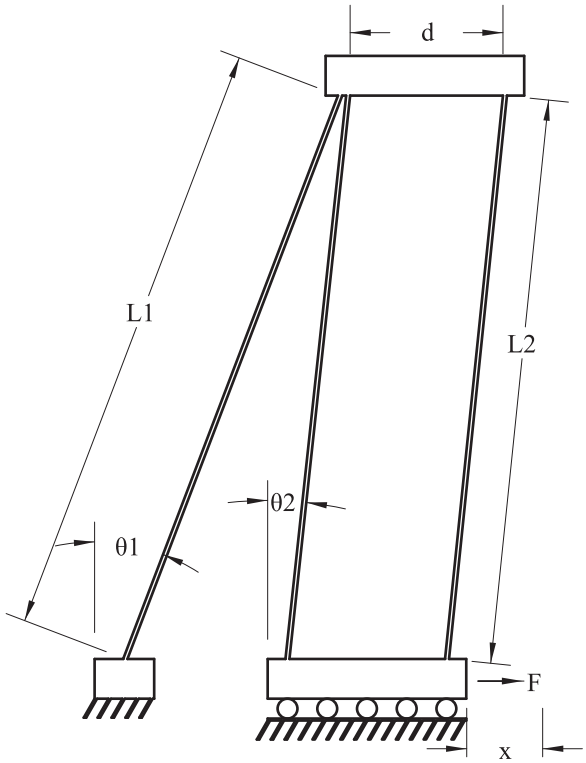

Fig. 1. Proposed constant-force mechanism.

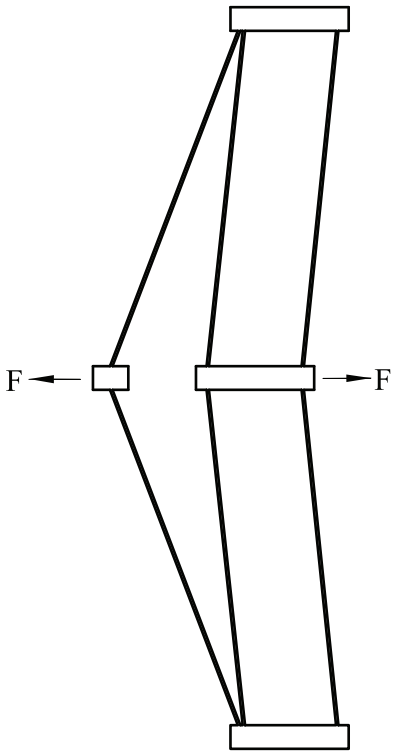

Fig. 2. A fully compliant version of the constant-force mechanism.