Mechanism and Machine Theory 124 (2018) 150–161

Contents lists available at ScienceDirect

Mechanism and Machine Theory

journal homepage: www.elsevier.com/locate/mechmachtheory

Research paper

A new pseudo-rigid-body model approach for modeling the quasi-static response of planar flexure-hinge mechanisms

Slaviša Šalinić*, Aleksandar Nikolić

University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, Kraljevo, 36000, Serbia

ARTICLE INFO

Article history:
Received 30 August 2017
Revised 1 December 2017
Accepted 28 February 2018

Keywords:
Flexure hinge
Compliant mechanism
Pseudo-rigid-body model
Serial
Parallel
Micro-motion stages

ABSTRACT

In this paper a new pseudo-rigid-body model (PRBM) of flexure hinges used in planar flexure-hinge mechanisms with small deformations is presented. Unlike the 1-DOF freedom PRBM used in the existing literature, the PRBM proposed has 3-DOF (degrees of freedom). Using the 3-DOF PRBM of flexure hinges, planar flexure-hinge mechanisms can be represented as rigid multibody systems whose adjacent rigid bodies are connected by 3-DOF joints. After applying this modeling procedure, the principle of virtual work yields a matrix relation for the determination of the quasi-static responses of a flexure mechanism due to external loads. The validity and accuracy of the approach for quasi-static analysis of planar flexure-hinge mechanisms based on the 3-DOF PRBM are examined using the examples of two types of compliant mechanisms: RRR and 3-RRR compliant micro-motion stages.

1. Introduction

Compliant planar mechanisms based on flexure hinges are widely present in many industrial applications such as micro/nano positioning, micro/nano measuring mechanisms, nanomachining etc. Unlike classical mechanisms, problems of friction, wear and bucklash do not occur in compliant mechanisms. Thanks to this fact, in many cases, compliant mechanisms have advantage in use over classical mechanisms.

In the literature there are various approaches for analysis of quasi-static response of planar compliant mechanisms with small deformations of flexure hinges. These approaches can be roughly divided into four major groups depending on whether they are based on using the finite element method (FEM) [1–3], the pseudo-rigid-body model (PRBM) method [4–7], the Castigliano's displacement theorem [8–10], or the matrix method [11–15]. It is interesting to note that [15] considers the planar compliant mechanisms, where the case is analyzed for the first time in the literature when the external loads are applied not only to the rigid links but also to the flexure hinges. The PRBM method, the matrix method and the Castigliano's displacement theorem based approaches use flexure hinges compliance coefficients which can be obtained in the form of symbolic expressions using the Castigliano's displacement theorem (see [8]) or by the integration of linear differential equations of beams [11,16]. Numerical values of these coefficients may be obtained by FEM [17,18]. In this context, it should be pointed out that in [18] investigations were carried out on the effect of flexure hinges coefficients obtained by various approaches on the accuracy of quasi-static analyses of the planar micro-motion stages.

* Corresponding author.
E-mail addresses: salinic.s@ptt.rs (S. Šalinić), nikolic.a@mfkv.kg.ac.rs (A. Nikolić).

https://doi.org/10.1016/j.mechmachtheory.2018.02.011
0094-114X/