Testings of discrete modelings of planar compliant mechanisms through flexible multibody simulations

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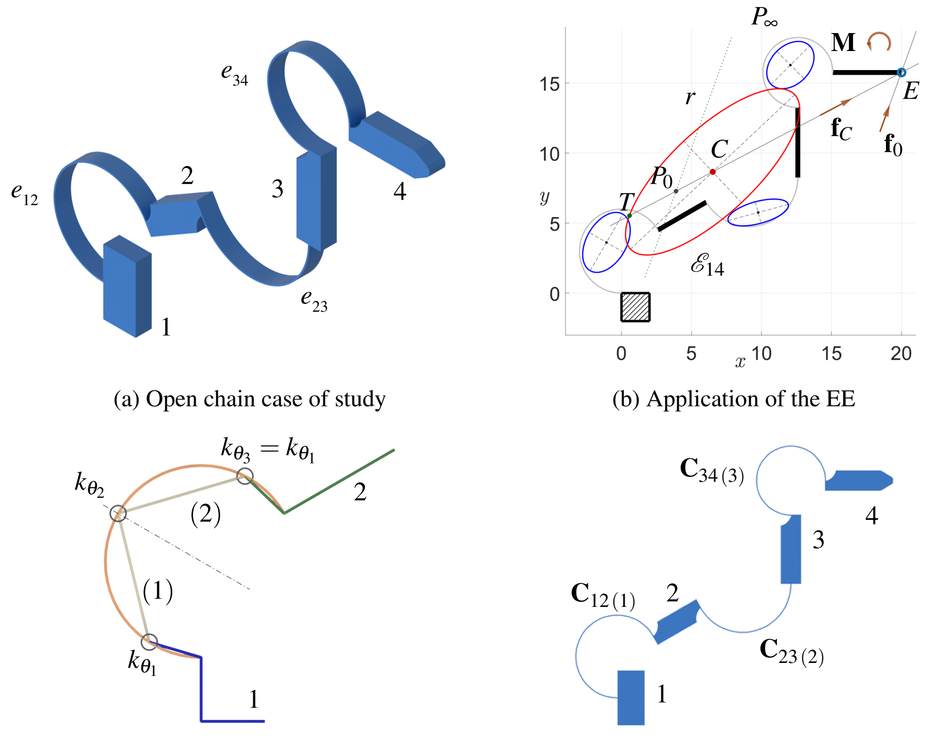
EXTENDED ABSTRACT

Compliant mechanisms derive their mobility from the load-dependent deformations of flexible elements, or flexures [1]. The contactless and generally monolithic nature of these systems determines reduction of wear, backlash, lubrication, fabrication time and costs, and compatibility to MEMS-based technologies. A wide range of analytical procedures and design strategies has been produced for the modeling of the load-dependent displacements of these systems. Exhaustive surveys of the most adopted models and procedures can be found in Refs. [2, 3, 4]. Analogously, in the multibody simulation field, compliant mechanisms can be modeled in several ways [5]. More specifically, a full-flexible (FFlex) modeling employs FEA computations carried out together with the general kinematic and dynamic analyses. As a result, simulations are often time-consuming and do not lead to the identification of significant parameters for the synthesis procedures. For this reason, in this paper, some simpler models are adopted and compared to the results obtained by means of Fflex simulations. More specifically, the adopted discrete models are:

a) the pseudo-rigid body model (PRBM): PRBMs replace the deformable continuum of the flexures with a finite number of rigid links connected by kinematic joints [6, 7]; in particular, a 3R PRBM for uniform circular beams is implemented [8];

b) a compliance matrix-based modeling [9]: the flexure or, in general, a two-ports suspension, is modeled by means of a linear loads-displacements relation. In multibody environments the method can be implemented through a chain-algorithm for higher order approximations, in what is here called Sequential Compliance Matrix-Based Method, SCMBM.

c) the ellipse of elasticity theory (EE): the theory is adopted in structural engineering modeling and has been recently introduced for the analysis of compliant mechanisms [10]. The theory allows for a straightforward first-order characterizations of flexible elements and compliant mechanisms.



(a) Open chain case of study

(b) Application of the EE

(c) PRBM modeling

(d) Matrix modeling

Figure 1: Case study of a four-links compliant open chain

Models a) and b) are implemented in discrete-flexible (DFlex) multibody simulations, and model c) is used to determine *a priori* the kinetostatic features of the compliant mechanism. It is worth noting that a compliance matrix and the ellipse of elasticity can both be defined in relatively easy ways for any kind of flexure, whereas the PRBMs usually require specific studies. As case study, the four-links compliant open chain shown in Fig. 1a is considered. The end-effector is represented by the output point E of link 4, that is the interaction point between the mechanism and the external environment. The mechanism, and the load conditions, are modeled by the EE (Fig. 1b). The circular flexures e_{12}, e_{12}, and e_{12} are modeled by shell elements in the FFlex simulations, and replaced by the 3R PRBM (Fig. 1c) and compliance matrices (Fig. 1d) in the DFlex simulations. Figure 2 shows a comparison of the results obtained with the different modelings, considering horizontal non-follower forces as load condition and the dispèlacements of e from the starting position E_0. In case of small displacements, the predictions by the EE are validated. In case of large displacements, the systems responds asymmetrically to forces with same modulus and opposite sense. The non-linear behavior is very well described by the DFlex simulations, performed with a computation time reduced by two orders of magnitude with respect to the FFlex simulations. Generally, the simulation discrete modelings show good agreement with the FFlex results in case of large deflections, and EE is validated in case of small deflections.

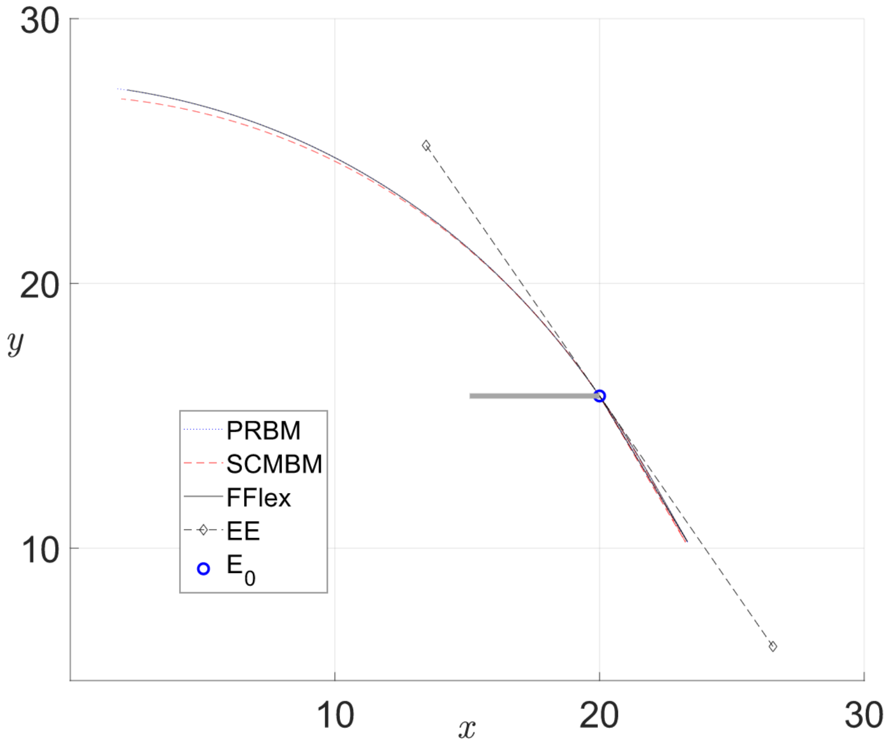


Figure 2: Compared results of the modelings in the case of study, and load conditions of horizontal forces.

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