A study on the dynamics of the flexible link mechanism with a spatial model of the translational joint with clearance

Krzysztof Augustynek, Andrzej Urbaś, and Jacek Stadnicki
*Department of Mechanical Engineering Fundamentals, University of Bielsko-Biala, Bielsko-Biala, Poland

Abstract. The paper presents the dynamics model of the RPSUP mechanism with a clearance in a translational joint. The spatial model of the clearance in the translational joint is proposed. In this model, inner surface of the slider is discretized into rectangular zones in which the contact between the slider and guide is detected. For each zone, three scenarios of the contact are possible: point, line, and surface contact. In numerical simulations interactions between the flexible coupler and the clearance in the translational joint will be studied and compared.

Introduction

The fifth class kinematic pairs (revolute and translational joints) are among the most popular types of joints in mechanisms. The possibility of modelling non-linear effects in these joints, such as friction or clearance, is very important from the point of view of the dynamics of the system [1–4]. There are many works in the literature devoted to both planar and spatial models of clearance in revolute joints [3]. The situation is different in the case of translational joints with clearance, where only a small number of papers deal with spatial models of clearance [1, 2]. In these models, some number of conditions are formulated to describe special cases of the position of the slider with respect to the guide.

This paper proposes an approach in which the internal surfaces of the slider are discretized into rectangular contact zones, where the contact between the slider and the guide can be analysed (Fig. 1). Depending on the number of nodes in contact and the depth of penetration, three cases of contact are considered: *point, linear and surface*. The normal contact force in node $(i,j)_p$ is calculated using the following formula [1]

$$\left\|\mathbf{f}_n^{(i,j)_p}\right\| = K^{(i,j)_p}\left(\delta_m^{(i,j)_p}\right)^{1.5} + C^{(i,j)_p}\dot{\delta}_m^{(i,j)_p},$$

where the generalized stiffness and damping $K^{(i,j)_p}$, $C^{(i,j)_p}$ depend on the type of contact (point, linear, surface), and $\delta_m^{(i,j)_p}$ is an average penetration depth in node $(i,j)_p$. The tangent force due to friction is modelled using the LuGre friction model.

The proposed model of the clearance will be analysed for the spatial RPSUP mechanism with the flexible coupler. The coupler is discretized using the Rigid Finite Element Method. The dynamics equations of motion are derived using the Lagrange equations of the second kind. Homogeneous transformation matrices and joint coordinates are applied in the derivations process. In numerical simulations, the influence of link flexibility and clearance in the translational joint on the dynamics response of the mechanism will be studied.

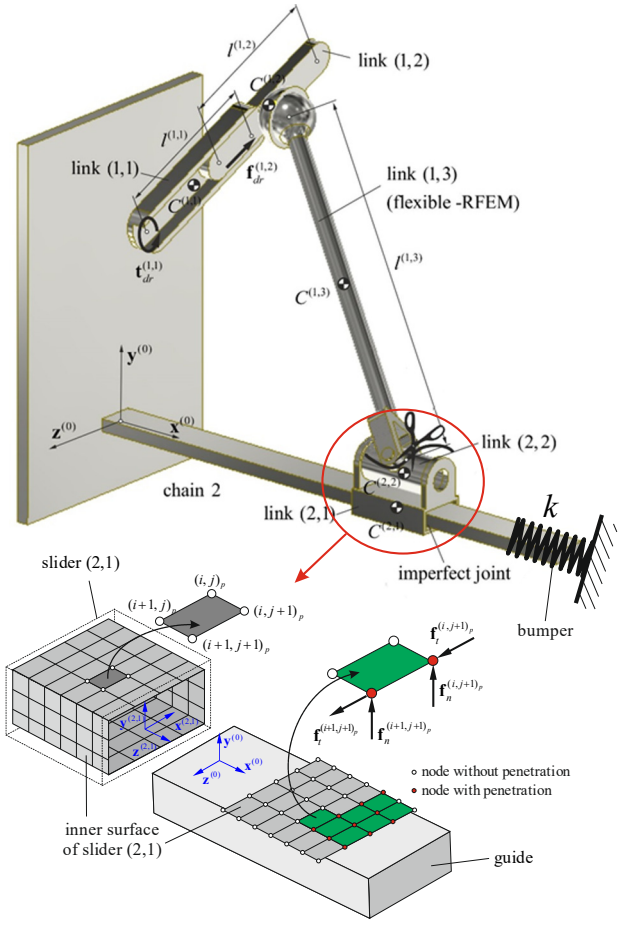

Figure 1: Model of RPSUP mechanism with the clearance in slider (2,1)

References

[1] Wu X., Sun Y., Wang Y., Chen Y. (2020) Dynamic analysis of the double crank mechanism with a 3D translational clearance joint employing a variable stiffness contact force model. *Nonlinear Dyn*. **99**:1937–1958.

[2] Qian M., Qin Z., Yan S., Zhang L. (2020) A comprehensive method for the contact detection of a translational clearance joint and dynamic response after its application in a crank-slider mechanism. *Mechanism and Machine Theory*. **145**:103717.

[3] Erkaya S., Doğan S., Şefkatlıoğlu E. (2016) Analysis of the joint clearance effects on a compliant spatial mechanism. *Mechanism and Machine Theory*. **104**: 255–273.

[4] Zheng X., Li J., Wang Q., Liao Q. (2019) A methodology for modeling and simulating frictional translational clearance joint in multibody systems including a flexible slider part. *Mechanism and Machine Theory*. **142**:103603.