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Synthesis of flexure hinges at topology optimization application

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Abstract: *Topology optimization methods[3] application in some cases at synthesis of high-accuracy notch flexure hinges can give controversial and not optimal recommendation.*
Key words: *topology, hinge, concave, convex, optimization, bending, error*

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I. Introduction

Developed in last two decades methods topology optimization of compliant mechanisms by right distribution of isotopic materials are general and interesting. However, practical application of these methods for synthesis of high-accuracy flexure hinges gave strange and controversial results.

1. Concave and Convex shape

Recent results of high-accuracy flexure hinges synthesis with topology optimization methods are shortly discussed by Ref.1 on the bottom of page 122: recently proposed (Rev. Sci. Instrum.87,0555106, 2016)on the basis of topology optimization methods Q-V-shaped hinge with convex sides and straight middle section provide design with small distance d_{ea} between center of the hinge and the center of its rotation for minimization of rotation error, but have smaller compliance (larger stiffness), larger stress, less limit of rotation, and less life expectancy at cycling regime of work than the regular V-shaped flexure hinge. Regular V-shaped, other flexure hinges and their bending elements, used in micro-nanomechanics, usually have concave configuration that provide larger compliance, smaller stiffness, smaller stress, larger limit of rotation, and larger life expectancy, but may have a larger $d_{ea,}$ which does not cause significant rotation error at correct elements position of the mechanism.

Tseytlin formulae[2] for synthesis of notch flexure hinges, based on the effective theory inverse conformal mapping with contour approximation, were successfully used by many researchers and specialists for cylindrical and elliptical notch flexure hinges synthesis. Researchers[4]in LIGO (Nobel Price 2017) used them for synthesis of low frequency elliptical hinges connected with optical system to capturing the gravitational waves. Later those formulae were developed by us[1] for many different concave profiles. These formulae are tractable, concise, and easy to use. Indeed, it is not necessary in all cases to have small distance d_{ea} from the center of flexure hinge to the center of its rotation to minimize the rotation error.

2. Kinematics

This is shown by us[1] in analysis the flexure hinge kinematics of rotation poles motion on pages 146-147: at a small rotation angle of the circle rolling on the straight line, the cycloid trajectory of contact point is close to the semi-cubic parabola. At a finite angle of rotation within α_z=0.1 rad (5.7^o), we have a small shift of instantaneous center of rotation (ICR-first pole) coordinates $X_{ICR}=\alpha_z^3 d_{ea}/6= 0.00017d_{ea}$ and $Y_{ICR}=\alpha_z^2 d_{ea}/2 =0.005d_{ea}$ from their initial ($-d_{ea}$, 0) position, which should be established at mechanism synthesis. This may be considered in many cases as a practically negligible shift despite that the distance d_{ea} is not very small one.

In conclusion, the application of topology optimization methods for synthesis of notch flexure hinges requires careful consideration of their features and options.

Reference

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