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Optimum Synthesis of Oscillating Slide Actuators for Mechatronic Applications

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Abstract: The oscillating-slide inversion of the slider-crank mechanism, commonly symbolized RPRR, is widely used to convert the displacement of an input linear motor (either electric, hydraulic or pneumatic), into the swing motion of a rocker. This paper discusses the optimum kinematic synthesis of the centric RPRR mechanisms for prescribed limit positions, while simultaneously satisfying either (*i*) minimum deviation from 90 degrees of its transmission angle, (*ii*) maximum mechanical advantage, or (*iii*) linear correlation between the input- and output-link motions. To assist practicing engineers, step-by-step design procedures, together with performance charts and parametric design charts are also provided in the paper.

Keywords: slider-crank inversion, limit positions, transmission angle, mechanical advantage, uniform motion, optimization;

1. Introduction

The centric *oscillating-slide* with translating input or RPRR in short (where the underscore indicates a powered joint), also known as *cylinder-incline*, *turning-block* or *swinging-block* linkage [1], [2] is one of the most widely used inversion of the slider-crank mechanism. It has numerous applications in robotics and industrial automation, aerospace, automotive, agricultural and earth moving machinery etc. where it serves to convert the input motion of a linear actuator into partial rotation of an output-link rocker [3], [4], [5], [6] [7] (Figure 1).

The synthesis of the centric RPRR mechanism for prescribed limit positions of the output link, given the minimum and maximum lengths of the linear motor, can be relatively easily performed graphically [7], [8], [9]. There is no guarantee however that best motion transmitting characteristics are achieved, quantified by the *transmission angle* [10], [11] or by the *mechanical advantage* [1], [12]. In addition, there are applications where a linear correlation between input and output is desired, such that the need for an additional encoder on the rocker shaft is eliminated [13].

This paper investigates through repeated optimizations and bivariate plots [14] the synthesis of centric RPRR oscillating-slide actuators for a prescribed rocker swing, given the fully retracted and fully extended lengths of the linear motor, while ensuring, throughout the motion range of the mechanism either of the following requirements: (*i*) minimum deviation from 90° of the transmission angle, (*ii*) maximum mechanical advantage, (*iii*) a near-linear correlation between input and output motions.

Transmission angle (noted μ throughout the paper) should not depart more than ±45° from the ideal value of 90°. If a self-return of the output link is ensured by gravitational or elastic forces, transmission-angles ranging between 30° and 150° are still regarded as satisfactory [6][9][11].

In most applications, the gravitational and inertia forces acting upon the actuator of a centric RPRR mechanism are small relative to the load forces. Therefore, the linear motor will act as a two-force member i.e. the reaction forces between the piston and the cylinder (or equivalent) will be small, which is a major advantage over the PRRR slider-rocker mechanism actuators [15], [16]. However, if piggyback-hydraulic cylinder or side-bracketed electrical-actuators are employed (Figure 2), these

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