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Kinematics Analysis of a Leg Mechanism as a Motion Converter

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Abstract – *This paper presents kinematics analysis of a leg mechanism for converting linear motion into rotary motion to be used as a Regenerative Shock Absorber (RSA). The kinematics analysis determines the positions, the velocities and the accelerations when a leg mechanism is subjected to a linearly reciprocating motion. The main objectives of this paper are to obtain valid mathematical models and to figure out the ability of the mechanism converting motion. The work carried out in this paper includes deriving and analyzing mathematical model using analytical kinematics.*
A numerical simulation is used to show the response of the mathematical models. The validation is performed by comparing the result from kinematic simulation software and numerical simulation of the mathematical models. The performance of a leg mechanism is evaluated under sinusoidal displacement input for typical amplitudes and frequencies. The validation results show that the proposed mathematical models are generally valid. Moreover, the mechanism can convert 0.04 m of linear motion into 116.84° of rotation motion.

***Keywords**: Kinematics Analysis, Leg Mechanism, Motion Converter, Linear to Rotary Motion*

Nomenclature

RSA	Regenerative shock absorber
TLM	Two leg mechanism
L_1	Total length of the bottom plate
L_2	Length of A point to B point in Y-axis
L_3	Length of the upper plate to the bottom plate in Z-axis
L_4	Length of A point to B point in X-axis
L_{UP}	Total length of the upper plate
L_{AB}	Total length of Rod AB
θ	Rotation angle of the bottom plate
V_A, V_B	Linear velocity of A point and B point, respectively
V_{BA}	Linear velocity of B with respect to A
ω_{BA}, ω_{BC}	Angular velocity of B respect to A and B with respect to C, respectively
$(\omega_{BA})_{XYZ}$	Angular velocity of B respect to A in *x*-, *y*-, *z*- axes, respectively
r_{BA}, r_{BC}	Relative position of B with respect to A and B with respect to C, respectively
a_A, a_B	Linear acceleration of A point and B point, respectively
a_{BA}	Linear acceleration of B with respect to A
α_{BA}, α_{BC}	Angular acceleration of B with respect to A and B with respect to C, respectively
$(\alpha_{BA})_{XYZ}$	Angular acceleration of B with respect to A in *x*-, *y*-, *z*- axes, respectively
i, j, k	Directions of the moving axes and fixed to the *x*-, *y*-, *z*- axes

I. Introduction

RSA has been of interest of many researchers for decades. Based on the energy conversion mechanism, the above systems can be classified into two main categories such as RSA using a linear generator and RSA using a rotary generator [1].

RSA using a linear generator directly converts the oscillating motion of mechanical energy into electrical energy without any motion transmission equipments. There are several drawbacks to this model such as a larger leakage magnetic flux, a smaller damping resistance, a small amount of energy harvesting and more energy consumption to provide better ride comfort [1]-[2]. In the other hand, RSA using a rotary generator needs a motion converter mechanism to convert linear motion into rotary motion.

The key of its model is in the motion converter mechanism. There are three types of a motion converter mechanism that have been widely developed in [2] and [3] such as hydraulic, ball screw and rack pinion.

Hydraulic transmission mechanism in regenerative shock absorber was patented by Avadhany et al [4]. Several drawbacks are reported in [5] such as the air trap in the hydraulic system that creates a delay in the response of shock absorber and has high costs for maintaining high precision, both in sealing and in pipelines connections.

Ball screw mechanism converts linear motion into rotary motion via a ball screw system with fixed nut that moves linearly [6]-[10]; some disadvantages of this mechanism are in an issue regarding its reliability and its friction caused by interaction between ball screw and nut.

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