College of Engineering

TENNESSEE TECH

The Department of

Mechanical Engineering

Announces the Thesis Defense

of

Cody Leeheng Chan

In Partial Fulfillment of the Requirements

For the degree of

Doctor of Philosophy in Engineering

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Tennessee Tech University

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FIELD OF STUDY

Mechanical Engineering

Dissertation Topic

Kinematic Effects of Joint Clearances on Serial Robots and Parallel Manipulators

EXAMINING COMMITTEE

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ABSTRACT

This dissertation aims to investigate the kinematic effects of joint clearance on serial robots and parallel manipulators. The research deals with planar and spherical linkages. The research studies the effect of joint clearances in two aspects, knowing or without knowing the external load. Without knowing the external load, the research focuses on estimating the maximum uncertainty range of the end-effector or the output angle induced by the joint clearances. This can be used to quantify the tolerance range and to prevent the mechanism reaching its singularity. With known external loads, the research considers the error vector of each joint to calculate the position and orientation deviation of the end-effector in static case. This can be used in input angle adjustment for robots and parallel manipulators.

The orientation uncertainty of the end-effector of planar mechanisms is investigated. Based on the imaginary clearance link model and the invariant link rotatability, the uncertainty problem is treated as a mobility problem of the floating link for the remodeled linkages. The joint rotation space method is presented to identify the mobility between any two links as well as the branch formation. The mobility of Stephenson six-bar linkages, 2-D.O.F. seven-bar linkages, and 3-D.O.F. eight-bar parallel manipulators are studied and demonstrated.

Based on the concept of free-body diagram analysis and contact force model, the research presents a simple kinematic model and methodology to estimate the clearance-induced error in static equilibrium for planar serial and parallel manipulators. Taking advantage of the commercial computer aid design software, the research presents an intuitive geometric method to analyze the position and orientation of the end-effector. The discussion is demonstrated systematically through the serial RR robots, five-bar linkages, 3RRR eight-bar linkages, serial PP robots, and prismatic parallel robots.

For the spherical linkages, considering the joint clearance, the research presents a kinematic model to evaluate the orientation uncertainty based on the spherical N-bar rotatability laws and the invariant link rotatability. The uncertainty range of the output angle of spherical four-bar linkages and the uncertainty region of the end-effector of five-bar linkages are studied.

BIOGRAPHICAL SKETCH

Cody Leeheng Chan was born in Jackson, Mississippi, in 1995. He attended National Tsing Hua University in Taiwan in 2013 and received the degree of Bachelor of Science in Power Mechanical Engineering in 2017. He began working on a Ph.D. in Engineering at Tennessee Tech later that same year. His research interest includes curvature theory, gear tooth profile generation, joint clearance analysis, and theoretical kinematics.

EDUCATION

Ph.D. Engineering
Tennessee Tech University, 2017-2021 (expected)

B.S. Power Mechanical Engineering
National Tsing Hua University, 2013-2017

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