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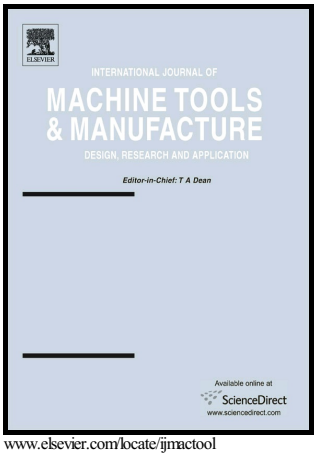

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A five-axis geometric errors calibration model based on the common perpendicular line (CPL) transformation using the product of exponentials (POE) formula

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Abstract: Geometric error calibration is a key procedure to improve machining accuracy of five-axis CNC machine tools. This paper proposes a new position independent geometric errors (PIGEs) calibration model of five-axis serial machine tools based on the product of exponentials (POE) formula. The proposed model is characterized by the common perpendicular line (CPL) transformation which is adopted to express the deviation between the nominal axis twist and the actual one. One major advantage of the proposed model is the axis twists in the proposed calibration procedure with CPL model strictly fit the constraints of the revolute axis and prismatic axis, thus the calibration procedure avoids the normalization and orthogonalization as required by existing calibration models based on POE formula. The other advantage of the proposed CPL model is that it only needs 4 independent parameters for PIGEs of a revolute axis and 2 for PIGEs of a prismatic axis, rather than 6 parameters for each axis as required by existing models. Apparently, the decrease of parameters brings a shrink to the scale of the identification coefficient matrix, and thus decreases the calculation amount. The proposed model is validated by simulations and experiments.

Keywords: Five-axis; geometric error; product of exponentials formula; kinematics; CNC

Nomenclature

$\mathbf{g}$	Transformation matrix
$\boldsymbol{\xi}$	Twist coordinate
$\boldsymbol{\omega}$, $\mathbf{v}$, h	Orientation, moment and pitch of the twist axis
$\mathbf{q}$	Point locating on the twist axis.
$\exp(\hat{\boldsymbol{\xi}}\cdot\theta)$	Exponential map of $\boldsymbol{\xi}$ with rotational or translational motion θ
$Ad(\mathbf{g})$	Adjoint transformation of $\mathbf{g}$
$\{O\}$, $\{W\}$, $\{T\}$	Machine frame, workpiece frame and tool frame
$\mathbf{P}_W$	Tool tip position with respect to workpiece frame
$\mathbf{P}_T$	Tool tip position with respect to tool frame

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