Accepted Manuscript

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PII: S0141-6359(18)30203-4
DOI: 10.1016/j.precisioneng.2018.07.005
Reference: PRE 6804

To appear in: *Precision Engineering*

Received Date: 3 April 2018
Revised Date: 30 June 2018
Accepted Date: 17 July 2018

A Generic Approach for Analysis of Mechanical Assembly

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Abstract: Assembly tolerance analysis is increasingly becoming an innovative method for checking whether specified tolerances satisfy assembly functional requirements. Skin model shapes that employ discrete geometry methods can be addressed efficiently when covering geometric tolerances, especially form defects over the product's lifecycle. The point cloud–based discrete geometry uses the actual surfaces to replace the ideal or substitute surfaces in conventional methods, which brings a significant improvement in analysis accuracy and reliability. However, the level of detail and the ordinal simulations restrict their use to simple assemblies. To overcome the issue of the skin model shape in representing deviation propagation, integration of the Jacobian model is proposed; the resulting skin model shapes-Jacobian model combines easy-to-use tolerance propagation and tolerance representation with accuracy guarantees. Besides, Relative positioning method enables calculation of the small displacement torsors for serial or parallel joints, which makes the proposed method a generic approach applicable to both serial and partial parallel kinematic chains. The obtained torsors in the Jacobian model are then used to calculate the final deviations of the functional requirement. The approach is finally illustrated by a practical example.

Key words: Assembly tolerance analysis; Skin model shapes; Jacobian model; Serial joints; Parallel joints; Small displacement torsors.

Symbols and Abbreviations

FR	functional requirement
FE	functional element
KP	kinematic pair or contact pair
IP	internal pair
T_r	rotational components of small displacement torsor
T_t	translational components of small displacement torsor
IFE	internal FE
KFE	kinematic (contact) FE
PFE	parallel FE

1. Introduction

Tolerance analysis is performed in manufacturing to predict the quality of an assembly when tolerances have been assigned to its components. A proper analysis result can provide guidance for industries to optimize parameters in design. The dimensional and geometric variations of each part in an assembly must be limited by tolerances to ensure not only standardized production, but conformance of the FRs assigned on the whole assembly. Tolerance analysis enables prediction of the effects of individual part deviations on assembly requirements and key functional characteristics. The results of stackup analysis of dimensions and tolerances are meaningfully conditioned by two things: tolerance representation and tolerance propagation.

Tolerance representation indicates the adopted mathematical or physical models that describe the possible variations for a specified GD&T scheme. In the literature, many mathematical representation models for tolerance analysis have been proposed, i.e., TTRS model [1], matrix model [2], vector loop [3, 4], Jacobian model [5], Torsor model [6], Jacobian-torsor model [7], GapSpace [8, 9], T-Map model