Physically Based Modelling for Evaluating Shape Variations

H. SUZUKI, K. KASE, K. KATO and F. KIMURA
The University of Tokyo
Department of Precision Machinery Engineering, Hongo 7-3, Bunkyo-ku, Tokyo 113, JAPAN.
Telephone: +81-3-3812-2111, ext. 6490, Fax: +81-3-3812-8849
email: suzuki@cim.pe.u-tokyo.ac.jp

Abstract
In the designing of mechanical products, it is important to analyze the causal relationship between variations in part's shapes and their effects on the product's functionality. Computer simulations are promising design tools for evaluating those effects. This paper describes our attempt to apply physically based modelling methods to implement simulations, in particular, those for calculating the contact states of an assembly of simple parts and its motion. These simulations adopt simplified physical models, since their real physical phenomenon involves numerous complex factors. In this sense, the simulations do not necessarily reflect real physical behaviors, but the results of the simulations are considered helpful for designers to qualitatively grasp the relationship between behaviors of an assembly and variations in part's shapes.

Keywords
Computer Aided Tolerancing, Variational Modelling, Physically Based Modelling, Contact State, Rigid Body Motion.

1 INTRODUCTION

Demands for computer aided tolerancing (CAT) systems are increasing and a number of studies have been conducted on this subject. One of the fundamental factors that has become clear through those studies is causal relationship, from geometrical errors in product's shape to product's functionality, interchangeability and other product life cycle properties. This factor is crucial for implementing CAT systems.

Of course, experienced designers usually have knowledge for this factor to some extent. They know how much tolerance must be given in order for a product to work properly with longer duration, etc. They also know how much accuracy can be achieved by what kind of manufacturing methods and their costs. Thus one straightforward approach for implementing CAT may be a knowledge based approach in which such knowledge of expert
designers is applied. This kind of CAT is very useful, however, it has some drawbacks. For instance, it does not work well for very novel designs.

Another promising approach which is more generic for implementing CAT is a simulation based approach where the physical behaviors of products with geometrical errors are evaluated so that designers can estimate effects on behaviors caused by the geometrical errors. For instance, several articles have been devoted to the study for analyzing cumulative geometrical errors of part’s tolerances in an assembly based on assembly simulations[6, 6, 6].

In this paper, we are also interested in such assembly tolerances as well as more kinematic behaviors related to interaction (contacts) between parts. For this purpose, techniques of physically based modelling are used, which have been developed in the field of computer graphics in order to create realistic animations by employing physical laws. In particular, theories and methods for rigid body motion are introduced.

In order to evaluate effects of geometrical errors, it is necessary to represent these geometrical errors as computational models. In the following sections, we first briefly discuss this issue. Then two kinds of simulations will be shown. The first one is to calculate contact states of two rigid objects. Figure 1 provides an example of this simulation, showing a kinematic bearing way comprising of the platen and the bed of a lathe. This simulation calculates contact states of the platen and the bed when their shapes have geometrical errors. In the second simulation, the motion of the platen in a contact state is calculated. Free and contact motions of a rigid body are also simulated. Those are a brief review of our recent research works.

![Figure 1 Double Vee Type Kinematic Bearing Way.](image)

2 MODELLING GEOMETRICAL ERRORS

Research on the modelling of tolerance information has been conducted by a considerable number of researchers [6, 6]. Requicha[6] classified the tolerance models into two classes, the parametric semantics model and the zone semantics model. The zone semantics model represents a “tolerance zone” defined in the industrial standards as a volume or a proper subset of $E^3$. The volume is basically constructed by offsetting a nominal shape of an object. In this sense, this semantics is mathematically faithful to the original definition of the standards. However, to my view, it is very hard to implement simulations, specifically for dealing with characteristics in assemblies such as contact and fit, with this semantics model, because the boundary of a part’s shape is not fixed and also because it is needed to handle complex systems of inequalities[6].