INTRODUCTION

Tolerance is imperative for seamless integration of computer-aided design (CAD) and computer aided manufacturing (CAM) (Bjorke, 1989; Wu and Yang, 1999) and influences greatly the quality, process planning, measurement, cost and assembly of the product. Many researches have been conducted on tolerance (Baer, 1979; Requicha, 1982; 1983; 1992; Clement, 1991). Most of these researches are focused on tolerance analysis and tolerance synthesis. In some commercial CAD/CAM systems the tolerance module has also been imbedded (EDA/VisVSAs in IDEAS, CelTol in Pro/E, 3DCS in CATIA, eMTolMate in eMPOWER, etc.). Furthermore, in those systems tolerance information has already been correspondingly used with entity element. However there are still some issues. The tolerances are just analyzed numerically in most of those modules, such as statistical tolerance analysis and worst-case tolerance analysis. Tolerance analysis can just be conducted for 2D engineering drawings and many preparation works. For example, generation of the dimensional chain must be completed by hand. Moreover, tolerance information is just a text attribute in essence and lacks the interpretation of the engineering semantics. It is very difficult to carry out effectiveness evaluation of the given tolerance specification. Additionally in above mentioned imbedded tolerance modules, the used tolerance type is still very limited. And only the dimensional tolerance is analyzed. The geometric tolerances, which are widely used in mechanical design, are still not included in these tolerance modules.

In this study, a 3D tolerancing system is developed based on the mathematical definition of tolerance (ASME, 1994). The objectives of this work are: (1) Constructing a computer understandable tolerance representation model; (2) Interpreting the tolerance semantics in 3D environment; (3) Conducting tolerance analysis in 3D environment.
SYSTEM STRUCTURE

Function demand analysis of the 3D tolerancing system

As an important part of the whole product modeling, the 3D tolerancing system must have the following attributes in order to satisfy the requirement of the industry:

(1) Three-dimension. The system should deal with all the related tolerance functionalities in 3D environment.

(2) Wholeness. The system should correctly deal with all kinds of tolerance types, especially the complex tolerance types.

(3) Rationality. The system should give a rational representation of tolerance. On the one hand, all kinds of tolerance information should be organized and expressed independently and the semantic difference of all kinds of tolerance type should also be reflected. On the other hand, a fundamental framework for tolerance information integrated in CAD systems should be established.

(4) Interactivity. The system should offer the function with which the users can revise the tolerance interactively. If the users are not satisfied with the given tolerance type and size, they can change those conveniently.

(5) Effectiveness. The system should verify the correctness and validity of tolerance. Meanwhile, suggestions and methods for modifying the tolerance should also be given to the unreasonable part.

(6) Interpretability. The system should give the semantic interpretation according to the engineering semantics for different tolerance types.

(7) Seamlessness. The system should be integrated with the fundamental CAD system seamlessly.

System structure

According to above analysis of the function tolerance, a 3D tolerancing system is developed based on mathematical definition as shown in Fig.1. There are four layers: the kernel layer, functionality layer, application interface layer and user interface layer.

(1) Kernel module. It is composed of the kernel algorithms of tolerance representation, interpretation and analysis based on mathematical definition with the ACIS geometric modeling kernel, tolerance type database and rule database. This module is fundamental for the other parts of the system.

(2) Functionality module. It is the executive part of the whole system, and includes tolerance representation module, tolerance correctness evaluation module, tolerance semantics interpretation module, variational geometry generation module and 3D tolerance analysis module. The main functionality of each module will be introduced in detail in the following parts.

(3) Application interface. It provides the interface between the 3D tolerancing system and the subsequent application such as process planning, manufacturability evaluation, virtual manufacturing, virtual inspection and other applications.

(4) User interfaces. Users can call the functionality module and carry out the tasks of tolerance representation, modeling, evaluation and analysis through the user interface. It can also be used to show the generated variational geometry.

DESIGN AND REALIZATION OF PRIMARY FUNCTIONS

Hierarchical tolerance representation model

This system has three tolerance representation layers: (1) Layer of Feature-based Topologically and