Master Thesis Proposal

A CAD based Computer-Aided Tolerancing Model for Machining Processes

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July 2003

Abstract

The Computer Aided Design (CAD) has been a very important tool for the design and manufacturing in recent years. However, the CAD has often been used as 'Computer Aided Drafting' for engineering parts in industry. The 'design' part of the CAD is often not very well implemented and by improving on it we can enhance the usefulness of the computer-based component of the manufacturing process. A typical example is the tolerance specification in the design process of engineering parts, in which the parts are 'drafted' with nominal dimensions and then specified with tolerances based on experiences or manual calculation. This process can be improved using Computer Aided Tolerancing techniques and its integration of CAD system. A CAD based Computer Aided Tolerancing (CAT) model, integrating methods such as solid models, transformations and Monte Carlo simulations will be proposed in this study. A computer simulation case study for the machining processes will be used to demonstrate the model.

Introduction

In the design phase of the manufacturing process, Computer Aided Design (CAD) tools have been widely used for building solid models for parts to be manufactured. The solid models are specified with nominal dimensions and tolerances. The specifications heavily rely on engineering requirements, experience and manual calculation. The influence of the manufacturing process on tolerances has not yet been well understood. As a result, the tolerance specifications have to be revised from time to time in the manufacturing phase following the design phase. This type of changes may lead to negative impact on industrial operations. Therefore, it is very meaningful to research and develop scientific methodologies for determining the tolerance specifications during its design phase.

Computer Aided Tolerancing (CAT) has been a recent research focus to solve the aforementioned problem. There are two main directions in this field [1, 2]. The first one is the tolerance analysis, which studies the tolerance stack-up (or the final tolerance) given the individual component tolerances. The second one is the tolerance synthesis, which is optimizing the individual component tolerances given the specification of the final tolerance. This study focuses on tolerance analysis.

Commonly used methods for tolerance analysis include the Worst Case Method (WCM) and statistical methods such as Root Sum Square (RSS) method and Monte Carlo simulation (MCS) [2]. The WCM adds up (i.e., stacks up) individual tolerances assuming each component is specified with its extreme dimensions. The statistical method assumes a distribution of each individual dimension. The assumed distribution can be a normal distribution or others. In general, the statistical methods can generate a more reasonable tolerance than WCM since the latter model assumes extreme conditions that rarely happen. Statistical methods will be applied in this study.

CAT is applicable to various manufacturing processes such as the machining process, which in general refers to a material removal process from a workpiece using cutting tools. The process usually involves a workpiece, a cutting tool (such as a milling tool or a drilling tool), a fixture (to locate and fix the workpiece), and a machine (to rotate and move the cutting tools and to cut off material from the workpiece.) After the material removal, the workpiece will have a newly formed surface. The geometric quality of the new surface is often measured by tolerance specifications, such as flatness, roundness, and so on.

Geometric and dimensional tolerances are specified with more than ten different parameters, such as flatness, parallelism, roundness, angularity and so on. However, the published methods for tolerance analysis only deal with a limited number of them. For example, only two types of tolerances, i.e., flatness and parallelism, were modeled in [2]. The methods in [3] cannot process the surface geometrics such as flatness. Therefore, there is a need of developing more effective models for tolerance analysis applied to the machining process using CAD tools [2-5]. Based on the literature survey, the focus of this research is to develop a CAD based CAT model that deals with more applicable tolerance specifications, assuming the machining process variation is known. The process variation includes the variation of the workpiece (before cutting), of the cutting tool, of the fixture, and of the machine.

The proposed methodology integrates the CAD tools and methods (e.g., transformation) with the CAT methods (e.g., Monte Carlo simulation) to calculate the final tolerance of a machining process. Compared to those published methods, this study will present a more comprehensive model dealing with more tolerance specifications. The methods presented in this study can be used in the design phase for machining.

Proposed Methodology

The proposed methodology includes the following aspects:

First, a CAD software (e.g., Rhino) is chosen to generate a solid model of a part (to represent a workpiece to be machined). Then this model will be used to output a raw file with the coordinates of the surface points. These coordinates are the nominal dimensions and positions for the part.

The second step is to assign various dimensions for the fixture, the machine and the tool, which will be used for the machining operations.

The third step consists in generating a probabilistic variation for each individual component using the Monte Carlo Simulation method, assuming that the variability of each component is previously known already.

The fourth step is to calculate the new surface on the part. In this calculation, the matrix transformation method is used to calculate how much the new surface is deviating from the ideal position due to the variability in the machine, the tool, the part and the fixture.

In the end, the newly generated surface will be used to calculate various tolerances, such as the flatness, parallelism, roundness, and so on.

Proposed Schedule

This study is to be carried out in the following steps:

(1) Literature Survey (Jul. 2003-Aug. 2003)
(2) Model (methodology) Development (Aug. 2003-Oct. 2003)
(3) A Case Study (Nov. 2003)
(4) Thesis Completion (Aug. 2003-Dec. 2003)

Reference

[1] Dong, Z., 1997, "Tolerance Synthesis by Manufacturing Cost Modeling and Design Optimization," Advanced Tolerancing Techniques, John Wiley & Sons, pp. 233-260.

[2] Zhong, W., 2002, Ph.D. dissertation, "Modeling and Optimization of quality and productivity for machining systems with different configurations," University of Michigan, pp. 19.

[3] Huang Q., Shi J., and Yuan J., 2003, "Part Dimensional Error and Its Propagation Modeling in Multi-Operational Machining Processes", ASME Transactions, Journal of Manufacturing Science and Engineering. Vol. 125, pp. 255-262.

[4] Roy, U., Zhang, X., and Fang, Y. C., 1997, "Solid Model-Based Representation and Assessment of Geometric Tolerance in CAD/CAM Systems," Advanced Tolerancing Techniques, John Wiley & Sons, pp. 461-490.

[5] Chang, T. C., Wysk, R. A., and Wang, H. P, 1997, Computer-Aided Manufacturing, 2nd edition, Prentice Hall, Chapter 1-3, pp. 1-116.