THE FLORIDA STATE UNIVERSITY
FAMU/FSU COLLEGE OF ENGINEERING

MECHANICAL TOLERANCING FOR INTEGRATED DESIGN AND MANUFACTURING

By
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ABSTRACT

Mechanical tolerancing is a critical phase of product and manufacturing process design. Tolerance, the permissible variation of a dimension, is integral to the product design, manufacturing process and customer satisfaction.

In practice, the tolerance specification task is traditionally performed sequentially, starting with the product design and followed with the manufacturing process. A lack of communication between engineering designers and process engineers creates a design that is frequently changed, resulting in longer product lead time. This separate activity leads to product designs which may not be amenable to optimal manufacturing methods. To enhance product manufacturability, quality and design robustness, the design and manufacturing tolerances should be optimized concurrently. The integration of the tolerances ensures that optimality is achieved, which significantly improves the manufacturability, assemblability and robustness of the product. The research presented in this dissertation has dual central objectives: the formulation of an analytical model for integrated design and manufacturing tolerancing and the development of an algorithm for the optimization problem.

Both design and manufacturing tolerances are investigated and modeled. Design tolerances are related to the functional requirements of mechanical assembly at the component level. Manufacturing tolerances are devised for a process plan for part fabrication.

Tolerance analysis and synthesis are two major tools in accomplishing the mechanical tolerancing tasks. A beta distribution approximation method is developed, formulated and validated for both tolerance analysis and synthesis. Genetic algorithms are modified and enhanced to carry out the optimization procedure. Tolerances are determined by considering functional design requirements, assembly stack-up conditions, and machining stock removals based on design robustness maximization. An application of tolerance analysis and synthesis based on the beta distribution approximation method is developed and presented. This provides a reliable method to concurrently optimize the design and manufacturing tolerances.

The probabilistic technique developed for the robust tolerancing problems is compared with the traditionally used root sum squares calculation. The results show that the formulation of the beta distribution approximation method not only simulates normal distributions, but also models various practical manufacturing processes beyond the capability of normal distributions.

This research has presented a systematic approach to analyzing and synthesizing design and manufacturing tolerances. By implementing the methodology presented in this research, the designer is able to assign optimal tolerances on component dimensions based on assembly requirements, to select the best manufacturing process and to obtain the optimal manufacturing tolerances for component fabrication.