Optimal Design of Multistation Assembly Systems

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Mechanical Engineering)
in The University of Michigan
2006

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To my family,
Yi, Henglong, Zhifang, Yifei, Kaiping, and Renhua,
who made all of this possible, for their endless encouragement and patience.

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ABSTRACT

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This dissertation studies tolerance allocation, fixture layout optimization, and the integration of tolerance allocation and fixture layout design, for multistation assembly systems. System cost, final product quality, and system robustness are three attributes of major importance considered in these systems. Accordingly, single objective and multiobjective problems are formulated and solved for design decisions on product tolerances, process tolerances, and fixture locating positions.

Little work has been done for tolerance allocation in compliant assembly systems, even though compliant assemblies are widely used in manufacturing industries. By modeling the compliant multistation assembly as a hierarchical manufacturing process, the analytical target cascading methodology is applied to product and process tolerance allocation for assessing the feasibility of multilevel optimization strategies. The manufacturing models and design methodologies are demonstrated using vehicle side frame assembly example. Cost-driven and quality-driven tolerance allocation

problems are formulated to minimize system cost and improve final product quality, respectively. The obtained results demonstrate a tradeoff between cost and quality and the allocation schemes for tolerances.

The fixture layout design for multistation assembly systems addresses the variation propagation and interactions among stations to improve the system robustness. Previous research focused on rigid systems; these methods are not applicable to compliant multistation assembly systems. Three key aspects of the compliant multistation fixture layout design are addressed: a sensitivity index definition, a selection of design variables for fixture locations, and an appropriate optimization algorithm enabling the integration with finite element analysis tools. The methodologies are demonstrated using a compliant vehicle side frame assembly example.

To consider tolerance allocation and fixture layout design simultaneously, a general framework is proposed to address the interactions of the aforementioned optimization processes and to quantify their integrated effects on relations among system cost, final product quality, and system robustness. A nested optimization strategy is applied to improve the efficiency of the optimization processes and to increase the accuracy of the results. The demonstrated tradeoffs between system cost and robustness and between product quality and robustness make it necessary to define evaluation criteria for multistation assembly systems in order to ensure best product quality, system robustness, and minimum cost.