Geometric Tolerance Analysis Methods for Imperfect-Form Assemblies

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The purpose of this research is to investigate a computer-aided approach to tolerance analysis for assemblies and mechanisms. In our approach, assembly tolerance analysis is performed by (1) generating a series of component models that are representative of as-manufactured components, (2) simulating the assembly of these imperfect-form component models, and (3) measuring geometric attributes of the assembly which correspond to functionality.

Step 1: A series of component CAD models is generated that incorporate geometric errors typical of the manufacturing process used to produce the components. Several types of machining processes have been investigated, including end-milling, slot-milling, and fly-cutting.

Step 2: Typical mating conditions are specified that model assembly relationships among components. Computational methods are well understood for computing component positions from mating conditions among perfect-form geometries. However, resolving mating relationships for imperfect-form geometries has not been studied in the literature. Mating between imperfect-form component variants is simulated by formulating the mating problem as a nonlinear programming problem whose objective is to minimize the distance from perfect fit between mating faces. A problem formulation and survey of optimization methods for solving the problem are presented in the paper.

Step 3: Geometric attributes that correspond to functionality are measured for each set of variant geometries. By measuring functional attributes through a series of representative form error geometries and magnitudes, the effect of particular geometric errors can be analyzed. This information can be used to set geometric tolerances for the components.

The problem formulations and solution methods in this research are integrated into a Tolerance Analysis Module that is summarized in the paper. The Tolerance Analysis Module is used for a high speed stapling mechanism example. Capabilities and limitations of the work are reported. Issues regarding geometric modeling and non-linear programming are highlighted that should lead to interesting future work.