Mechanical Engineering Thesis Defense

Generalized T-Map Modelling Procedure & Tolerance Sensitivity Analysis using T-Maps

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abstract

Geometrical tolerances define allowable manufacturing variations in the features of mechanical parts. For a given feature (planar face, cylindrical hole) the variations may be modeled with a T-Map, a hyper solid in 6D small displacement coordinate space. A general method for constructing T-Maps is to decompose a feature into points, identify the variational limits to these points allowed by the feature tolerance zone, represent these limits using halfspaces, transform these to the central local reference frame and intersect these to form the T-Map for the entire feature. The method is explained and validated for existing T-Map models. The method is further used to model manufacturing variations for the positions of axes in patterns of cylindrical features.When parts are assembled together, feature level manufacturing variations accumulate (stack up) to cause variations in one or more critical dimensions, e.g. one or more clearances. When the T-Maps model is applied to complex assemblies it is possible to obtain as many as six dimensional stack up relation, instead of the one or two typical of 1D or 2D charts. The sensitivity of the critical assembly dimension to the manufacturing variations at each feature can be evaluated by fitting a functional T-Map over a kinematically transformed T-Map of the feature. By considering individual features and the tolerance specifications, one by one, the sensitivity of each tolerance on variations on an assembly level dimension can be evaluated. The sum of products of tolerance values and respective sensitivities gives value of worst case functional variation. The sensitivity equation can be used for statistical tolerance analysis by fitting a Gaussian normal distribution function to each tolerance range and forming an equation of variations from all the contributors. The method for evaluating sensitivities for each contributing feature is explained with engineering examples. The overall objective of this research is to develop method for automation friendly and efficient T-Map generation and statistical tolerance analysis.

May 14, 2018; 10:00 AM; ECG 315