Functional dimensioning and tolerancing software for concurrent engineering applications

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Abstract

This paper describes the development of a prototype software package for solving functional dimensioning and tolerancing (FD&T) problems in a Concurrent Engineering environment. It provides a systematic way of converting functional requirements of a product into dimensional specifications by means of the following steps: firstly, the relationships necessary for solving FD&T problems are represented in a matrix form, known as functional requirements/dimensions (FR/D) matrix. Secondly, the values of dimensions and tolerances are then determined by satisfying all these relationships represented in a FR/D matrix by applying a comprehensive strategy which includes: tolerance allocation strategies for different types of FD&T problems and for determining an optimum solution order for coupled functional equations. The prototype software is evaluated by its potential users, and the results indicate that it can be an effective computer-based tool for solving FD&T problems in a CE environment.
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1. Introduction

Functional Dimensioning and Tolerancing (FD&T) is a concept widely used for specifying dimensions and tolerances of the component parts and sub-assemblies of a product according to their functional requirements. These functional requirements arise from all life cycle issues, such as manufacturing, assembly and inspection. Concurrent Engineering (CE) is an engineering and management philosophy, which also deals with the life cycle issues of a product. CE is based on the idea of carrying out as many stages of product development concurrently as possible, rather than in a sequential order. It calls for the

formation of a cross-functional product development team, which includes people from a wide range of departments, such as: product planning, design, manufacture, assembly, quality assurance, marketing, sales and finance.

Dimensions and tolerances influence almost all aspects of product development which are of interest to CE team members who consider all the life cycle issues of a product during its design stage. Therefore, a CE approach will be ideal for selection of dimensions and tolerances through applications of FD&T methodology. Furthermore, FD&T can serve as a common link between all members of the CE team; hence it can enhance the CE team performance [1,2]. It is also argued in [3] that CE offers the best option for finding the values of dimensions and tolerances using informal optimization methods because the data required for

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application of formal optimization methods are often not available at the early design stage.

However, for the successful implementation of FD&T principles in a CE environment, appropriate tools are needed. The development of such a tool is the main objective of this project. It will be a computer-based tool to be used by product development teams for quick 'what-if' analyses for evaluation of different design alternatives and their influences on dimensions and tolerances.

2. Review of existing FD&T tools

The first commercially available 3D tolerance analysis software package VSA was introduced by Variation Systems Analysis Inc.[1] in 1982 [4]. At present there are a number of other tolerance calculation software packages available in the market, such as CETOL from Sigmetrix [6], DCS from Dimensional Control Systems [7], Mechanical Advantage from Cognition Corporation [8], Analytix from Saltire Software [9], VALISYS from Tecnomatix [10], Crystal Ball from Decision Engineering [11] and CATS-1D XL from ADCATS [12].

VSA, CETOL and DCS are the three most popular brands of the commercially available tolerance calculation packages. VSA and DCS were initially supported by the big three automotive manufacturers (i.e. General Motors, Ford and Chrysler) and are widely used in automotive industry. CETOL, previously known as TI/TOL, was backed by Texas Instruments and based on research carried out at Brigham Young University's ADCATS program. Its focus has been mechanical aspects of electronically based products.

Detailed description of these packages and their capabilities can be found on their respective websites; only briefs are given below:

- *VSA* is 3D tolerance analysis software package available as modules within a number of leading CAD systems. It has a module for checking parts' Geometric Dimensioning and Tolerancing (GD&T) schemes. It allows two types of simulations for tolerance analysis: Monte Carlo simulations and High-Low-Median (HLM) simulations.

Monte Carlo simulation method provides distribution curve and quality parameters of the total output variation. In graphic mode it can handle three[2] types of distributions of the input tolerances: actual, normal and Pearson. HLM analysis is based on variance analysis technique and is used for determining the percent contribution of each input factors to the total output variation.

- *CETOL* is a 3D vector assembly modeling package fully integrated with Pro/ENGINEER; a CATIA version is due out this year. It has the capability to apply three tolerance accumulation models: Worst case (WC), root sum square (RSS) and mean shift based on Six Sigma analysis. It can handle normal and non-normal distribution of input tolerances. It does not require any simulation and provides three outputs, viz. distribution curve and quality parameters of the total output, contribution plot and sensitivity plot.

- *DCS* is a tolerance simulation software package integrated with Mechanical Desktop CAD package. It consists of two modules: 1-DCS for solving 1D problems and 3DCS for solving multi-dimensional problems. It has the capability to apply three tolerance accumulation models: WC, RSS and Monte Carlo simulation. Monte Carlo simulation can use different types of distributions for input variables. It can also take actual part data and use it by direct loading or selecting the best curve to fit the data.

- *Mechanical Advantage* comes as a module within Mechanical Advantage CAD package. It is a feature-based variational geometry package which can perform WC, RSS and Monte Carlo analysis.

- *Analtix* is a mechanism design and analysis software package which runs on Microsoft Windows. It has a tolerance analysis module for tolerance stack-up calculations using RSS or WC accumulation models. It is capable of performing a percent contribution analysis.

- *VALISYS* is a 3D assembly stack-up analysis software package which uses Monte Carlo simulation technique for variation analysis. It is fully integrated with Unigraphics CAD system and has a module for GD&T syntax checking.

- *Crystal Ball* is a Windows Excel spreadsheet add-on software and performs tolerance and risk analysis

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[1] Recently purchased by Electronic Data Systems (EDS) [5].

[2] Eight in text mode.