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Virtual Geometry Assurance Process and Toolbox

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Abstract

Geometrical variation in individual manufacturing and assembly processes often propagates and accumulates, resulting in products that do not fulfil functional, esthetical or assembly conditions. Geometrical quality problems are often discovered late with huge cost for changes and delays as a consequence. The ability to simulate and foresee geometry problems early, allows robust concepts to be developed, tolerances and assembly sequences to be optimized and key inspection features to be selected. This paper presents a comprehensive geometry assurance process with an efficient set of tools that supports the geometry assurance process from early concept phases, through verification and pre-production and finally during production.

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Keywords: geometry assurance; robust design; tolerance managment

1. Introduction

Tolerance analysis and variation control is an area that has been addressed quite extensive over the years. Historically, the area started with mass production in early 20th century, where interchangeability among parts resulted in the need for tolerances to be specified. After the Second World War, Japanese quality began to improve a lot, followed by a quality improvement in the west in the 1980´s. In total, this quality development has been supported by persons like Shewart [1], Deming [2], Juran [3] and Taguchi [4].

A *robust design* is a design insensitive to variation. The ideas of robust design and quality improvement, however, were originally introduced by Taguchi [4]. The factors affecting a concept are divided into control factors, easy to control, and noise factors, which are hard to control. Transfer functions, relating inputs (control factors) to outputs determine whether variation will be amplified (sensitive concept) or supressed (robust concept). Taguchi also introduced the "quality loss function" as a concept for assessing the monetary loss as a function of deviation from a target, see Figure 1.

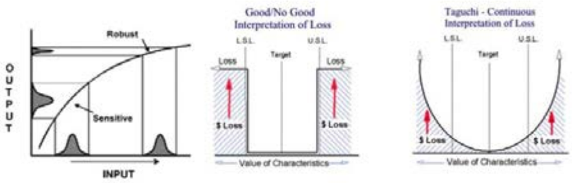

Figure 1: Robust Design [4]

In the theory of *axiomatic design*, see Suh [5], the design activity is described as a mapping between functional requirements (FR:s) and design parameters (DP:s) and the proper selection of DP:s that satisfy FR:s. According to Suh, a good, *uncoupled* design, is characterized by the fact that each output (FR) is controlled by only one input (DP). A *decoupled* design is an acceptable design that has to be tuned in a certain order, whereas a coupled design is very difficult to tune and control (Figure 2). Generally, minimizing the number of parameters controlling an output parameter is an effective way to increase design robustness.

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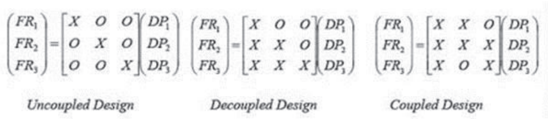

Figure 2: Axiomatic Design [5]

Tolerance analysis has in the literature often been treated somewhat separated from robust design which may be reflected by the fact that it in industry often is performed quite late, when the design is frozen and there is no way to change the embodiment design in order to increase robustness. Ideally, tolerance allocation should be performed top down (Figure 3), i.e. product requirement should be broken down to part tolerance based on sensitivities, cost etc. Summaries of tolerance analysis methods and issues can be found in [6]. In Figure 3, the sensitivity coeffients between part tolerances and product tolerance (the transfer function) is 1 which means that a change in one of the part tolerances t_1, t_2 or t_3 will have equal effect of the product tolerance t. However, in most real applications, 3D effects related to the six degrees of freedom for each part and how the locators are positioneed will result in sensitivity coefficients that may be difficult to calculate manually, and also to quite complex tranfer functions. Computer aided tolerancing (CAT) tools like RD&T, VSA, 3DCS, CETOL can then provide a good support [7-10]. Söderberg [11], proposes how CAT tools can be used to support the product development process and bridge the gap between tolerancing and product development.

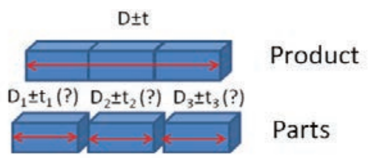

Figure 3: Tolerance allocation

According to Ebro [12], typically 60 % of all late changes in the development of a new product are related to sensitive or unclear concepts or tolerances. The company costs for late changes can be quite extensive and the potential to shift late changes to early prevention of failure, with focus on more robust concepts, has therefore a great potential.

1.1. The scope of the paper

The areas of quality, robustness and tolerancing have in the literature been addressed, to a large extent, separately and on different abstraction levels. The relation to the product development process is, in the literature, sometimes not obvious. This has also been pointed out in [13]. Therefore, this paper aims at bringing these areas more close together by describing a working procedure and a set of tools for managing variation from early design phases through the whole product realization loop. The paper builds on the geometry assurance process developed by the authors since 1997, partly reported in [11]. The main motivation for this paper is to describe new research results in specific fields, specifically within non-rigid analysis, and to give an outlook on some future needs and challenges. The research results, and the working procedure described, have been implemented at a large number of companies, which can be seen as verification of its usefulness. Some general conclusions, based on the industrial implementation of the results, are also reported.
The structure of the paper is that Section 2 presents the geometry assurance process and the importance of locating schemes. Section 3 presents the geometry assurance toolbox with support in concept phase, verification phase and production phase. Section 4 presents an outlook for the area and Section 5 concludes the paper.

2. Geometry assurance and locating schemes

In this section, the geometry assurance process and the importance of locating schemes is described.

2.1. Geometry assurance

Geometry assurance can be described as a number of activities, all contributing to minimizing the effect of geometrical variation in the final product. Activities can be found in all the different phases of the product realization loop (see Figure 4):

In the *concept phase* the product and the production concepts are developed. Different concepts (sub-solutions) are analysed and optimized to withstand the effect of manufacturing variation and tested virtually based on available production data. In this phase, the concepts are optimized with respect to robustness and verified against an assumed production system by statistical tolerance analysis. The visual appearance of the product is optimized and product tolerances are allocated down to part level. See Section 3.1.

In the *verification* (pre-production) *phase* the product and the production system are physically tested and verified. Adjustments are made to both product and production system to correct errors and prepare for full production. In this phase inspection preparation and off-line programming of coordinate measurement machines and scanning equipment takes place. Here, all inspection strategies and inspection routines are decided. See Section 3.2.

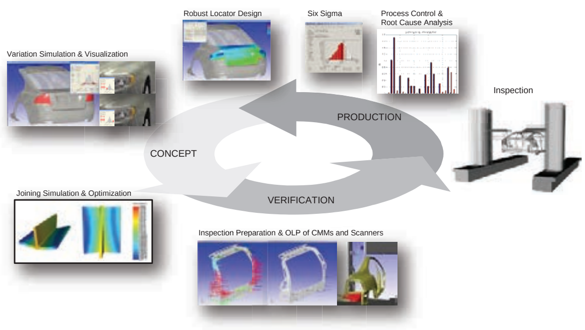

Figure 4: Geometry assurance activities