

Creating an Efficient Geometrical Measurement Planning Process

Richard Lindqvist and Tobias Jansson

¹KTH, Royal Institute of Technology, Stockholm, Sweden; Saab AB, Linköping, Sweden

²Saab AB, Linköping, Sweden

ABSTRACT

The scope and purpose of this paper is to give input and propose solutions to the creation of an efficient and productive geometrical measurement planning process. The case study outline what is important and how to identify and determine the preconditions and input data which is required to start the preparation and planning activities of geometrical measurements. That is why the following three main research and development questions should be answered:

Firstly; What is the need and why does an efficient and productive geometrical measurement planning process contribute to decrease cost upstream as well as downstream in terms of reduced lead times in measurement planning process work?

Secondly; Why are reduced uncertainties related to geometrical; functionality, specification and verification, important? And how are they linked to each other and how can they be theoretically modeled and defined in terms of uncertainties?

The last question is; How is the current geometrical measurement planning process constructed and what does it contain and how is it functioning?

By applying a more systematic and holistic approach in product realization and measurement planning activities, the accomplished study indicates improvements and high potential for cost savings, from 3 up to 12 times. Hence the improvement potential is strongly dependent of the actual geometrical complexity level of the airframe assembly being studied. Results from this study will further improve and develop current applied geometrical measurement planning process and will contribute to a more effective and productive working methodology and process.

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INTRODUCTION AND BACKGROUND

One department within the business unit of Saab Aeronautics is responsible for dimensional management and production engineering metrology. The department is using different kinds of enabling technological software tools, methodologies, standardized processes and international and company specific standards and best practice. *Dimensional Management* and *Dimensional Engineering* as expressions has been around for more than 10 years and specifically within the automotive industry, [1-2], it has been the common expression when it comes to managing dimensions, geometry and surface structure requirements and the approach has been systematic and holistic way of thinking and working. Therefore, benchmarking has in general been made towards the automotive industry and nowadays, similar working tools and methodologies has been adopted and applied in the aerospace industry, [3]. The department at Saab Aeronautics is working according to a closed loop dimensional management and production engineering metrology process, Fig. 1.

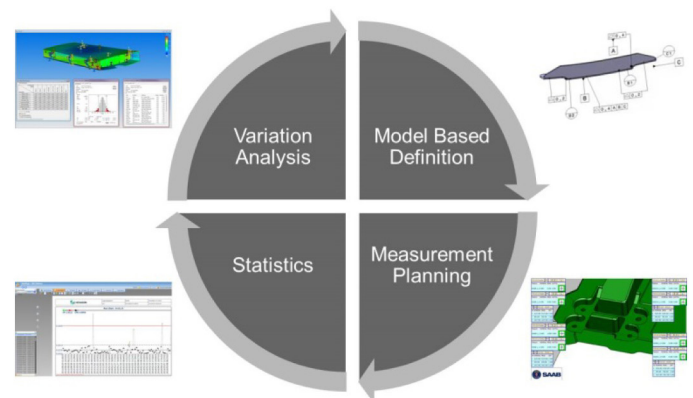


Fig. 1. The MBD (Model Based Definition) methodology concept seamlessly integrates the digital information data. It contains result data from geometrical variation analysis, geometrical specification and verification and express requirement for process control of Critical Requirements, i.e. geometrical requirements, e.g. Key Characteristics (KC) [4-5].

The closed loop dimensional management process is based on four different digital data management core domains. The first domain starts with tolerance stack-up calculation in one dimension and more complex tolerance calculations and analysis are computed using variation analysis software, [6], i.e. *Monte-Carlo* simulation techniques. In the second domain the creation and modeling of 3D (three dimensional) digital MBD (Model Based Definition) airframe designs in CAD (Computer Aided Design) system is performed. This domain is the main input to the next domain which is the geometrical measurement planning activity. The geometrical measurement planning activity is carried out off-line using metrology software, [7]. After the measurement planning activities has been carried out the physical measurements will be executed by the use of proper geometrical metrology equipment on the assembly workshop floor. The geometrical measurements are filed in static reports using the pdf (portable document format) format; hence xml (Extensible Markup Language) files are also outputted from the metrology software and filed in a company internal measurement database, [8]. When sufficient and reliable data has been stored in the database, advanced SPC (Statistical Process Control) analysis can be performed and process and machine capability data and statistical variation spreads and different statistical distributions can be applied. This information can then be transformed back to the first domain and close the loop of the digital thread. Valuable knowledge is reused in new airframe design concepts as well as in existing airframe designs for continuously improvements.

Limitations and Scope of Study

This study covers typical problems the geometrical measurement planner is facing when he or she is about to begin its measurement planning activities and start programming the portable coordinate measuring machines, i.e. a laser tracker with T-probe system [9]. Therefore in this particular study, illustrated in Fig. 2, the limitations and scope of study is set to the first domain titled “Model Based Definition”.

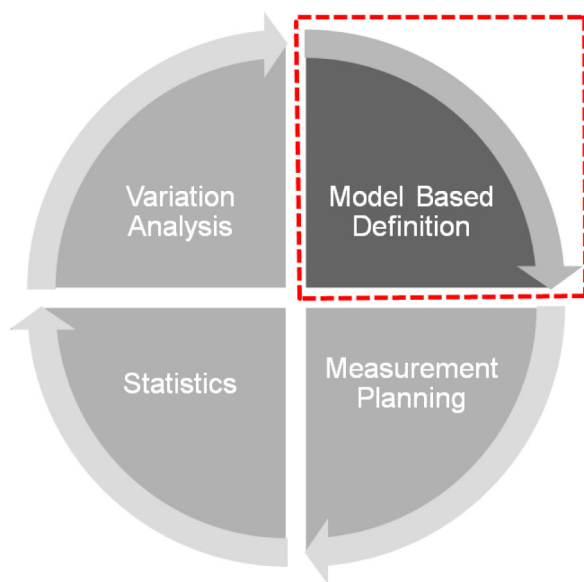


Fig. 2. The main focus in this study is in the domain of MBD - Model Based Definition - because here all the input data to the geometrical measurement planning domain is gathered and compiled.

METHODS AND MATERIALS

The working methodology for the obtained results in this study can be summarized as follows; Problem description, results, discussion and analysis found so far is mainly based on the authors experience from product realization work and input and feedback from other different Saab Aeronautics engineering disciplines and from experiences and benchmarking parts of the Swedish automotive industry (Cars, Trucks and Construction Equipment). It is also based on observations, interviews and workshops addressing best work practice within the Saab Aeronautics organization. The work has included methods and processes that should be applied and followed. Applicable and valid international ISO (International Standardization Organization) and ASME (American Society of Mechanical Engineers) standards and company specific developed standards, manuals and instructions have also been important input data to this study.

PROBLEM DESCRIPTION

What has been discovered so far is that execution of the measurement planning activity is sometimes delayed and/or interrupted because of errors and inaccuracies in the main input data, i.e. in the definitions and specifications of the geometrical product and assembly process characteristics. In the worst case scenario, input data is lacking or even missing in the 3D models or referencing note packages within the 3D model drawings. The geometrical product and assembly requirements should always follow and be specified according to international standards, [10, 11, 12, 13]. These circumstances drive cost upstream in the geometrical measurement planning process. Hence, the research and development questions used in this study are basically comprised of three main questions and two sub questions:

1. What is the need and why does an efficient and productive geometrical measurement planning process contribute to decrease upstream cost as well as downstream in terms of reduced lead times in the measurement planning process work?
2. Why are reduced uncertainties related to geometrical; functionality, specification and verification, important? And how are they linked to each other and how can they be theoretically modeled and defined in terms of uncertainties?
3. How is the current geometrical measurement planning process constructed and what does it contain and how is it functioning?
 - 3.1. What are the weaknesses in the current geometrical measurement planning process and how should those weaknesses be eliminated or be replaced to something more efficient and productive?
 - 3.2. How could the geometrical measurement planning process be further explored, developed and constructed in order to become more efficient and productive?

GENERAL ECONOMICAL ASPECTS IN RELATION TO GEOMETRICAL QUALITY FAILURE

In this chapter research and development question number one is addressed. The term and acronym *CoPQ* (Cost of Poor Quality) is derived from a thesis by Sörqvist titled *Poor Quality Costing*, [14].

However, *CoPQ* was popularized in 1987 by the quality expert at IBM (International Business Machines Corporation) Mr. James Harrington. In the thesis by Lindqvist, [15], one can read that the general amount of the *CoPQ* is in the range of 10-40 % of a company's yearly turnover. From recent studies on geometrical quality failure presented by Hellström and Soppela, [16], they showed that there is a relationship between geometrical quality failure cost and geometrical deviation from a designed target value. In their degree project Soppela and Hellström also reports on a recent limited study by Falck and Rosenqvist, [17], mainly addressing the Swedish automotive industry, including one OEM (Original Equipment Manufacturer) and its sub-tiers. In that study Falck and Rosenqvist showed that there is a strong relationship between geometry and quality related errors. They also showed and explained that they saw a strong pattern between quality errors and geometry and they indicated in their report that approximately 70-90 % of the total quality errors were related to geometry.

UNCERTAINTY IN GEOMETRICAL PRODUCT SPECIFICATION AND VERIFICATION

In this chapter research and development question number two is addressed. To understand the following theoretical reasoning and the description of a new conceptual uncertainty model and its inherent definitions of various types of existing uncertainties, firstly a brief introduction to the subject area is outlined. The starting point and reference material is taken from research work by Anwer, Bally and Mathieu, [18]. Currently, a CAD model is defined by a finite number of parameters comprised of reference system points, single point's coordinates, angles, lengths and control points of NURBS (Non-Uniform Rational B-Spline) surfaces etc. In the mechanical engineering world simplification of the geometrically complex real world is necessary. Conceptual models of products, assemblies and parts are designed and constructed in CAD systems, but how accurate are they and what types of uncertainties could be identified, defined, estimated, verified and validated? In Fig. 3 an illustration of a nominal model, continuous and discrete skin model is displayed. It is important to accurately quantify the difference between the nominal (CAD) model and the discrete (measurement data) model. The continuously model is represented by the real manufactured physical part and its inherent geometrical variations and deviations.

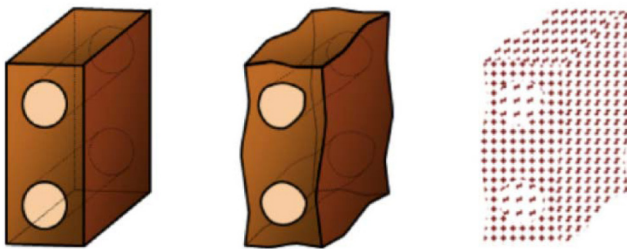


Fig. 3. The illustration from left to right - From a perfect nominal CAD model (As-designed - Specification operator) through manufacturing (As-built) and to final geometrical verification (As-verified - Verification operator). Original illustration and picture reworked from, [18].

A New Holistic Conceptual Uncertainty Model Approach

Most of the physical objects in real world which are designed by humans and engineers have specific purposes and targets, i.e. the physical objects have functional requirements that need to be fulfilled and continuously be fulfilled in order to function properly. When the functional characteristics of a physical object are identified and defined then it should be transformed into specifications, i.e. geometrical requirements should be specified and tolerances should be allocated and encoded in the 3D models. Ultimately the specification should reflect how the specification should be verified and with minimal uncertainty between the so called *specification operator* and the *verification operator*, [12]. In Fig. 4, one holistic conceptual uncertainty model approach has been explored and developed in an attempt in trying to explain these uncertainty relationships and interrelationships, [19]

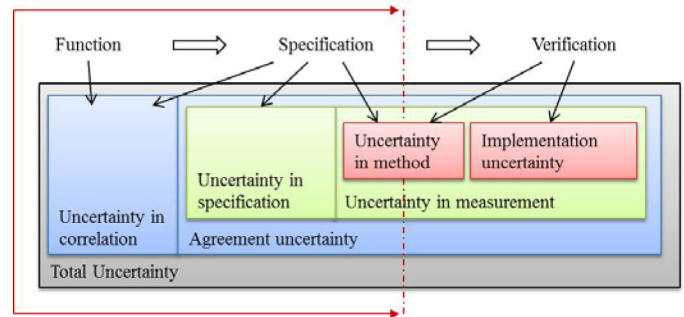


Fig. 4. The Total Uncertainty in Geometrical Product Specification (GPS) and Verification includes but are not limited to: Total uncertainty which is a combination of uncertainty in correlation and agreement uncertainty. Agreement Uncertainty is a combination of Uncertainty in specification and Uncertainty in measurement. Uncertainty in measurement is a combination of Uncertainty in method and Implementation uncertainty.

Definitions

Uncertainty in correlation is the uncertainty if a part that has been manufactured and has been verified and has shown and proved to be within the specified requirements will generate the intended functionality or inversely; a part that has been shown not to be within the specified requirements even though fulfills the intended functionality.

Uncertainty in specification is comprised of the uncertainties in the requirement definition and specification operators with insufficient defined requirements.

Uncertainty in method is the uncertainties which will appear if the physical measurement method is performed in a way which will not meet or conform to the specification operators.

Implementation uncertainty is the uncertainties inherent in the actual measurement process and the measurement equipment, i.e. the implementation of the measurement method in practical and physical measurements.