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# A theoretical and practical approach to geometrical part assurance

Richard P. Lindqvist[a,c*], Karl-Johan Karlsson[b], Lars Mattsson[a]

[a]*KTH, Department of Production Engineering, Brinellvägen 68, 114 28 Stockholm, Sweden*
[b]*Volvo Construction Equipment, 631 85 Eskilstuna, Sweden*
[C]*SAAB AB, Bröderna Ugglas gata, 581 88 Linköping, Sweden*
* Corresponding author. Richard P. Lindqvist. Tel.: +46-734-183957. *E-mail address:* ricli@kth.se; richard.lindqvist@saabgroup.com

**Abstract**

Metrology is the science of measurements; production engineering metrology is the science of applied metrology in production and in product realization. In this paper the automotive, construction equipment and aerospace industry are particularly addressed. One theoretical and practical approach to geometrical part quality assurance focusing on manufacturing processes and systematic work and use of objective, value adding production engineering metrology is proposed. This paper aims to describe a practical approach on how to carry out geometrical assurance of parts produced in manufacturing processes using traditional production methods. One example using machining, i.e. turning, of a part is used to explain this approach.


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*Keywords:* geometry; quality; assurance; control, metrology, concept; practical; approach

## 1. Introduction

The global manufacturing industry needs to constantly meet increasing geometrical quality requirements on their products and in their manufacturing and assembly processes. In order to meet these increasing geometrical requirements the need for productive metrology is emerging. That is why the Kunzmann et. al., Weckenmann and Rinnagl, Savio [1-3], and Ekberg, [4], statements on production engineering metrology and its inherent productive and value adding properties in the product realization work are important. Though, Ekberg, [4], highlights the importance of careful and proper implementation of metrology in the industrial production process. Ekberg shows the level of impact that metrology has on the added value to parts and assembled products in a process perspective. Proper measurement and inspection planning through source inspection with feedbacks from the process at certain points is crucial for both keeping up the yield and also continuously keeping the process capable and stable. Ekberg gives one example about the photo mask process and pinpoints how bad inspection planning will generate extreme consequences. Another aspect Ekberg discuss is the problem when metrology equipment and/or the production method do not fulfill their intended specifications. In many cases the user is completely dependent on the equipment without any chance to verify its performance. According to Sörqvist, [5], this will lead to poor quality output, i.e. yield, from the processes and generate poor quality costing. Solutions to these kinds of problems generate additional costs. In investments but will in the long run pay off since part quality can be controlled, monitored and assured by selecting appropriate value adding metrology and apply practical approaches to geometrical quality assurance in part manufacturing.

## 2. Background

Production engineering metrology focusing on geometrical metrology, from now on only referred to as metrology, is not only being applied in final geometrical inspection of a part. Considerations to metrology problems and integration in


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different stages of the production processes should be made in early design and development phases and throughout the product realization process. According to the international GPS (Geometrical Product Specification) and Verification concept, [6], should questions comprising geometrical tolerances and uncertainties be considered during all phases in a product realization context, i.e. research, design, manufacturing, assembly and functional testing. The most convincing reason for this is if it seems to be difficult to manufacture and measure a part, it will be substantially more costly to re-design the part in a later stage compared to taking the manufacturing and metrology issues into consideration early in the product realization process.

General theories, principles, rules and tools regarding dimensional management and geometrical assurance of part design and part manufacturing are intended to be defined, developed and documented in international ISO (International Standardization Organization) standards, [6]. Though, these ISO standards are informative, they do sometimes lack in practical descriptions on how to actually carry out and perform the work, i.e. going from theory into practice. However, Swedish companies tend to develop their own company specific standards within this competence area. For instance, a lot of work has been done nationally and within the Swedish automotive industries and at different companies, e.g. Volvo Cars, Scania Trucks, Volvo Construction Equipment and also in the aerospace industry, i.e. Saab Aeronautics, [7]. Based on this input of experience and knowledge from the automotive and aerospace industry and the current knowledge gained from ISO GPS and Verification standards, this paper aims to describe a practical approach on how to carry out geometrical assurance of a production method in a production process and one example will be used to explain the approach.

## 3. The concept of geometrical part quality assurance

The concept of geometrical part quality assurance is here introduced and thoroughly explained. An example on how to carry out this work in a practical manner is presented by using one authentic example. Firstly the different roles of metrology are discussed and definitions are proposed. Then a theoretical reasoning about geometrical features and characteristics inherent and impacting the production process is proposed and a systematic method to be able to control and monitor the production process from early stages of the industrialization work is introduced. Focus is set to the uncontrollable geometrical features and characteristics which are “locked” in machine tools, fixtures, cutting tools and machine parameters. Ultimately they should be secured and assured during prototype and pre-production testing, which finally will generate a smooth transition into serial production.

### *3.1 The different roles of metrology*

When designing, and later on manufacture parts by the use of traditional machining techniques, in this case turning technology, the hypothesis is that there is an existing and close engineering relationship and collaboration between design engineering, production engineering and the metrology disciplines. With this hypothesis in mind, four main roles for metrology can be identified during a products realization lifecycle:

- A ***proactive*** role, i.e. metrology data is used to assure the parts functional characteristics and to assure correct chosen production method that will produce to required geometrical quality level.
- A ***production controlling*** role, i.e. metrology data is used to continuously control the geometrical quality output of the produced parts.
- A ***monitoring*** role, i.e. different types of measurements is performed in order to follow up the production result.
- A ***100% inspection*** role. This could be seen as a rather wasteful and costly method but sometimes it is a necessary and important role. One example is material defects such as pores and scratches which could endanger that a part will be discarded in the final inspection of the part. If such material defect measurements could be introduced, automated and integrated in adherence to the machining process it would generate value to the production process.

These four different roles put partially different requirements on the applied geometrical and dimensional metrology. In particular it puts requirements on the alignment of the planned measurements. Traditionally, applied metrology within the last four areas has in general been emphasized to parts dimensional characteristics. In this paper we will emphasize the *proactive role*, as a foundation for evaluation of production methods.

### *3.2 Metrology resources and organizational issues*

In measurement planning work the metrology planner should be able to choose inspection and measurement resources and suitable measuring equipment. When thinking about the *proactive role of metrology*, where dimensional and geometrical assurance work has been carried out, is it then possible to rationally choose what characteristics that should be used as a *production controlling metrology role*? And what other geometrical characteristics will receive a *metrology monitoring role*? A trend of today is the movement of measuring tasks from dedicated measuring rooms to the different machining groups at the workshop floor. Before taking this action the pros and cons of such a movement should be carefully analyzed as part of the proactive measurement planning. Here is the controllability aspect important. Those characteristics which a machine operator can monitor and influence through adjustments and cutting tool changes should be measured at the source, i.e. at the machine tool.

Those characteristics which are more or less ”locked” in methods, fixtures, and machine parameters should be secured through geometrical assurance work and then only be followed up in order to keep control of the production methods inherent parameters and characteristics over time. That kind of follow up activity could favorably be performed in specific measuring rooms with quite sparse inspection intervals. The starting-point for this approach is that measurements that cannot be used to control the production process through the machine operator should be avoided. There are more drawbacks in allocating an unnecessary number of measurement tasks at the machine tool:

- Every measurement is associated by a cost and should only be initiated and performed if it is profitable and adds value