Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 43 (2016) 41 – 46

www.elsevier.com/locate/procedia

14th CIRP Conference on Computer Aided Tolerancing (CAT)

Enabling reuse of inspection data to support robust design: a case in the aerospace industry

Julia Madrid[a,]*, Johan Vallhagen[b], Rikard Söderberg[a], Kristina Wärmefjord[a]

[a]*Chalmers University of Technology, 41296 Göteborg, Sweden*
[b]*GKN Aerospace Engine Systems, 46181 Trollhättan, Sweden*

* Corresponding author. Tel.: +46-317-721-344. *E-mail address:* julia.madrid@chalmers.se

Abstract

The use and reuse of information and knowledge from manufacturing are crucial to secure the quality of the product throughout the product realization process. Robust design, variation simulation, virtual verification and root causes analysis are activities that require inspection data to ensure a robust process. In many industries, the level of inspection data reused is rather low. In this study, general barriers for reusing data concerning manufacturing processes have been identified in scientific literature and compared with specific barriers identified in a case study performed at an aerospace engine manufacturer. As an output of this comparison, barriers to the reuse of inspection data have been classified in three types: informational, technical, and organizational. In addition, the informational barriers are decomposed in four questions: *Why*, *What*, *When* and, *How* to measure. A support to answer those questions and overcome the informational barriers is proposed.

Peer-review under responsibility of the organizing committee of the 14th CIRP Conference on Computer Aided Tolerancing
Keywords: Inspection planning; Quality assurance; Knowledge management; Robust design.

1. Introduction

New business demands on manufacturing companies require fast, flexible and highly customized product and production development processes. The objective is to deliver more variants of high quality products, reducing cost and reaching the market faster than before. To do so, the aim is to shift the competence of controlling quality towards earlier stages in the development process, before production starts. A proactive approach to assure quality would reduce the need for physical prototypes and manufacturing rework. Quality can be virtually assessed, controlled and optimized, making products more robust and insensitive to manufacturing variation [1, 2].

In order to virtually verify both product and production concepts the need for probabilistic design, variation modelling, variation analysis tools and simulations has increased [1, 3, 4]. These new methods and tools require using as much manufacturing process knowledge and inspection data as possible in the early stages of the product development process.

Much of the research on improving and predicting quality assumes the existence of process capability information but how to deliver such information is less discussed. Thus, some researches have focused on enabling the reuse of manufacturing knowledge and information [5, 6]. Andersson et al. [6] provided a framework to support the reuse of manufacturing experience as a source of knowledge. Moreover, research on Knowledge Base Engineering (KBE) focuses on creating computerized support to reuse manufacturing knowledge [7].

However, the level of reused inspection data in design activities is still rather low in many industries, as reported by [8-10]. Inspection measurements are used to monitor quality during production but are not efficiently utilized as a source of knowledge during design in order to create more robust product and processes [10, 11]. Therefore, research has focused on supporting the communication of capability data to designers either by the creation of process capabilities databases [8, 12] or the creation of information models [10]. But less research has been done on enabling the reuse of inspection data in design by supporting the process of generating adequate process capability data.

Peer-review under responsibility of the organizing committee of the 14th CIRP Conference on Computer Aided Tolerancing
doi:10.1016/j.procir.2016.02.137

This paper contributes to the area of reuse of manufacturing knowledge, considering inspection data as the source of knowledge, by supporting inspection planning activities. Two questions are addressed:

- RQ1: What are the barriers to reuse inspection data?
- RQ2: How can the inspection planning and execution be supported so that it generates adequate process capability data to be reused?

This paper begins presenting the different users of inspection data. In section 3, a case study at the aerospace industrial partner is presented, where specific barriers to the reuse of inspection data to support life calculations are identified. In order to verify those findings, generic barriers to the reuse of inspection data in design activities have been identified in scientific literature, see section 4. In the final section, support for the generation of inspection data to enable its reuse is proposed.

2. Users of inspection data

All manufacturing processes are disturbed by variation [13]. Variation can be represented in statistical terms. A quality improvement would consist of centering the probability distribution of the quality characteristic at a target value and then reducing variation. Therefore, inspection data and statistical methods play a central role when assuring quality, both in production and even in early stages of the product development process [2, 13, 14].

2.1. Production, the traditional user

Until the 80s the way to assure quality, or rather to control quality, was by acceptance sampling and SPC [2, 14, 15].

A review of the most relevant SPC methods can be found in [14]. The control chart proposed by Shewhart [16] is one of the primary techniques of SPC. In the control chart, when unusual sources of variation are present, sample statistics will plot outside the control limits, indicating investigation of the process should be done and corrective measures should be taken. In addition, root cause analyses are carried out during production by utilizing variation data to detect the problems within the manufacturing process [17]. The systematic use of these methods is a good way to reduce variation. However, these methods are based on data from ongoing production, thus quality is improved in late stages of the product realization process.

2.2. Quality assurance activities, the new users

The increased attention in robust engineering [18, 19] has occurred due to it is preferable to reduce variation during the design phase, before production starts. Comparing concepts and optimizing design parameters, in order to increase the quality of the product, has a lower cost than reducing variation during manufacturing.

Quality assurance can be seen as a set of activities which are employed throughout the product development process to provide the necessary evidence that the intended quality will be achieved and maintained [15].

In the case of product dimensions and tolerances, as quality characteristics, research on methods and tools to deal with geometrical variation has gain increased attention [18]. Within this area, Söderberg et al. [1] proposed a Geometry Assurance process, which is a set of activities and tools linked to the product development cycle in order to assure geometry. Geometry assurance consists of controlling the effect of geometrical variation from early design concepts phases, through verification, preproduction and finally during production, see Fig. 1.

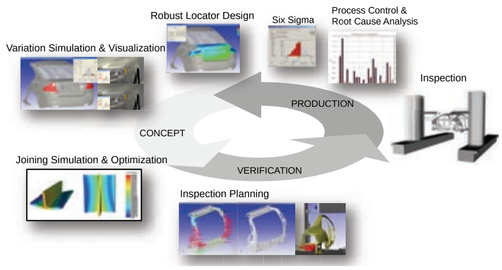

Fig.1. Geometry assurance process by Söderberg et al. [1]

Inspection data is generated and used during the production phase. The purpose is to monitor production processes and to detect and correct errors by using methods for root cause analysis and six sigma [17].

In addition, inspection has the objective to capture the information about the process capabilities in order to be reused in the next concept phase, where inspection data is reused for variation simulation [20]. Virtual development activities are the new users of the inspection data.

Today many actors and activities during the product realization process need inspection data as an input [9], which is the reason why the number of inspection points can become quite large. Inspection strategies and planning have the objective to find the minimum and optimal set of inspection features to feed all those activities [21].

3. Barriers to the reuse of inspection data – Case study in the aerospace industry

In this section a case study carried out at an aerospace industrial partner is presented. Barriers to the reuse of inspection data in a design activity, fatigue life calculation, are identified. The discussion of the barriers can be found in section 5.

3.1. Background and problem description

The turbine structure in the rear part of a turbofan engine has a range of functional criteria from various fields of engineering. One of the functionalities is to withstand significant thermal and structural loads, which is related to the life of the component.

For the larger engines of today, the turbine structures are welded assemblies consisting of cast, forged and sheet metal parts. Different welding methods are employed for their fabrication. Fig.2. shows the different welds of the product.