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Model Driven Manufacturing Process Design and Managing Quality

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Abstract

Besides decisions in design, decisions made in process planning determine the conditions for manufacturing the right quality. Hence systematic process planning is a key enabler for robust product realization from design through manufacturing. Current work methods for process planning and quality assurance lack efficient system integration. As a consequence companies spend unnecessary lot of non-value adding time on managing quality. This paper presents a novel model-based approach to integrate process planning and quality assurance. The presented model enables a more efficient and holistic way for managing quality from design to manufacturing. New possibilities to communicate process design intent and present important quality assurance information in a more structured and comprehensive way is also enabled.

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Keywords: Model-driven; Process planning; Process design; Process Rationale; Quality assurance

1. Introduction

In the well-known novel by Lewis Carroll [1], the following dialogue takes place between the main character Alice and the Cheshire cat when Alice asks the cat about which way to go;

> *'Would you tell me, please, which way I ought to walk from here?'*
> *'That depends a good deal on where you want to get to,' said the Cat.*
> *'I don't much care where —' said Alice.*
> *'Then it doesn't matter which way you walk,' said the Cat.*

The same is true for process planning which definitely is a matter of making decisions on how one ought to convert the designers' idea into a physical product. The overall aim of process planning is to design a robust manufacturing process capable of producing components of right quality at a competitive cost.

Product quality does not only depend on control activities and downstream inspection in the manufacturing process. The decisions made in product design and in process planning determine the conditions for manufacturing the right quality.

Every manufacturing process and operation must be designed in the best possible way. Each process step shall contribute and ensure that the overall process chain leads to the right product quality.

1.1. *Manufacturing process design*

Process planning is definitely more than the term itself might indicate. It includes both creativity, where ideas or solutions are synthesized, and analysis where decisions must be made by evaluation of proposed ideas. The analytical activities, such as comparing and evaluating different alternatives, have been thoroughly studied by [2, 3, 4, 5, 6, 7, 8, 9] to mention a few. Several thousand publications about process planning have been published but few have studied the creative part of process planning. In a paper [10] about a solution for model-based interactive learning of process planning in master level production engineering courses, Lundgren et al. mention that there is a big difference between the way a novice and an expert acts. Where the novice calculates, using rules and facts for determining actions (just like a computer following a program) the expert not only sees what needs to be achieved, he or she also sees immediately how to achieve this goal.

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To emphasize that process planning includes both creativity and analysis we use the term “process design” to refer to the activity whose outcome is the process plan.

The creative part of process design is subjective, and depends on the process planner´s expertise, knowledge base and creativity. For the same set of requirements, virtually an infinite number of possible solutions can be created. Since the process planner must be able to abandon or discard bad ideas quickly to enable the creation of new ideas by exploring different possibilities etc., creativity and analysis are inter-related in process design.

The outcome, i.e. the process plan, is mostly represented in different kind of documents. Usually, these documents only communicate what to do and leave out the important manufacturing process design intent. As process design reasons are not expressed in a clear and explicit way the rationale behind the decisions and why they were made becomes hidden for others.

Communication of design rationale in product design has been discussed by Price et al. [11]. However, besides the work presented by Lundgren et al. [12], process design rationale have not been thoroughly discussed in current process planning research.

Being able to communicate process design intent, i.e. the reasoning behind the decisions and why they were made, in an efficient way would be valuable in process plan evaluation and quality assurance activities.

1.2. *Quality assurance in manufacturing industry*

Quality assurance in production is as important for robust product realization as effective process planning. The purpose of quality assurance is to ensure that processes and products comply with defined requirements. Historically, quality assurance has evolved from a focus on part inspection of manufactured products to a more holistic approach where quality assurance is an integrated activity throughout the whole product realization process.

Colledanio et al. emphasizes that the mutual relations among quality, production planning and maintenance control should not be underestimated. They propose “Production Quality" as a new paradigm aiming at going beyond traditional six-sigma approaches. Innovative and integrated quality, production logistics and maintenance design, management and control methods as well as advanced technological enablers have a key role to achieve the overall "Production Quality" goal [13]

1.3. *Management and analysis of risks in manufacturing*

Today, manufacturing engineers are using different CAx applications for process planning and quality assurance. For process planning CAM is widely used, mainly for creating and verifying toolpaths for CNC machine tools. For quality assurance other types of software is used. Available software applications to support quality assurance activities as process Process Failure Mode and Effect Analysis (PFMEA), Measurement System Analysis, and creation of Control plans etc. can be categorized as PLM software as solutions from PTC, Dassault Systémes, Siemens PLM and ARAS, or CAQ software as from Q-DAS, Babtec, Boehme-weihs, IQS. In addition, a common solution is to build on desktop applications such as MS Office (Word, Excel etc.). Regardless of software category, they share the problem of effective information integration between process planning and quality assurance.

Careful planning in an early phase is emphasized in the Advanced Product Quality Planning and Control Plan (APQP) reference manual. It was first issued by Chrysler Corporation, Ford Motor Company, and General Motors Corporation in 1994 and in 2008 a revised 2nd edition was published [14].

The importance of the principles in the APQP reference manual is indisputable. But the task of creating and managing APQP required documents such as a PFMEA, results in high workload. Furthermore, the creation of them is almost exclusively done in a document-centered approach, separated from the process planning activity.

One of the main objectives with process planning is to define a process with a predictable outcome. Hence, the decisions made during process planning contribute to a large extent to set the manufacturing conditions for the final product quality. Bagge suggests in his Doctoral thesis that risk assessment activities as PFMEA should be an integrated activity in process planning [15]. But lack of efficient system integration between process planning and quality assurance make it difficult to fully exploit valuable information in the process plan.

The way a process planner design the process plan depends a lot on the process planner´s ability to identify and address potential problems in advance. Experienced process planners can prevent problems from occur in manufacturing by designing the manufacturing process in a pro-active way. Process plan information such as; process step, process sequence, manufacturing resources, etc. is important in quality assurance activities as PFMEA. But there is very limited, if any, integration at all between process planning applications, e.g. CAPP/CAM and quality assurance applications. As a consequence, manufacturing companies fail to exploit valuable data created in process planning when working with quality assurance.

Besides failing to exploit valuable information created in process planning, today’s quality assurance work methods result in unnecessary waste of manufacturing engineer expertise. As the required quality assurance documentation in many cases is created by process planners, their competence is used in an inefficient way when they re-create information already created in process planning. Instead of doing the documentation the focus should be on improving production contributing to create customer value.

1.4. *Model-driven process planning*

While process planning and quality assurance today is performed in a disconnected manner, there is a huge potential in applying a model-driven approach. Model-driven process planning is a methodology that emphasizes the application of digital models to create, represent and use information of products, processes and resources. The objective is to support