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Model-driven Process Planning and Quality Assurance

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Abstract

Systematic process planning is a key enabler for robust product realization from design through manufacturing. Every process and operation must be designed in the best possible way to ensure that the overall process chain leads to the right product quality. During the last two decades a shift from inspection of manufactured products to a more holistic approach with quality assurance as an integrated activity throughout the product realization process has emerged in manufacturing industry. The importance of the principles addressed in the methods and tools used in automotive industry for quality management is indisputable. However, the tasks of creating and managing documents for Process Failure Mode and Effect Analysis (PFMEA), Control plans, Initial process studies and Measurement System Analysis (MSA) results in high workload. Also, lack of interoperability between different computer applications used in process planning and quality assurance results in information fragmentation, data duplication and potential data inconsistency. This paper proposes a novel, model driven approach for process planning integrating quality assurance which emphasizes the application of digital models to create, represent and use information of products, processes and resources. By reducing the amount of data and document duplication, the presented model driven approach has potential to radically increase the direct value adding part of manufacturing engineer's daily work also contributing to achieve a more holistic view in interdisciplinary work between different experts in product realization.

Keywords: Computer Aided Process Planning (CAPP); Quality assurance; Model driven

1. Introduction

Systematic process planning is a key enabler for robust product realization from design through manufacturing. Quality does not only depend on downstream control activities. In manufacturing, every process and operation must be designed in the best possible way. Each step shall contribute and ensure that the overall process chain leads to the right product quality.

Toyota is known for applying a front-loading approach in work projects, i.e. they allocate the main work effort on careful planning in the early stages of product realization. Thereby they are able to address potential problems in advance, and to put in countermeasures before the problems even has occurred.

The same is true for skilled process planners who anticipate problems early in process plan design and put in place countermeasures to avoid that problems occur in manufacturing, thereby designing a robust manufacturing process.

Hence, a frontloaded approach applied in process planning can imply that early decisions made by skilled process planners set the manufacturing conditions for product quality, a pre-requisite to create customer value.

Careful process planning in an early phase is emphasized in the Advanced Product Quality Planning and Control Plan (APQP) reference manual. The importance of the principles in the APQP reference manual is indisputable. However, the tasks of creating and managing its required documents for Process Failure Mode and Effect Analysis (PFMEA), Control

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plans, Initial process studies and Measurement System Analysis (MSA) results in high workload.

A major shortcoming with today´s work methods for process planning and quality assurance is that the creation of APQP required documents is done separated from the process planning. As the documentation in many cases is done by process planner, their competence is used in an inefficient way. Instead of doing the documentation the focus should be on improving production contributing to create customer value. In that sense, today's quality assurance work methods fail to capitalize on the valuable approved information already created in process planning.

Besides the work effort of creating the required documentation, the lack of interoperability between different computer applications used in product realization results in information fragmentation, data duplication and risk of inconsistent data. Representation mismatch increase information ambiguity and causes interpretation difficulties (Fig. 1).

When today's engineers spend time on work caused by information fragmentation – valuable time is spent on non-value adding work. Therefore, currently available APQP tools and work methods must be improved. To increase overall efficiency, it´s very important to base the detailing work within product realization on already created and approved results.

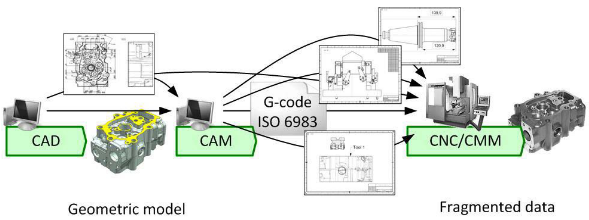

Fig.1. Today´s work methods results in data fragmentation, data duplication and risk for inconsistent data.

1.1. Research premises

This research is based on following fundamental premises:

- A process plan is a detailed manufacturing solution from the process design intent.
- Process planning is performed based on a process design rationale.
- Decisions made in process planning determine the conditions for manufacturing the right quality.

1.2. Process design and process design rationale

Price M. A. et al. defines design intent for a general system as: ''*The set of functions which the system was designed to deliver in the anticipated operating environment*'' [1]. In a process planning context this can be reformulated as: "*Process design intent is the expected manufacturing capability which the planned process was designed to deliver in the anticipated manufacturing environment*". Process planning is performed based on a process design rationale, i.e. a logical reasoning as a basis for a process planner in making decisions. A process design rationale can be formalized as an explicit listing of decisions made during process design and the reasoning behind the decisions, i.e. why those decisions were made. Ability to communicate process design intent in an efficient way is valuable in process plan analysis activities such as PFMEA.

2. State of the art

2.1. Process planning

Process planning is a central and important activity in the product realization process. Process planning is a key area for manufacturing which has been studied within the international academy for production engineering, CIRP since its formation in 1951. According to CIRP dictionary [2], Process Planning is defined as an activity which;

"*Includes all planning measures to be taken once to ensure the production of a part, an assembly or a final product at the lowest cost and best quality, which are mainly interpretation of the part design data, selection of the manufacturing processes and process optimization, determination of the routing plans as well as planning of the means of production and manpower assignment*.".

During process planning a myriad of decisions are made. Decisions which have different impact, determine the level of manufacturing robustness, i.e. the capability of the resulting process plan to enable efficient manufacturing of products.

Usually a process planner evaluates several alternative solutions. For the same manufacturing requirements there can be different process alternatives. In addition, there are interfaces to other important work within an organization interacting with process planning, e.g. product development, production equipment acquisition and factory design.

Altogether, this means that process planning is more or less iteratively performed, rather than being a straight forward process, and a holistic view is required to achieve the most appropriate manufacturing solution.

The iterations and the process design rationale is however "lost" in the final process plan and its representation as work instructions, NC-programs, Control plans, etc. These resulting artifacts of process design contain no hints of the process design rationale behind their creation.

Operation sequencing and setup planning can be considered as two important activities in process planning, and particularly operation sequencing has been a main topic for many years in CAPP research. For both activities, decisions can be motivated from a process design rationale.

In setup planning, manufacturing feature information and Product Manufacturing Information (PMI) including Geometric Dimensioning and Tolerance (GD&T) of a workpiece model, can be used to determine appropriate setup sequence and perform feature clustering for each setup. Process design rationale can for instance be described here in terms of loosely and strictly related tolerances [3, 4].

In operation sequencing, manufacturing interactions, as described by Faheem W. et al. [5] is a way of managing operation precedence constraints in a rational way. The