Knowledge Management in Process Planning

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Abstract

Considerable research and development efforts have been devoted to Computer Aided Process Planning (CAPP). Nevertheless, because the CAPP problem is complex and is characterized by many interdependent technical and business parameters and variables, no viable off-the-shelf solution is yet available that can be easily or widely implemented in industry. This paper presents an overview of the CAPP field and describes a holistic component manufacturing process planning model based on an integrated approach combining technological and business considerations. The model was derived based on available literature, an overview of the state-of-the-art in Digital Manufacturing, Product Lifecycle Management (PLM) and CAPP solution providers, and a survey of Small Medium Enterprise (SME) manufacturers. This model will form the basis for developing improved decision support and knowledge management capabilities to enhance available CAPP solutions.

Keywords: CAPP, Abrasive processes, Knowledge management.

1 INTRODUCTION

One of the most important steps in converting a design concept into a manufactured product is process planning. Such planning determines the manufacturing operations, operation sequence and resources required to manufacture a product based on an engineering drawing or a CAD model. A process plan elaborates the machines, setups, tool specifications, operation time estimates, etc. required to convert raw material into a part [1].

Traditionally, process planning was performed manually from scratch, hence requiring retrieval and manipulation of a great deal of information from many sources, including established standards, machinability data, machine capabilities, tooling inventories, stock availability and existing practice. Much research and development has been devoted to developing a computerized solution for process planning - Computer Aided Process Planning (CAPP). Nevertheless, because the CAPP problem is complex and characterized by many interdependent technical and business parameters and variables, no viable off-the-shelf solution can yet be easily or widely implemented in industry. Moreover, because expert process planners are becoming an expensive and rare resource in industry, their productivity, effectiveness and consistency must be enhanced through improved decision support tools and knowledge management capabilities.

In this paper we have developed an ontology for the "extended" process planner environment and the process planner decision-making process model. These models are used as the basis for developing decision support and knowledge management templates and capabilities to support the process planning decision process for component manufacturing in the cutting and abrasive process domain. In these models a holistic approach was adopted that incorporates traditional technological aspects of process planning as well as complementary business aspects. Since the process plan is used in production scheduling as well as in machine control, it affects production efficiency, final cost and product quality [2]. Hence, process planning has a major impact on manufacturing profitability. Emphasizing the business aspects of CAPP will enhance existing CAPP solutions that currently focus on technological feasibility and optimization.

In addition, this paper presents PLM/CAD-CAPP solutions available in industry today from leading providers such as UGS, PTC, and Dassault Systemes, as well as their current development directions. Moreover, we discuss some additional complementary capabilities, identified during the literature review, market survey and industry survey, required to complete the holistic solution.

1.1 CAPP Overview

There are two basic approaches to computer-aided process planning — variant and generative [3].

Variant CAPP was the first approach used to computerize planning techniques. It is based on the notion that similar parts will have similar process plans. Part coding and classification based on group technology are used to implement this concept. A "standard" plan is formulated and stored for each part family [4].

Variant CAPP has the following advantages: (a) once a standard plan has been written, a variety of components can be planned; (b) programming and installation are comparatively simple; (c) the system is understandable, and the planner has control over the final plan; and (d) it is easy to learn and use. Yet several problems are also associated with variant CAPP: (a) the components to be planned are limited to previously planned similar components, and process optimization is not included; (b) experienced process planners are still required to modify the standard plan for a specific component; (c) variant planning cannot be used in an entirely automated manufacturing system without additional process planning [2].

Generative CAPP envisions creation of a process plan from information available in a manufacturing database without human intervention. Upon receiving the design model, the system is able to generate the required operations and operation sequence for the component [5]. A generative process-planning system comprises three main components: (a) part description, (b) manufacturing databases, and (c) decision-making logic and algorithms. Because the definition of generative process planning used in industry today is somewhat relaxed, any system containing some decision-making capabilities on process selection is called a generative system.

Generative process planning is regarded as more advanced than variant process planning. Ideally, a generative process-planning system is a turnkey system with all the decision logic built in. However, due to differences among manufacturing shops, decision logics have to be customized for each shop. The generative process-planning approach has the following advantages: (a) process plans are generated rapidly; (b) new components can be planned without relying on previous similar parts; and (c) there is potential for integrating with automated manufacturing facilities to provide detailed objective control information [2][3]. Most research systems are of the generative CAPP type [6].

1.2 Digital Manufacturing Overview

Historically, manufacturing process planning was manual and based primarily on the experience and knowledge of individual process planners, who typically developed manufacturing process plans after product planning. The failings of this sequential approach contributed to the advent of concurrent engineering, enabling simultaneous product and process planning. Most digital manufacturing technology suites are built around this core manufacturing process function.

Digital manufacturing has become a key component of Product Lifecycle Management (PLM). PLM systems are the current solution for managing the integrated Knowledge Information and Data (KID) regarding product design, production process and production capabilities. Digital manufacturing seeks to define and manage manufacturing process information and support effective collaboration among engineering disciplines by using full digital product and plant definitions. It facilitates a holistic view of product and process design as integral to the product lifecycle and enables referencing to process constraints and capabilities during product design. Digital manufacturing supports product data release, engineering change management, factory modeling, visualization and collaboration, simulation of operations, and ergonomic and human factor analyses. The PLM platform is, therefore, the natural backbone for enabling technological KID management for CAPP.

2 LEADING PLM/CAPP SOLUTIONS

This research encompasses process planning of abrasive component manufacturing and therefore excludes additional CAPP capabilities such as assembly planning and shop floor planning. A field study collected information on process planning solutions available in industry and mapped the state-of-the-art in the field. Interviews with leading solution providers, among them UGS, PTC and Dassault Systemes, demonstrate the state-of-the-art in digital manufacturing. The companies employ similar strategies offering manufacturers an integrated solution for digital management of product and process KID. All of the proposed solutions include the following components:

- CAD system
- Process planning capabilities
- CAM system
- PLM KID management capability
- Interface to Enterprise Resource Planning (ERP) and Manufacturing Execution Systems (MES) systems

Figure 1 presents the current system configuration, as well as the strategic aim of future systems. Current and future solutions differ mainly in the applicability of the PLM and Digital Manufacturing component as the KID backbone to support CAD-CAPP-CAM systems and the not-yet-existing feedback loop for improving design and process planning productivity and profitability. Current CAPP solutions are suited to mass production of specific product types, e.g., the power train market, the automotive industry, and, more recently, the aerospace industry.

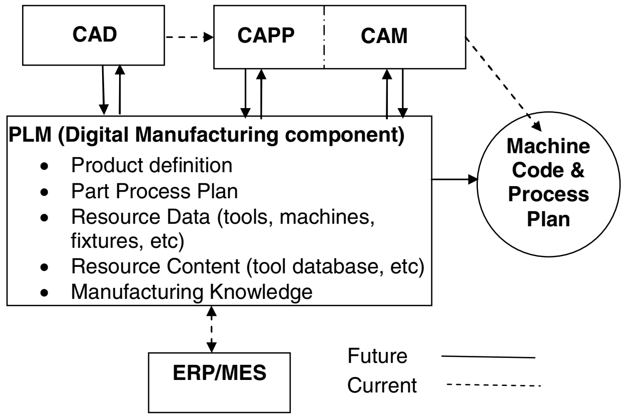

Figure 1: Current and future process planning solutions.

Figure 2 presents the most common knowledge-based methods used in CAx. Historically, computer aided design was the first to support knowledge in engineering processes and thus incorporates the largest number of knowledge management methods. Computer aided process planning and manufacturing have also introduced similar techniques, but knowledge generation and transfer must be carried out separately for each application and specific environmental conditions.

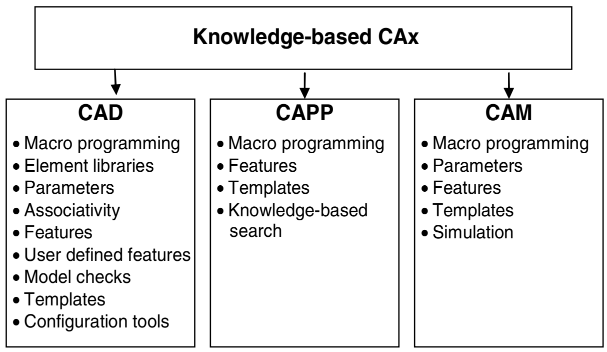

Figure 2: Established knowledge tools in CAx systems.

Generally, solution providers focus on CAD and CAM tools rather than on CAPP. However, available CAM solutions have been expanded to include some CAPP functionalities, e.g., feature recognition, process plan definition for compound features (including tool selection) and rule-based prioritization of machine operations. Because CAM systems are well accepted and implemented in the market, their expansion was appropriate. Moreover, cooperation between process planners and manufacturers—or shop floor—is more common than between process planner and designer. This trend of including CAPP capabilities in CAM systems is contrary to the expected benefits from collaboration between designers (CAD) and process planners (CAPP). Integrating product and manufacturing process design is vital, for it facilitates optimization of product cost. This integration also reduces product development lead time,