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A feature model editor and process planning system for sheet metal products

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Abstract

Sheet metal is widely used for industrial and consumer products because of its malleability into complex shapes. However, in the aerospace industry manufacturing planning of sheet metal products is still mainly carried out manually. Most of the previous research in this field has been primarily devoted to computer aided process planning for rotational and prismatic parts. This paper describes the development of an advanced software toolset used for the automation of sheet metal fabrication planning for aircraft components. The system is specifically designed to be implemented and maintained by manufacturing engineers, rather than computer programmers. Therefore a systematic user requirement capture has been carried out, and the planning knowledge has been captured within a leading aerospace company, which was the main sponsor of the project. The prototype system was then developed in collaboration with a software consultant company and finally evaluated and benchmarked through industrial case studies which proved that the system provides an efficient and effective approach to sheet metal fabrication process planning, when compared with other commercially available systems.

Keywords: Sheet metal fabrication; CAPP; CAD/CAM; Aerospace manufacturing; Feature modelling

1. Introduction

It has been recognised that process planning is the crucial link in the manufacturing cycle, as it determines how a product is to be manufactured. Traditionally process planning is carried out manually by experienced engineers who interpret engineering drawings of products and determine the 'best' route and manufacturing methods based on available materials, processes, the time scale and cost restraints. Manual planning is time consuming, labour intensive and may involve human errors [1]. It is also not unusual for different planners to specify different routes for the same part, which do not always incorporate the optimal solution to the problem. Standardisation, best practice and the company's knowledge are difficult to maintain. As a solution, computerisation of process planning has evolved. Early planning systems were primarily for documentation generation, storage of bulk information and retrieval of generated plans [2]. The most maturely developed area so far has been focused on the machining applications [3,4]. Research and development in fabrication applications such as heat treatment, forging, injection moulding, and sheet metal fabrication is still premature, and the reported systems for sheet metal fabrication rely on a high level of interaction by the expert who provides decision-making at different stages of planning [3,5,6]. The main aim of this research is to develop a user-oriented planning system for sheet metal fabrication in the aerospace sector. The idea is not to replace the role of expert process planners, but instead, to provide an advanced tool to assist them to be more efficient and consistent in their work. This project was set up in collaboration with an aerospace manufacturing company, and a software consultant company. In the aerospace company sheet metal forming processes are used to manufacture various components, such as bending and straight flanging, surface contour sheet, linear contouring, deep recessing and flanging, and shallow recessing. About 80% of the process plans being produced are mass produced components consisting of standard details and features with certain differences, whilst the remaining 20% are complex components which are small in quantity, but high in detail and quality. The first version of the prototype CAPP system developed was to generate process plans for bending and flanging of the mass produced components [7]. A further development allows the user to enter the product data as a feature tree for simple sheet metal components. Future developments of the system will be able to cope with the remaining more complex components and possibly be modified for prismatic and rotational parts as

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well. The initial stage of the research was conducted on-site at the aerospace company, to understand the manufacturing processes and process planning tasks, and to capture user requirements for computer aided process planning functions [8]. The second stage was carried out on-site with the software consultant company. The results gained from the requirements capture enabled a more realistic planning system to be developed. Although the prototype system is dedicated to the aerospace manufacturing sector, the underlying methodology can also be tailored to general sheet metal fabrication. The manufacturing logic as well as the data about the tools, work centres and manufacturing practices is kept in a database. The CAPP system draws on this database at run time to generate the process plan. This data-code separation allows the system to be generic and flexible.

2. Stages of system implementation

The system has been developed, improved and expanded through a number of stages. At each stage feedback from process planners have been collected and carefully considered for the next stage. One of the most important tasks is to capture manufacturing knowledge which is used to develop the Master Plan. The Master Plan contains all the manufacturing processes and the logic that determines which processes and machines to use. It is effectively the company's 'know-how'. The knowledge capture begins by arranging brainstorming meetings with the company's process planners and other relevant people. All the factors affecting the decision-making and all the bending and flanging processes used for the mass produced components were collected. At the initial stage of the brainstorming sessions, normal brainstorming rules were applied, in which no analysis, filtering, review or classification was allowed, thereby keeping up the pace and not inhibiting creative thoughts. When the stream of relevant factors had been exhausted, the second stage of the knowledge capture started, in which the factors previously identified were reviewed and arranged into logic flowcharts. The developed logic represents the Master Plan and this document was distributed to all participants. Any disagreements to the points were raised in open discussions and solutions to the disagreement were found. The Master Plan and relevant manufacturing information was entered into the initial version of the prototype system and tested on dummy component parameters, which were compared with the generated process plans. The process planners then tested the working system with the sheet metal Master Plan installed. After the Master Plan was implemented other functions and facilities of the system were developed. In a real situation the maintaining and further development of the Master Plan is the chief process planner's responsibility. Other process planners require only minimal computer skills to use the predefined decision logic.

3. Software tools used

The prototype CAPP system can be regarded as a database application program, which consists of the following components: a high level language, a user interface, a database management system, a data language and an operating system. An object-oriented programming language C++ was used to create the main functional modules. The chosen Graphical User Interface software is 'Galaxy' — an application development environment, which is used for designing and developing the ground up large-scale, C/C++ based, platform independent and distributed applications. The relational database management system selected is Oracle 7 server which enables the sharing of data between applications, where the data is stored in one place and used by many systems. The Oracle relational database is manipulated by the data language — Structured Query Language (SQL) *Plus. SQL is the industry's standard language adopted by all database vendors. Oracle's SQL*Plus is a superset of standard SQL and has some Oracle specific features that can be used for writing reports and controlling the way screen and paper output is formatted. In addition, a feature model editor was developed using Visual Basic and Visual C++ which can be regarded as a standalone feature input system for any process planning systems [9]. The operating platform chosen was Windows NT version 4 running on a Personal Computer.

4. Options and modules of the main planning system

The developed prototype system provides two options of planning strategies, i.e. Variant and Generative as shown in Fig. 1. The first three modules are used to initiate the system and allow the user to log on. The Variant option includes the Header Detail, Routing and Operation Description modules. The Generative option constitutes the following modules: Product Definition, Work Centre, Master Plan (with Logic Definition), View Routing and View Plan modules.

4.1. The Variant planning option

The *Variant option* allows step-by-step manual planning which is still useful in some simple applications. Fig. 2 is a screen shot of the Variant planning option showing the three modules (Header, Routing and Operation Description) at the very top of the screen with the Header module opened. The Header module asks the user to input the following information: part data (number, name, description), material data (name, category, specification), project data (company name, location, effectivity, Mod standard, batch number), drawing data (number, standard, issue), authorisation data (compiled by/date, approved by/date, inspected by/date), part dimension (length, width, thickness), stock dimension (length, width, thickness), association data (specification name, number and issue). At the bottom left-hand side