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Machine tool capability profile for intelligent process planning

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ABSTRACT

An optimized metal cutting process plan can only be developed with an accurate capability profile of a machine tool. Based on the information within this profile, a manufacturing decision making process can ascertain the time and production cost of parts. In this paper, a standardized methodology for modelling manufacturing resources is realized to enable accurate representation of actual resources and custom constraints. An example case study demonstrates the application of the machine tool capability profile through the selection of available cutting tools rather than using nominal cutting tools.

1. Introduction

Process planning for metal cutting is among the most knowledge-intensive activities in manufacturing. In this activity the product information is mapped on to the available information for the various existing manufacturing resources to determine a plan of action to convert the raw material into the final product [1].

This activity is currently supported by information technology in the form of computer aided process planning [2]. A considerable amount of research has been carried out to introduce more intelligence into process planning [3]. Process planning relies on manufacturing resource models to supply the necessary information regarding the physical devices used for manufacturing [4].

In the state of the art, the nominal model of manufacturing resources is used for process planning. The information contained within this model, neither reflects the actual state of the resources, nor does it reflect any policy constraints that have been implemented in the manufacturing enterprise. This results in generation of process plans that might not be entirely effective in the context of the available resources and policies.

In this paper a STEP-compliant methodology for representing resources is extended to allow the representation of machine tool capability profiles in a time-based manner while enabling users to define custom rules and policies. The extended data model can support the information requirements for profiling techniques such as prediction and online monitoring of resources as chosen by the user. The advantages of the methodology and the augmented model are then presented through the use of a case study. A discussion on the possible implementations of the methodology is then presented together with the conclusions derived from the work.

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2. Resource for CAPP

Process planning in metal cutting is the consolidation of activities that seek to define the necessary steps to change the shape of the raw stock to the desired product [1]. The activities range from the selection of technologies and manufacturability analysis at the high level [5] to sequencing operations and generating numerical control codes at the low level. At all levels, process planning relies on the availability of production resource information [6]. Human planners utilize their knowledge of technological capability of various types of machines while computer aided systems rely on resource models. CAM systems require users to select a machine type before generating tool paths and post-processors rely on internal models of machines to achieve their purpose. Fig. 1 provides an IDEF-0 representation of process planning.

Vichare et al. [7] presented a review of resource in the domain of metal cutting computer numerically controlled (CNC) machines and concluded that a universally applicable representation of such devices can only be realized through the development of a standardized manufacturing resource model. Efforts for developing this standardized model as part of the ISO14649 (STEP-NC) [8] standard are well under way at the time of writing of this paper. This representation provides an accurate representation of machine tool functionality. The functionality is determined through modelling the mechanical elements building the machine tool together with the kinematic relationships between these elements. Combining this information with the placement of cutting tools and the workpiece on individual machine elements, allows the capability of the machine tool in achieving the controlled motion of the tool with respect to the workpiece to be ascertained. Fig. 2 shows an EXPRESS-G [9] representation of the high-level elements from the proposed standardized model.

Also by solving the inverse kinematic chain from the workpiece to the tool-tip it is possible to determine the position

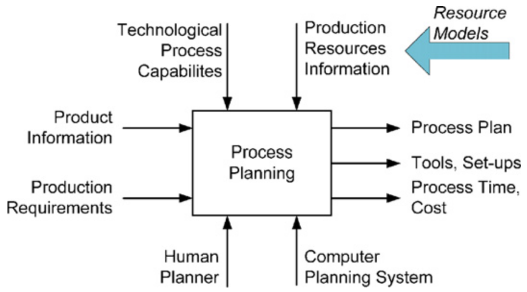

Fig. 1. IDEF-0 diagram for the process planning activity, adapted from [1].

of the individual axes on the machine tool to achieve a specific tool position with a pre-determined orientation in relation to the workpiece. While the model can provide the necessary information for the process planning activity to proceed, the information relates to the nominal state of the manufacturing resources.

3. Capturing capability profiles of manufacturing resources

Any manufacturing resource that is used continuously changes over time. Using nominal models of manufacturing resources when planning the process of production, results in the generation of non-optimal plans. This is illustrated as an IDEF-0 diagram in Fig. 3.

Often in industry, specific constraints are imposed on manufacturing resources by management. For example, a specific CNC machine might be allocated to a specific part family and not be used for other parts, notwithstanding the fact that the machine has the capability to produce other parts. These production policies are not always considered when the process plan for a component is being generated.

Due to these considerations, automatically generated process plans, often require further input from the engineers on the shop floor to ensure their appropriateness to the actual status of the resources and production policies as dictated by the manufacturing enterprise.

In order to enable the process planning system to determine the most effective plan with respect to the actual available resources, it is necessary to provide resource information that reflects the status of the physical devices at the time that they will be utilized for manufacturing the part. This time-sensitive image of the resource, called by the authors a capability profile, is a representation of the capabilities that a specific machine tool will be able to provide in a specific time on a specific product.

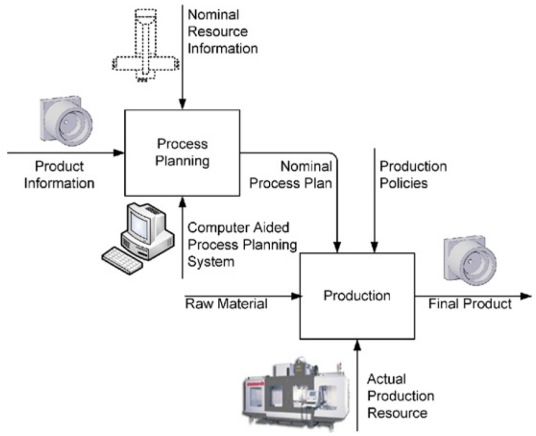

Fig. 3. IDEF-0 representation of the state of the art in process planning.

An IDEF-0 diagram is used in Fig. 4 to illustrate how the existence of the capability profile affects the process planning and production activities. The capability profile can be generated by many techniques including prediction and online monitoring of resources and is subject to policies set by the user. Regardless of the generation technique, it is imperative that the profile is associated to the representation of the resource within the manufacturing information.

The CAPP system can then utilize this resource capability profile instead of the nominal resource information to create a capability adjusted process plan. The quantity, intensity and effectiveness of the adjustments depend on the adaptability of the process planning system. A CAPP system capable of accessing the integrated body of manufacturing knowledge existing in the enterprise such as that suggested in the universal manufacturing platform [10] would provide the highest flexibility. This is due to the fact that in such an environment the process planning system would have access, not only to the process data, but also an integrated representation of the entire body of the manufacturing information including resource and product data.

4. Process planning supported by capability profiles

The manufacturing resource capability profile contains all items of information that a nominal resource model contains. Individual items of information are then replaced by the input gathered from the actual status of manufacturing devices on the shop floor or predictive models. Fig. 5 illustrates an example implementation of a computer aided resource profiling system.

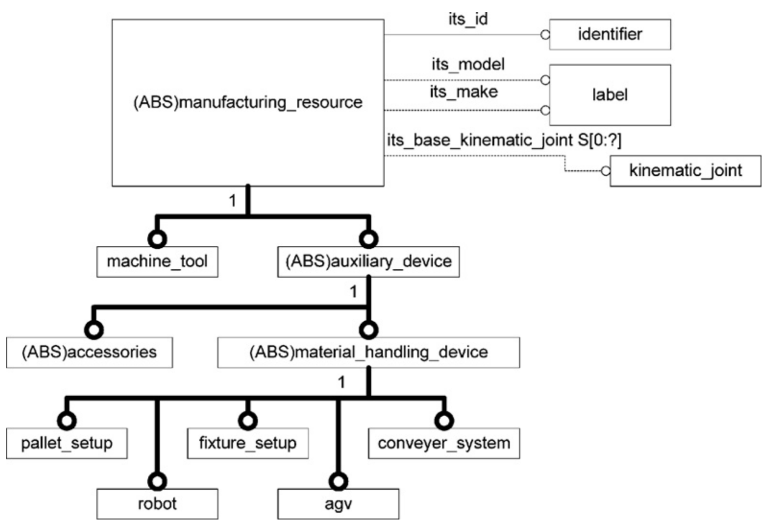

Fig. 2. EXPRESS-G diagram of the manufacturing resource model.