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A model for integrating process planning and production planning and control in machining processes

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Abstract

The goal of process planning is to propose the routing of a previously designed part and results in a sequence of operations and their parameters. It concerns and requires detailed information about the process. The goal of production planning, on the other hand, is to schedule, sequence and launch the orders introduced on the routing sheet into the job-shop according to the enterprise's strategic goal and the actual conditions of the production plant. The goals, information and decisions taken in process planning and production planning and control are often very different and, because of that, it is very difficult to integrate them.

The objective of this work is to develop a model that can be applied in the future to the development of an integrated process planning and scheduling tool using an integrated definition (IDEF) methodology to design an activity model, which integrates process and production planning in metal removal processes. An activity model will be used to develop a system that allows the user to plan the process and the production at the same time in collaborative engineering work. To design the activity model, a wide range of parts were evaluated and processed in an actual job-shop factory. Several activities were developed in detail to be tested in real cases, and an example of one of them is introduced in this article.

Keywords: Machining processes; Computer aided process planning (CAPP); Production and planning control (PPC); Activity model; Sequencing in machining processes

1. Introduction

The goal of process planning in a production environment is to select and define, in detail, the process involved in transforming raw material into a specific end product with a given shape and certain specifications. In other words, to determine the feasibility of processes and operations that, together with the necessary parameters, assure the finished manufactured part is obtained without any problems [1]. The purpose of production planning and control (PPC) is optimising the flow of material and the use of the machines involved in manufacturing, taking into account various management goals like reducing the work in progress, minimising shop floor throughput and lead times, improving responsiveness to changes in demand and improving delivery date adherence. Typical PPC system functions include planning material requirements, demand management, capacity planning and the scheduling and sequencing of jobs.

Needless to say, both process planning and production planning have complementary goals in order to improve continuing company productivity and, eventually, competitiveness. That said, optimal manufacturing routes, from the point of view of process planners, are often very different from the optimal routes in the opinion of production planners. Their respective goals can be as different as reducing the cost of each part in the first case, and reducing the time a specific machine is occupied in the second. In addition, these optimal routes can vary over time since they depend on the current situation of all the factors involved in the production process (availability of machines, parts, workers, etc.). Nevertheless, although process planning and production planning do not share all of the same objectives, their objectives are complementary in the sense that they should lead to a single optimal

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solution that shortens the manufacturing cycle as much as possible while increasing production flexibility and, in turn, company productivity.

In order to be able give optimal manufacturing orders at any given time regarding, for example, production times or costs, automated systems to assist in process planning, also known as computer aided process planning (CAPP), will be designed to varying degrees of success. These CAPP systems were originally developed as a link between design and manufacturing, filling the existing gap between computer aided design (CAD) and computer aided manufacturing (CAM) [2,3] and responding to the need for material requirement planning (MRP) to work with standard and optimised routes which can be used in production planning. The inputs in these systems are the technological variables involved (tolerances, materials, etc.) that allow the calculation of a specific output: the routing, which is a sequence of manufacturing operations containing details about the depths of pass, the speeds, the dimensions, the assembly steps, the tools, etc. [4]. However, the fact that these CAPP systems are completely separate from the management variables under the control of the production planner (stocks, available machines, workers, etc.) means the sequence provided by the system must be the optimal one according to the defined objectives. Even so, such an optimal process plan may not guarantee the best way to manufacture the part in the plant at a specific moment, as it could lead to the overload, or under use, of some machines, with subsequent bottle-necking. Generally, and depending on the severity of these bottlenecks, this problem is reduced in what [5] calls production rescheduling: the CAPP system is required to generate alternative routes and to implement them during the following shift or the following day according to the PPC analysis. For this reason, if the CAPP system does not take into account the existing management restrictions, it is recommended to generate more than one plan [6,7].

Until now, many studies have undertaken to individually optimise the two tasks, process planning and production planning, individually. The process planning problem has only been partially analysed in many research studies, among which the following stand out: (a) joining process planning with the part design [8], (b) improving the choice of machining process parameters for cylindrical parts [9] or for prismatic parts [10], or finally (c) optimising the sequence of operations [11–13].

The same has happened with respect to PPC. Many research studies have focused on specific aspects of the problem, leading only to partial solutions, which do not necessarily correspond to the overall best solution to the problem. Some of these research studies have used the three "classic approaches" of production organisation according to Ref. [14]—JIT, manufacturing resource planning (MRP II) and theory of constrains (TOC)—and have worked on emerging techniques such as workload control (WLC), constant work in process (CONWIP) and paired cell overlapping loops of cards with authorisation (POLCA). Some of the new approaches are the resulot of MRP leading to further advanced manufacturing technology (AMT) such as enterprise resource planning (ERP), advance planning and scheduling (APS) systems and workflow management systems (WMS).

From that research it can be inferred that effective paths of communication and integration between CAPP and PPC are essential. Grabowik et al. [5] has called attention to the weak links existing between information systems and the CAD–CAPP–PPC systems in the majority of companies. He has also pointed out that carrying out this integration will require work on three basic aspects: (a) the complete integration of CAD systems, technological preparation of production systems (like CATIA, ProEngineer, etc.) and planning management systems (such as MRP/ERP, SAP, BAAN, etc.); (b) integration through universal standards of data exchange (e.g., STEP and IGES); and finally (c) the use of technological and constructive features.

That said, and despite taking into account the efforts made by Refs. [15–19], very few studies have attempted to integrate these two fields of research. In fact, the effective integration of process planning and production planning and control is not a trivial matter. Both processes work with a more than considerable amount of data, sometimes shared, but at times with nuances in the definitions that make the integration complex. Process planning resource databases are static and are usually not updated to reflect the situation on the shop floor. PPC, on the other hand, is time dependent and deals with dynamic environment. In addition, process planners are generally focused on operations carried out on individual parts, while PPC systems deal not only with multiple parts, they also deal with multiple products to be manufactured in the same system.

At this point, it should be clear that the purpose of this study is to establish a frame of reference or model where process planning is integrated with production planning so that their objectives are shared and made compatible to provide a joint solution with better global product manufacturing results and time and/or cost reductions. This model was intended to be the basis for the creation of future management systems that integrate process planning and PPC.

Achieving this goal will require correctly modelling all the actions carried out in both fields even though they often concern two very different areas of the company: design and management. Therefore, this study begins by examining the various steps or actions involved from the moment the requirements of a part to be manufactured are known until it is produced and launched into the market. Knowing the structure and type of information required to carry out each activity as well as the functions of each action are essential for the correct integration of the two planning tasks. Consequently, IDEF modelling techniques will be used to introduce an integrated model of process and production planning.