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Computer-aided process planning in virtual one-of-a-kind production

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Abstract

This paper reports a framework for computer-aided process planning (CAPP) in virtual One-of-a-Kind Production (OKP). The emphasis will be placed on the particular problems of developing a CAPP system in virtual OKP company. A virtual manufacturing company or a manufacturing network normally consists of geographically dispersed master company's branches, sub-contractors, joint ventures, and partners. In this paper, we will address issues raised from highly customised products, the concurrent approach of product development and production through a manufacturing network, incomplete product and production data in OKP, the need for quickly capturing marketing opportunities and early response to the customer's demands, continuous customer influence upon production, the optimal selection of partners, and partner synthesis in virtual manufacturing. The CAPP framework proposed in this paper includes a reference architecture for structuring a CAPP system in virtual OKP, a new CAPP method which is named the 'incremental process planning (IPP)', and an optimal/rational cost analysis model. It also includes three data models for data modelling and structuring of the product, the process, and manufacturing plants used in virtual OKP.

Keywords: Computer-aided process planning (CAPP); One-of-a-kind production (OKP); Virtual manufacturing (VM)

1. Introduction

Global competition is forcing manufacturing companies to develop the ability to quickly produce customised or even One-of-a-Kind Production (OKP) products of high quality at competitive prices. The features and characteristics of OKP has been well-discussed by a number of authors. A comprehensive literature review on these discussions and a clear definition of OKP were given by Tu [1]. In practice, an OKP company could be loosely understood as an advanced jobbing shop which provides different services (or customised products) in a certain manufacturing domain (i.e., 'Kind' in OKP), e.g., a ship-building manufacturer, a steel frame fabricator, a

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mould/tool manufacturer, a metal-cutting machine shop, etc.

The keen global competition has also caused many manufacturing companies to cut 'fats' (or costs) through strategically moving their manufacturing bases and facilities from developed areas, e.g., Hong Kong, Western Europe, and the USA, to developing countries and areas which provide favourable conditions, such as lower labour costs and other cheaper resources. This movement is leading to a new manufacturing mode called virtual manufacturing. A virtual manufacturing company is a global manufacturing network where the nodes are branches, subcontractors, joint ventures, or partners of the master company [2]. These nodes have been called 'virtual cells' by Tu [1]. The virtual cells of a virtual manufacturing company are geographically dispersed. Virtual manufacturing companies are seen as a new generation of companies involved in agile [6] and global manufacturing. In order to be able to control and synthesise production in such a global manufacturing network, researchers have concentrated on developing a reference architecture and control principles for this network. Virtual OKP companies which are the focus of this research, belong to this new generation. A virtual OKP company aims to produce one-of-a-kind products through a global manufacturing network. With the support of developing technologies, a virtual OKP company can flexibly capture opportunities in the market and quickly respond to the customers' varied demands on design and manufacturing processes. As discovered by the authors through a literature review and industrial visits, the virtual OKP is likely to become a promising and important part of the manufacturing philosophy in the world.

However, there are a number of issues raised from the special requirements and/or problems in the virtual manufacturing, particularly in the virtual OKP. These requirements and/or problems include highly customised products, the concurrent approach of product development and production, incomplete product and production data, the need for quickly capturing marketing opportunities and early response to the customer's demands, continuous customer influence upon production, and the optimal selection of partners and partner synthesis in virtual manufacturing.

Furthermore, in virtual manufacturing, product development and the synthesis of partnership for product realisation are two important activities. Process planning will play a key role in linking these two activities. Current CAPP systems have been developed based on conventional process planning theory. In OKP, continuous customer influence on production runs concurrently with product development and production. Process planning based on conventional CAPP systems becomes very difficult in this situation. Conventional process planning theory is a linear process model. It can only run in series, not concurrently. Hence, the concepts, methods, and theories for CAPP in virtual OKP need to be developed to support the production planning and control in virtual OKP.

This paper will propose a framework for CAPP in virtual OKP. The emphasis will be placed on the particular problems of developing a CAPP system in virtual OKP as mentioned above. The proposed CAPP in virtual OKP will be of particular help to the manufacturing companies which want to gain agility [6] and, consequently, their competitive edge in the marketplace. The proposed CAPP framework includes a reference architecture for structuring a CAPP system in virtual OKP, a novel CAPP method which is named the 'incremental process planning', and an optimal/rational cost analysis model. It also includes three data models for data modelling and structuring of the product, the process, and partner manufacturing plants used in virtual OKP.

To avoid confusing readers, we would like to define the computer-aided process planning system in virtual OKP in the following according to the conventional definitions of process planning [3–5] and the particular needs of virtual OKP.

CAPP in virtual OKP is a computer-aided decision making support and planning tool which aims to generate the methods and cost estimates to economically and competitively convert the technical specifications of customer's requirements into a wanted product. The technical specifications of customer's requirements are understood as the design of a product which is modelled by a proper product modelling tool.