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Journal of Materials Processing Technology 129 (2002) 629–633

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

Research on flexible transfer line schematic design using hierarchical process planning

G.W. Zhang*, S.C. Zhang, Y.S. Xu

School of Mechanical Engineering, Tianjin University, Tianjin 300072, PR China

Abstract

This paper proposes an approach to a bidding-based flexible transfer line (FTL) schematic design system. The architecture of the flexible transfer line schematic design system (FTLSDS) is established. The system consists of four processes: part feature modeling, process planning, FTL facility layout and FTL evaluation. For FTL schematic design, a five-level process planning strategy named the hierarchical process planning method is proposed. This method includes the selection of the manufacturing feature machining operation, part set-up planning, feature sequencing, operation sequencing and process plan generating. The major decision relies on set-up planning. The framework of the machine modular design system to support machine requirement design for FTL is implemented. In the process of evaluation, quality, flexibility, reliability, machine load, and cost are taken into account.

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Keywords: Flexible transfer line; Schematic design; Hierarchical process planning; Operation sequencing

1. Introduction

The flexible transfer line (FTL) is now used widely in many manufacturing domains to realize efficiently, high quantity and economic production. These manufacturing domains include automobiles, tractors, internal-combustion engines, and so on. In today's competitive business environment, it is vitally important for machine tool manufacturers to design FTLs more effectively and efficiently according to a wider variety of customer demands. Successful industrial companies must be able to adapt quickly to fast-changing conditions in the market and to competitors within a shorter lead time at a low cost. It is a pre-condition to acquire the FTL order that the manufacturers must provide their customers with the plans of the FTL and an accurate quoted price as quickly as possible.

It has been recognized that computer aided process planning (CAPP) plays an important role in an integrated computer aided design (CAD) and computer aided manufacturing (CAM) system. Process planning involves determining the necessary manufacturing processes and their sequence in order to produce a given part economically and competitively. The major process planning activities are the interpretation of product design data, the selection of a part blank, the selection of machining processes, the determination of machine tools, the selection of cutters and fixtures, the sequencing the operations, the determination of cutting parameters, the calculation of overall production times, and the generation of process sheets. There are two main approaches to CAPP, namely the variant approach and the generative approach [1]. The variant approach relies on existing standard plans developed from previously manufactured similar parts, and involves retrieving the plan by a group technology (GT) code and making the necessary modifications to the plan for the new part. The generative approach involves the generation of new process plans automatically by means of decision logic and process knowledge, without referring to previous existing plans. In general, process planning is limited by manufacturing facility resources, but the CAPP for FTL schematic design is different. It first generates a near optimal process plan without regard to facility resources, and then selects machine tools or designs special purpose machine tools by means of the modular design principle. In this paper, a suitable process planning strategy for FTL schematic design is proposed.

A design methodology of a manufacturing systems usually can be defined as a set of procedures that analyses and segregates a complex manufacturing system design task into simpler manageable sub-design tasks while still maintaining their links and interdependencies [2]. The FTL design procedure is in the same way. The design procedure includes the following steps:

* Corresponding author. Tel.: +86-22-87401573.
E-mail address: zgw_tju@eyou.com (G.W. Zhang).

0924-0136/02/$ – see front matter © 2002 Elsevier Science B.V. All rights reserved.
PII: S0924-0136(02)00670-2

Step 1: requirements of manufacturing system design;
Step 2: selection of manufacturing operations;
Step 3: selection and design of machine tools;
Step 4: design of the manufacturing system configuration;
Step 5: design evaluation;
Step 6: implementation; and
Step 7: re-configuration.

This paper describes a bidding-based approach in the integration of part feature modeling, hierarchical process planning and evaluation. Concerning with the research on the methodology of FTL schematic design for prismatic parts using hierarchical process planning, the main objective is to develop a flexible transfer line schematic design system (FTLSDS) which can drastically decrease the FTL development time.

2. Architecture of FTLSDS

By analyzing the manual FTL design process, the architecture of the FTLSDS is established (see Fig. 1). The system consists of four processes: part feature modeling, process planning, FTL facility layout and FTL evaluation. The part feature modeling is used to fulfil a part model description. Through the part description file, the part description information is exchanged. The process planning generates the part process plans which provide a reasonable basis for FTL facility layout. According to the part process plan, FTL can be designed in some configurations. In terms of measuring reliability and productivity, flexibility, machine load, and cost of configurations, the designer can decide which configuration is better. Finally, the system provides estimates of the approximate manufacturing system cost.

The information in the system database includes part description, machine tools, machine tool modules, cutters, materials, fixtures, cutting parameters, process plans, manufacturability evaluation information and other useful information. The planning knowledge in the knowledge base involves manufacturing feature operation selection, set-up planning, cutting tool selection, operation sequencing, cutting parameters calculation, and manufacturability evaluation. As object-oriented programming offers several advantages over procedural programming, the system adopts the object-oriented approach to establish the object-oriented part model, object-oriented manufacturing facility model, object-oriented FTL resource model, and object-oriented process planning model.

The integration of this system has two technical merits. One is that all functional modules mutually support and interact with each other, whilst the other is that they share the information that is produced in different modules.

3. Part feature modeling

In order to meet the requirements of customers who have different 3D CAD software, it is necessary to use feature technology. The feature-based approach can be used to perform the manufacturing knowledge representation. The features of the part can be divided into two classes: design features and manufacturing features. The manufacturing features are linked by different machining methods. The major manufacturing features of prismatic parts include plane, cylinder, hole, slot, pocket, and fillet. However, design features do not always correspond to manufacturing features. Feature technology can give a solution for this problem. In general, the feature technology approach can be classified into feature extraction, feature-based design, and feature conversion [3]. Feature extraction is mainly concerned with identifying certain features from the various types of product representations such as boundary representation (B-rep) or constructive solid geometry (CSG). Feature-based design aims at building a product model with a pre-defined set of design features. Feature conversion is the methodology that converts features defined in one domain to those of other domains (e.g., the conversion from design features to manufacturing features). Part feature modeling in FTLSDS has two methods to realize the part information description. One method is feature recognition and conversion and the other is feature-based design. The most important thing for designing and developing a part feature

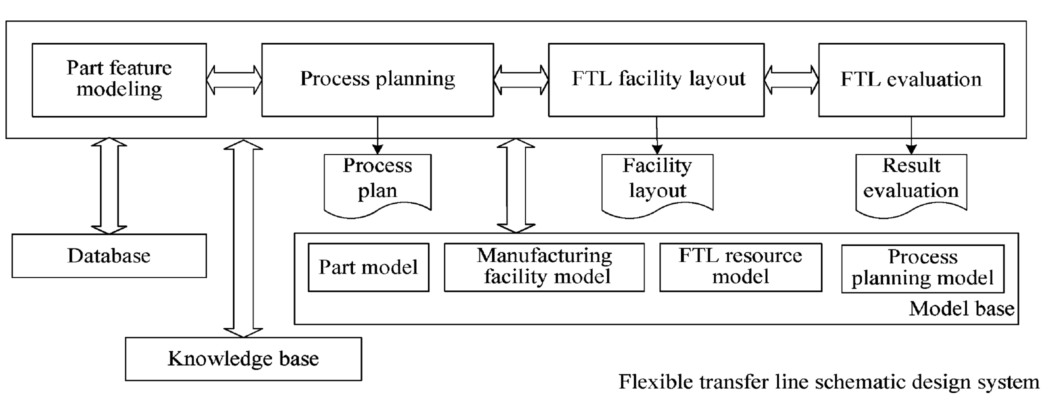

Fig. 1. The architecture of FTLSDS.

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