Computers in Industry 60 (2009) 296–316

Contents lists available at ScienceDirect

Computers in Industry

journal homepage: www.elsevier.com/locate/compind

Intelligent feature based process planning for five-axis mill-turn parts

Kriangkrai Waiyagan *, E.L.J. Bohez

Department of Design and Manufacturing Engineering, Asian Institute of Technology, P.O. Box 4, Klong Luang, 12120 Pathumthani, Thailand

ARTICLE INFO

Article history:
Received 25 January 2007
Received in revised form 12 September 2008
Accepted 26 September 2008
Available online 25 November 2008

Keywords:
Intelligent process planning
Prisronal part
Machining features classification
Five-axis lathe
Machining feature definition

ABSTRACT

This paper proposes a new process planning system for five-axis mill-turn parts. This system focuses on parts including both prismatic and rotational features newly defined as Prisronal parts. The three main parts of the new system are as follows: (a) a novel machining features classification based on machining processes and number of simultaneously controlled axes of five-axis lathe; a new group code system is proposed. (b) Machining feature definition with representation; this model not only includes geometric and manufacturing data in the open layer but also includes machining processes and machining knowledge viewed as production rules of expert systems. (c) Process plan generation model; a process plan is generated based on machining features and rules. A user interactively identifies geometric entities to machining features provided as templates by the system. Machining processes and particular machining rules are designed and built-in each machining feature in the hidden layer. Auxiliary rules are provided for setup selection, precedence relation, and tool selection. Benefits of the system are fast and accurate process plan generation.

1. Introduction

Process planning is a decision-making process. It is done normally by a human and depends on individual experience. A feasible and efficient solution requires a proficient process planer. Process plans made by a human expert are inconsistent, inaccurate, time-consuming and costly Elias [1]. Therefore, an expert system could be a good choice for CAPP. This paper presents a new intelligent expert process planning system for five-axis mill-turn parts. Three important problems need a solution for developing this system. The first is representation of workpiece geometry and technological data. The second is identifying machining processes and knowledge-based rules. The third is generating a process plan. To overcome the first and second problems, Feature concepts are applied Shah et al. [2,3]. To solve the last problem, machining processes, knowledge-based rules and heuristics are designed and attached to each feature. The system is based on variant and generative approach. The variant concept is applied in the sense of the machining features classification and a group code system whereas the generative concept is applied in term of rules for decision-making processes. This study is distinctive from previous CAPP research by focusing on prisronal parts. "Prisronal part" is the author's definition. It is defined as "a class of parts having primitive shapes with one common centerline like cylindrical, cone or round shapes including other symmetric and/or asymmetric rotational machining features for example holes, faces, slots, grooves or pockets in different orientations". Prisronal parts are usually found in automotive, ship and aerospace industries such as shafts, propellers and impellers. The paper is structured as follows. Section 2 gives literature review. Section 3 shows the four components of feature-based process planning system: design of system architecture, machining features classification, a new group code system, and machining feature definition and representation. Section 4 shows process plan generation model. Section 5 shows a case study. Finally, conclusions are given.

2. Literature review

2.1. Computer-aided process planning

Computer-aided process planning (CAPP) is considered as the main bridge between Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM). Introductions to CAPP are given by Chang and Wysk [4], Gideon and Weill [5] and Gu and Norrie [6]. Two major CAPP approaches are variant and generative. The variant approach is based on Group Technology (GT). Two examples of group code systems are the Opitz system and KK-3 coding system. The Opitz system was developed by H. Opitz [35]. The Opitz consists of a form code and a supplementary code. The KK-3 was developed by the Japan Society for Promotion of the

* Corresponding author. Tel.: +66 2 524 5687; fax: +66 2 524 5697.
E-mail addresses: st037211@ait.ac.th, bohez@ait.ac.th (K. Waiyagan).

0166-3615/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.compind.2008.09.009

The Opitz system for rotational parts

Form code					Supplementary code			
3	4	8	5	4	3	2	0	0

The KK-3 System for rotational parts

Digit	Component condition		Code
1	Main drive		2
2	Others		6
3	Steel bar		-
4	Carbon steel B1112		-
5	Dimension length (L) 570 mm.		-
6	Dimension diameter (D) 160 mm.		-
7	L/D = 3.56		-
8	External surface with functional tapered surface	Yes	3
9	Concentric screw thread	None	0
10	Functional cutoff & groove	None	0
11	Extraordinary shape	None	0
12	Forming (slot)	Yes	2
13	Cylindrical surface(polygonal)	Yes	1
14	Internal primary shape	None	0
15	Internal curved surface	None	0
16	Internal flat surface	None	0
17	End surface	Flat	0
18	Regularly hole	None	0
19	Special hole (angled hole)	Yes	8
20	Non-cutting process	None	0
21	Accuracy		-

The Opitz system for rotational parts

Form code					Supplementary code			
3	4	8	1	9	3	2	0	0

The KK-3 System for rotational parts

Digits	Component condition		Code
1	Main drive		2
2	Impeller		3
3	Steel bar		-
4	Carbon steel B1112		-
5	Dimension length (L) 100 mm.		-
6	Dimension diameter (D) 160 mm.		-
7	L/D =0.625		-
8	External surface with functional tapered surface	Yes	7
9	Concentric screw thread	None	0
10	Functional cutoff & groove	None	0
11	Extraordinary shape	None	0
12	Forming	None	0
13	Cylindrical surface (others)	Yes	9
14	Internal primary shape	None	0
15	Internal curved surface	None	0
16	Internal flat surface	None	0
17	End surface	Flat	0
18	Regularly hole	None	0
19	Special hole	None	0
20	Non-cutting process	None	0
21	Accuracy		-

Fig. 1. Benchmark parts coded by Opitz system and KK-3 system for rotational parts.

Machine Industry (JSPMI) in 1976 and uses 21-digit decimal system Chang et al. [7]. These systems are suitable for classifying parts including only common turning and milling features. Two sample mill-turn parts are coded by both systems as shown in Fig. 1. The results show that complex parts such as an impeller are not classified further. The generative approach relies on manufacturing knowledge. The system emulates intelligence of human process planners to generate process plans. An intensive survey can be found in [8]. Most researchers have restricted their problems to particular types of parts: rotational and prismatic. A survey to the state of the art of CAPP systems is shown in Table 1.

A lot of research has been done for two-axis turning and three-axis milling. At this moment, there are no studies devoted to CAPP

Table 1
Recent CAPP systems.

Parts	Authors	Viewpoints of CAPP	Machine tools	Reasoning techniques	Programming languages	Representation of geometrical and technological details
Rotational	Roa et al. [9]	Entire process started from feature based modeling system (FBMS) until generating NC tool path	2-axis lathe	Expert system	–	Feature based recognition and modeling
	Yeo [10]	Entire process started from feature recognition until generating NC tool path	2-axis lathe	The goal directed forward chaining technique	Goldworks & Common Lisp	Feature recognition
	Loh et al. [11]	Automated feature recognition, operation planning and machinability data selection	2-axis lathe	Artificial intelligence (AI)	Goldworks & Common Lisp	Feature recognition
	Zhao et al. [12]	Tool selection and cutting conditions	2-axis lathe	Expert system	Prolog	IGES with feature recognition
	Arezoo et al. [13]	Tool selection and cutting conditions	2-axis lathe	Expert system	Prolog	Syntax descriptions
	Shunmugam et al. [14]	Operation sequencing	2-axis lathe	Genetic algorithm	C++	Interactively entered by user
	Yildiz et al. [15]	Tool path generation	2-axis lathe	Definition rule of features	Delphi 7	DXF with feature recognition