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Development of database and searching system for tool grinding

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Analysis and modelling

ABSTRACT

Purpose: For achieving the goal of saving time on the tool grinding and design, an efficient method of developing the data management and searching system for the standard cutting tools is proposed in this study.

Design/methodology/approach: At first the tool grinding software with open architecture was employed to design and plan grinding processes for seven types of tools. According to the characteristics of tools (e.g. types, diameter, radius and so on), 4802 tool data were established in the relational database. Then, the SQL syntax was utilized to write the searching algorithms, and the human machine interfaces of the searching system for the tool database were developed by C++ Builder.

Findings: For grinding a square end mill with two-flute, a half of time on the tool design and the change of production line for grinding other types of tools can be saved by means of our system. More specifically, the efficiency in terms of the approach and retract time was improved up to 40%, and an improvement of approximately 10.6% in the overall machining time can be achieved.

Research limitations/implications: In fact, the used tool database in this study only includes some specific tools such as the square end mill. The step drill, taper tools, and special tools can also be taken into account in the database for future research.

Practical implications: The most commercial tool grinding software is the modular-based design and use tool shapes to construct the CAM interface. Some limitations on the tool design are undesirable for customers. On the contrary, employing not only the grinding processes to construct the grinding path of tools but the searching system combined with the grinding software, it gives more flexible for one to design new tools.

Originality/value: A novel tool database and searching system is presented for tool grinding. Using this system can save time and provide more convenience on designing tools and grinding. In other words, the company productivity can be improved.

Keywords: CAD/CAM; Tool grinding; Searching system; Relational database

1. Introduction

Due to rapid developments in the modern cutting technology and materials [1-5], the demand for all kinds of high precision tools is increasing. The grinding of cutting edges of tools is known as the most important and the final procedure for manufacturing. It is also a critical issue for determining geometry shapes, cutting performance, wear on the cutting edge and tool life [6]. The CAD/CAM tool grinding software can be generally classified into the modular architecture and open architecture systems. A modular-based system is used by reason of time saving on the tool design. However, it is very difficult for users to design and develop new cutting tools. An open-based system has flexibility in designing tools. When users employ it to design new tools, they have to possess complete foundation, understand the tool grinding processes, and the approach and retract sequences. The tool management system and the database system have been proposed in order to improve productivity and save tooling cost, etc [7-12]. Owing to the lack of the searching system for tool grinding, the data of standard cutting tools were established in the tool database system. The principal aim is to save time on the tool grinding and design. Experimental results show that the proposed system is convenient and efficient for designing new cutting tools.

2. Grinding processes planning

End mills are widely employed for all kinds of mechanical machining. They can be categorized into the square end mill, ball nose end mill, and radius end mill, etc. And further, other two kinds of commonly utilized tools are reamers and drills. Reamers can be classified into the straight fluted reamer and the spiral fluted reamer. Drills can be assorted into the flat drill and the twist drill. These seven types of tools of the above are called standard cutting tools. The parameters of geometry shapes and angles of end mills include the helix angle, rake angle, relief angle, clearance angle and the width of land, etc [13]. The values of these parameters are related to materials of machining, and affect the cutting performance and tool life.

The radial rake angle and the axial rake angle are varied according to tool functions and different grinding methods. The grinding method of the radial rake angle of end mills is divided into the flute and the shear flute, and the axial rake angle is divided into the flat gash and the curve gash. The flat gash is employed on the square end mill and the small radius end mill.

The relief angle is varied according to the choice of wheels, and different grinding methods. In general, the relief angle can be classified into the flat, concave, and the eccentric relief angle. In this paper, the grinding processes of cutting tools are based on a five-axis tool grinder. Moreover, the definition of each axis of the machine, and the grinding processes of the rake angle and the relief angle of end mills are shown in [14].

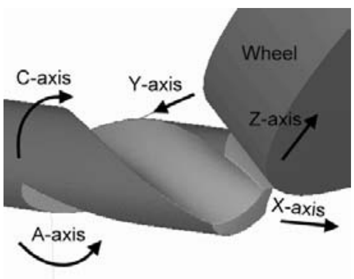

Fig. 1. Diagram of grinding a point angle

Once the tool grinder is used to grind the point angle, the NC path is generated according to the outside diameter of cutting tools, tilt angle and shape of wheels, point angle, chisel edge angle, and the lip relief angle. The grinding sequence of a point angle is: X, Y, C, and A axes start at the same time first, and shift to the approach distance of grinding face of a wheel and the lip surface. Z-axis moves downward to the approach distance. X-axis shifts to the grinding face of a wheel and the lip surface. X, Y, Z, A, and C axes start simultaneously to grind from the drill point to the margin of drill based on the contour of cutting tools. X-axis returns in the horizontal direction to make the wheel exit the groove. Then, X, Y, A, and C axes return to the starting point. Another flute can be ground according to the sequence of the above. Figure 1 shows the diagram of grinding a point angle.

3. Relational database system

The tool code is the identity of tools. There are different codes for various characteristics of tools. Each tool has the specific code which is the main index of the relational diagram. From 1 mm to 20 mm in diameter of standard cutting tools were coded in Table 1. The meaning of a tool with the code 1080235RRC as an example is shown in Figure 2.

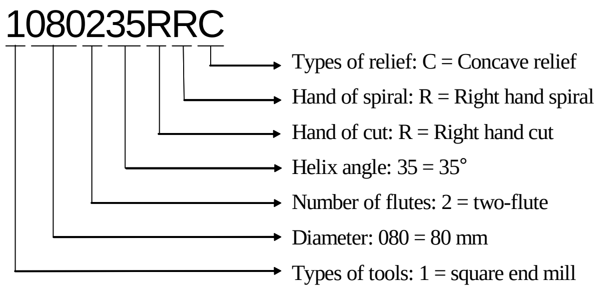

Fig. 2. Meaning of a tool with the code 1080235RRC

The basic concept of the relational database is the table [15]. Each table contains some columns which are called fields. The same properties of data are stored in each column. The table also contains some rows which are called records. The various properties of data are stored in each row. The table assumes a two-dimensional form, and therefore it is easy to understand the relation of each data element. It also shows the advantages of adjustment and expansion of data structures.

a)

Tool ID	Tool
T1	Square endmill
T2	Ballnose endmill
T3	Radius endmill
T4	Reamer Straight
T5	Reamer
T6	Flat Drill
T7	Twist Drill

b)

NO	Tool ID	Tool	Diameter	Helix	Point
706030060	T7	Twist Drill	6	30	60
706030090	T7	Twist Drill	6	30	90
706030118	T7	Twist Drill	6	30	118
706035060	T7	Twist Drill	6	35	60
706035090	T7	Twist Drill	6	35	90

Fig. 3. Data tables: (a) types of tools; (b) twist drill

Table 1.
Tool coding table

Characteristics	Item	Code	Characteristics	Item	Code
Types of tools	Square end mill	1	Number of flutes	2-flute	2
	Ball nose end mill	2		3-flute	3
	Radius end mill	3		4-flute	4
	Reamer straight	4		6-flute	6
	Reamer	5		8-flute	8
	Flat Drill	6	Helix angle	25°	25
	Twist Drill	7		30°	30
Diameter	1 mm	010		35°	35
	1.5 mm	015		45°	45
	⋮	⋮		50°	50
	20 mm	200		55°	55
Radius	0.1R	010		60°	60
	0.2R	020	Hand of cut	Left	L
	0.3R	030		Right	R
	0.5R	050	Hand of spiral	Left	L
	0.75R	075		Right	R
	1R	100	Types of relief	Flat	F
	1.5R	150		Concave	C
	2R	200		Eccentric	E
	2.5R	250	Point angle	60°	060
	3R	300		90°	090
	4R	400		118°	118

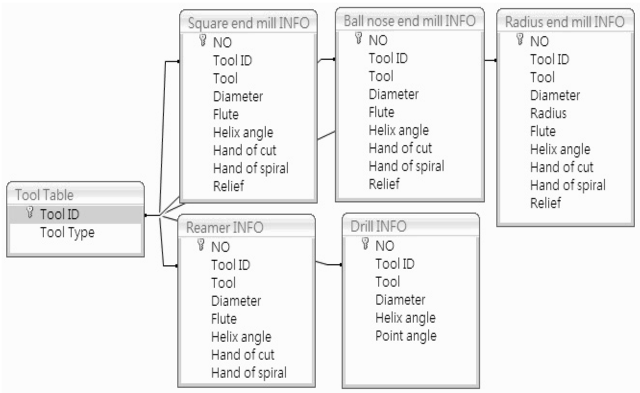

Fig. 4. Relational diagram of data tables of the tools

The tool database was constructed according to the types and characteristics of tools. Figure 3 can be obtained from these relations. The data table for the types of tools defines the identification codes and the tool names. The square end mill data table, ball nose end mill data table, radius end mill data table, reamer data table, and the drill data table define all kinds of the characteristic names and identification codes. The data tables probably contain the tool name, diameter, number of flutes, helix angle, hand of cut, and the point angle, etc. The main indexes of the data tables are the Tool ID and the NO in Figures 3a and 3b, respectively. Then, we established the relation between each table to form a systematic diagram which is called the relational diagram. It is also the main structure of the database. The relational diagram of data tables of the tools is shown in Figure 4. Based on the tool coding principle, there are 1576, 936, 1800, 130, and 360 data in the tool database for the square end mill, ball nose end mill, radius end mill, reamers, and the drills, respectively.

4. Searching system of database

The SQL syntax was employed for the searching rules after combining the relational database and the tool coding system. The following are the searching algorithms of tool data.

1. According to the types of tools, searching the tool which to be ground from database.
2. Deciding the type of tools based on the relative characteristics to search a suitable tool.
3. When some characteristics of tools are unknown or unspecific, the searching system will list the tools of similar characteristics, and the sorting sequence is by the diameter, number of flutes, helix angle, hand of cut, hand of spiral, and types of the relief.

The C++ Builder software was used to develop the human machine interfaces of the searching system of the tool database. The interfaces of parameters of the tools are the most important to the searching system. They can be divided into the types, and characteristics of tools which are shown in Figures 5a and 5b, respectively. Figures 5c and 5d show the searching results for a square end mill and a twist drill, respectively.

5. Experimental results

In the experiments, the testing cutting tool was a square end mill with two-flute, and the outer diameter is 8 mm. For a tool designer who has sufficient knowledge on cutting tools, the searching system is not combined with open architecture tool grinding software, one has to spend approximately 30 minutes and 45 minutes on the tool design and the change of production line for grinding other types of tools, respectively. It only needs approximately 14 minutes and 22 minutes when the searching system is combined with the tool grinding software. However, the time is depended on the designer's familiarity with tools in degree. Furthermore, the parameters of grinding processes were fixed in the practical grinding, only the parameters of the approach and retract sequence were changed. The size of cutting tools shapes maybe need to compensate in grinding. Therefore, the shifting sequence and the distance of each axis should be taken into consideration to avoid collision. In industry, each axis will return to original point of machine and shift to the grinding point when the grinding processes are changed. Table 2 reveals that the efficiency analysis for the approach and retract time, and the overall machining time were improved up to 40% and 10.6%, respectively.

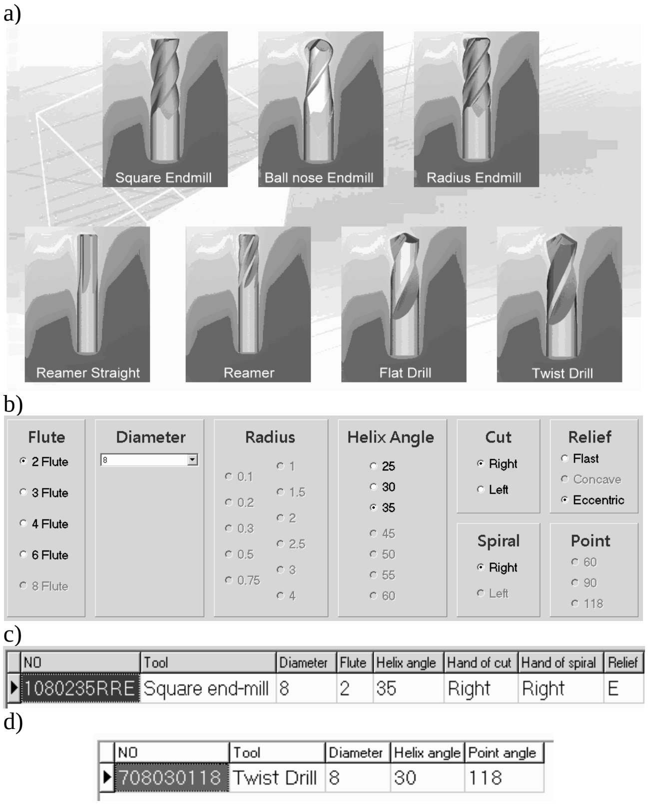

Fig. 5. Human machine interfaces: (a) types of tools; (b) characteristics of tools; (c) searching result for a square end mill; (d) searching result for a twist drill

Table 2.
Efficiency analysis of approach and retract procedures

Item	Proposed grinding processes	Grinding processes in industry
Machining time (a)	354 s	396 s
Practical grinding time (b)	291 s	291 s
Approach and retract time (c = a - b)	63 s	105 s
Saving of approach and retract time (d)	105 - 63 = 42 s	
Efficiency improved of approach and retract (d/c)	42/105 = 40 %	
Efficiency improved of overall machining (d/a)	42/396 = 10.6 %	

6. Conclusions

This paper develops the database and searching system of the tools, and the following conclusions can be obtained:
1. A total of 4802 data of standard cutting tools were established in the tool database.
2. Obviously, the searching system with open architecture of the tool grinding software has more flexibility and convenience in designing new tools. Moreover, the time of new tools design and the change of production line can be reduced.
3. The efficiency was improved approximately up to 40% by the approach and retract time, and the overall machining time, 10.6%.
4. The rules of the tool coding system can be used to solve difficulties of tool data management for tool manufacturers.

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