Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 30 ISSUE 1 September 2008

Design and implementation of cutting tools search system

J.Y. Chen [a,*], H.S. Lu [a], B.Y. Lee [a], C.H. Chen [b]
[a] Department of Mechanical and Computer-Aided Engineering, National Formosa University, No. 64, Wunhua Rd., Huwei Township, Yunlin County 632, Taiwan
[b] Institute of Mechanical and Electro-Mechanical Engineering, National Formosa University, No. 64, Wunhua Rd., Huwei Township, Yunlin County 632, Taiwan
* Corresponding author: E-mail address: jychen@nfu.edu.tw

Received 06.05.2008; published in revised form 01.09.2008

Analysis and modelling

ABSTRACT

Purpose: The main purpose of this paper is to analyse the grinding processes and develop a search system of database for cutting tools.
Design/methodology/approach: A tool grinding software with open architecture was used to analyse the grinding processes of square end mills, tapered square end mills, ball nose end mills, tapered ball nose end mills, radius end mills, tapered radius end mills, straight flute reamers, helical flute reamers, flat drills, twist drills, and step drills. According to the characteristics of these tools, 20270 data were established in the relational database. The SQL syntax was then utilized for writing the search algorithm, and the C++ Builder was employed for designing human machine interfaces of the search system of the tool database.
Findings: 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 the proposed system. More specifically, the efficiency in terms of the overall machining time was improved up to 10.58%, 9.36%, 4.64%, and 7.52% for grinding the radius end mill, tapered radius end mill, twist drill, and step drill, respectively.
Research limitations/implications: Special tools have diversification. They can not be taken into consideration in the database system owing to the tools have specific profiles. Therefore, it is difficult to encode by formal rules.
Practical implications: The most commercial tool grinding software is the modular-based design and uses tool shapes to construct the CAM interface. However, it is very difficult for users to design new cutting tools. Utilizing the grinding processes to construct the grinding path of tools, and the search system of the database provides more flexible options to develop new cutting tools.
Originality/value: The database and search system of cutting tools were presented in this paper. We can save time for production line change, tool design, and tool grinding by employing this kind of system. It also gives more convenience. That is, company's productivity and benefit can be improved.
Keywords: CAD/CAM; Search system; Grinding processes; Relational database

1. Introduction

The demand for all kinds of high precision cutting tools is increasing due to rapid developments in the modern cutting technology [1-5]. The grinding for cutting edges of tools is known as the most important and the final procedure of 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. On the contrary, 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]. A database system is the basis of the most information system. It is different to the file system. All data in the database system are suitablly organised in order to meet the requirements and managemnet. Owing to the lack of the search system for tool grinding, we established the data of cutting tools 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 of cutting tools

End mills are widely used in all kinds of milling applications. They may have square, ball nose, radius, tapered square, tapered ball nose, or tapered radius ends, etc [13]. The basic type of end mills is the square end mill. Furthermore, other two kinds of commonly utilized tools are reamers and drills. Reamers are classified into the straight and spiral fluted reamers. Drills can be assorted into the flat, twist, and step drills. These types of cutting tools of the above are taken into account in the tool search system of database.

The parameters of geometry shapes and angles of end mills include the rake angle, relief angle, helix angle, clearance angle and land, etc. The values of these parameters are related to tool materials and conditions of machining, and affect the cutting performance and tool life. In this paper, grinding processes of cutting tools are based on a five-axis CNC tool grinder. Figure 1 shows the definition of each axis of the machine [14]. The grinding processes of the rake angle and the relief angle of end mills, and the point angle of drills can be found in [15, 16].

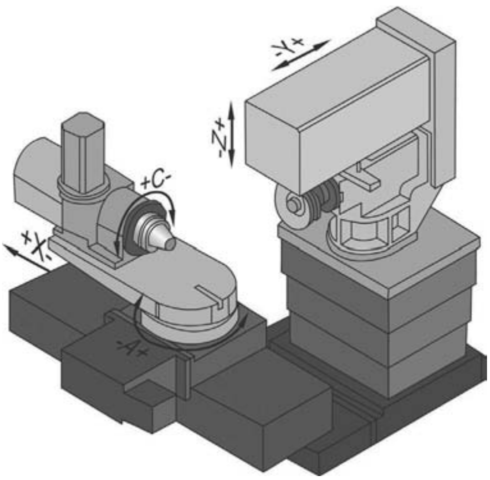

Fig. 1. Definition of each axis of a five-axis tool grinder

2.1. Grinding processes of a chamfer angle of reamers

With the tool grinder to grind a chamfer angle of reamers, the NC path is generated according to the outside diameter of the cutting tools, tilt angle of wheels, relief angle, and relieved land. The sequence of grinding a chamfer angle is: X, Y, C, and A axes start at the same time, and shift to the approach distance of the grinding face of a wheel and the cutting face of an end mill. There is 1° difference between A-axis and the slope of tool shapes. Then, the rotation degree of C-axis is the relief angle. Finally, Z-axis moves downward to the approach distance. Y-axis shifts to the grinding face of a wheel and the cutting face of a reamer. X, Z, and C axes start simultaneously to grind the chamfer length from the end face to the radial relief face. Y-axis returns in the horizontal direction to make the wheel exit the groove. Then, X, Y, and C axes return to the starting point simultaneously. Another flute can be ground according to the sequence as mentioned above. The diagram of grinding a chamfer angle of reamers is shown in Figure 2, and the arrow is the moving direction.

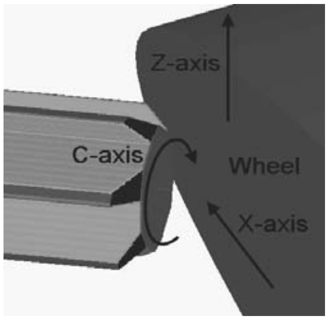

Fig. 2. Diagram of grinding a chamfer angle

2.2. Grinding processes of a tapered helical flute of end mills

Once the tool grinder is employed to grind a tapered radial helical rake angle, the NC path is generated according to diameters, core diameters and rake angles of the front-end and the back-end, helix angle of the front-end, flute length, and taper angle. The sequence of grinding a tapered helical rake angle is: X, C, and A axes start at the same time first. Y-axis moves forward. Then, the rotation degree of A-axis is the helix angle of the front-end which we want. X and Y axes shift to the grinding face of a wheel and the cutting face of an end mill. Finally, Z-axis shifts to the approach distance of grinding. X, Y, Z, A, and C axes start simultaneously to grind the taper surface of the flute length. Z-axis moves upward in the vertical direction to make the wheel exit the groove. X, Y, A, and C axes return to the starting point simultaneously. Another helical flute can be ground according to the sequence of the above. Figure 3 shows the diagram of grinding a tapered helical flute of end mills.

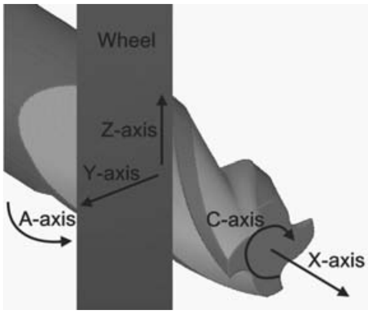

Fig. 3. Diagram of grinding a tapered helical flute of end mills

2.3. Grinding processes of a step of step drills

With the tool grinder to grind a step of step drills, the NC path is generated according to the outside diameter of tools, wheel shapes, diameter and length of step. The sequence of grinding a step is: X, Y, C, and A axes start at the same time. X-axis shifts to the grinding face of a wheel and the step face of a step drill. Y, C, and A axes shift to the approach distance of the grinding face of a wheel and the step face of a step drill. Z-axis moves downward to the approach distance. X, Z, and C axes start simultaneously based on the tool shapes to grind the step length. Z-axis returns in the vertical direction to make the wheel exit the groove. Then, X and C axes return to the starting point simultaneously. Another helical flute can be ground according to the sequence as mentioned above. The diagram of grinding a step of step drills is shown in Figure 4.

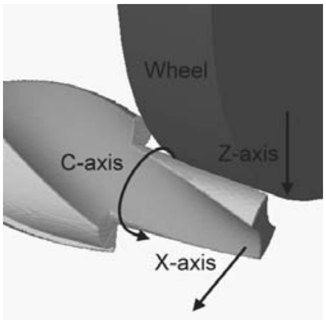

Fig. 4. Diagram of grinding a step of step drills

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. From 1 to 20 mm in diameter of tools were coded in Table 1 which has types of tool, number of flutes, diameter, helix angle, hand of cut, types of relief, taper angle, and point angle, etc. in characteristic sequence. Thus, Figure 5 shows an example of the meaning of a tool with the code 83060100230010020RRF.

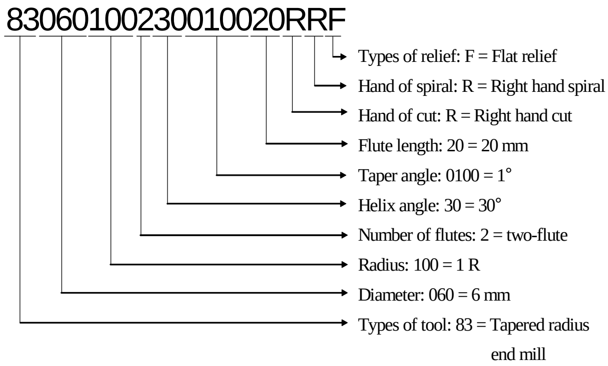

Fig. 5. Meaning of a tool with the code 83060100230010020RRF

The integrity rules of the relational database are very important for designing an excellent database. Many relational data management systems emphasize to execute the integrity rules which have two critical characteristics [17]. One is the entity integrity, and the other is the referential integrity. The entity integrity assures that each entity has a unique identifiable data, and the referential integrity assures that each attribute does not have illegal items. The fundament of a relational database is a table which is easy to understand and accept, owing to the table is a two-dimensional form. Therefore, it shows the advantages of adjustment and expansion of data structures.

The tool database system was estabilished by the types and the characteristics of each tool. Figure 6 can be obtained from these relations. The data table for the types of tool defines the identification codes and the tool names. The others for the square end mill, ball nose end mill, radius end mill, straight flute reamer, helical flute reamer, flat drill, twist drill, tapered square end mill, tapered ball nose end mill, tapered radius end mill, and step drill data table define all kinds of the characteristic names and identification codes. The main indexes of the data tables are the Tool ID and the NO in Figures 6a and 6b-d, 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 the data tables of the tools is shown in Figure 7. Based on the tool coding principle, there are 1576, 936, 1800, 130, 360, 2064, 2064, 8064, and 3276 data in the tool database for the square end mill, ball nose end mill, radius end mill, reamers, drills, tapered square end mill, tapered ball nose end mill, tapered radius end mill, and step drill, respectively.

4. Search system of database

The flowchart of the data search system is illustrated in Figure 8. It can be categorized into the external layer, conceptual layer, and interior layer. In order to find out the optimal processing module to query, the external layer proceeds to the query processing module according to user's query conditions. When the system is restarted, it proceeds the follow-up query actions based on the failure recovery processing module. The conceptual layer is the bridge to connect the external layer and the interior layer. The results obtained from the optimal processing module and the failure recovery processing module are processed by the reshuffled management module. The processing procedures can be divided into the access processing module and the file processing system. The data structure is truly stored in the interior layer which is the tool database system. The processing procedures include data computing methods, system directories, and transaction logs.

Combining the relational database and the tool coding system, the SQL syntax was employed for the search rules. The following are the search algorithms of tool data.

1. According to the types of tool, the algorithms search the tool which to be ground from the tool 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 search system will list the tools of similar characteristics, and the sorting sequence is by the number of flutes, diameter, radius, helix angle, taper angle, hand of cut, hand of spiral, types of relief, point angle, diameter of the first step, flute length of the first step, chamfer angle of the first step, diameter of the second step, flute length of the second step, chamfer angle of the second step, diameter of the third step, and flute length of the third step.

The C++ Builder software was used to develop the human machine interfaces of the search system of the tool database. The interfaces of parameters of the tools are the most important to the search system. They can be divided into the types, and characteristics of tools which are shown in Figures 9a and 9b, respectively. Figure 9c shows the search result for a tapered radius end mill.

Table 1.
Tool coding table

Characteristics	Item	Code	Characteristics	Item	Code
Types of tool	Square end mill	1	Flute length 2	5 mm	05
	Ball nose end mill	2		10 mm	10
	Radius end mill	3		15 mm	15
	Straight flute reamer	4	Flute length 3	5 mm	05
	Helical flute reamer	5	Radius	0.1R	010
	Flat drill	6		0.2R	020
	Twist drill	7		0.3R	030
	Tapered square end mill	81		0.5R	050
	Tapered ball nose end mill	82		0.75R	075
	Tapered radius end mill	83		1R	100
	Step drill	9		1.5R	150
Number of flutes	2-flute	2		2R	200
	3-flute	3		2.5R	250
	4-flute	4		3R	300
	6-flute	6		4R	400
	8-flute	8	Helix angle	25°	25
Diameter	1 mm	010		30°	30
	1.5 mm	015		35°	35
	⋮	⋮		45°	45
	19.5 mm	195		50°	50
	20 mm	200		55°	55
Diameter 1	6 mm	06		60°	60
	8 mm	08	Taper angle	30′	0030
	10 mm	10		1°	0100
	12 mm	12		1°30′	0130
	14 mm	14		2°	0200
	16 mm	16		2°30′	0230
Diameter 2	8 mm	08		3°	0300
	10 mm	10		5°	0500
	12 mm	12		7°	0700
	14 mm	14		10°	1000
	16 mm	16	Hand of cut	Left	L
	18 mm	18		Right	R
Diameter 3	12 mm	12	Hand of spiral	Left	L
	14 mm	14		Right	R
	16 mm	16	Types of relief	Flat	F
	18 mm	18		Concave	C
	20 mm	20		Eccentric	E
Flute length 1	5 mm	05	Point angle	60°	060
	10 mm	10		90°	090
	15 mm	15		118°	118

a)

Tool ID	Tool
T1	Square end mill
T2	Ball nose end mill
T3	Radius end mill
T4	Straight flute reamer
T5	Helical flute reamer
T6	Flat drill
T7	Twist drill
T81	Tapered square end mill
T82	Tapered ball nose end mill
T83	Tapered radius end mill
T9	Step drill

b)

NO	Tool ID	Tool	Diameter	Number of flutes	Helix angle	Hand of cut	Hand of spiral
5080625LR	T5	Helical flute reamer	8	6	25	Left	Right
5080625RL	T5	Helical flute reamer	8	6	25	Right	Left
5080630LR	T5	Helical flute reamer	8	6	30	Left	Right
5080630RL	T5	Helical flute reamer	8	6	30	Right	Left
5080825LR	T5	Helical flute reamer	8	8	25	Left	Right

c)

NO	Tool ID	Tool	Diameter	Number of flutes	Helix angle	Taper angle	Length	Hand of cut	Hand of spiral	Relief
8101022500304RRE	T81	Tapered Square end mill	1	2	25	30"	4	Right	Right	E
8101022501004RRE	T81	Tapered Square end mill	1	2	25	1'	4	Right	Right	E
8101022501304RRE	T81	Tapered Square end mill	1	2	25	1'30"	4	Right	Right	E
8101022502004RRE	T81	Tapered Square end mill	1	2	25	2'	4	Right	Right	E
8101022502304RRE	T81	Tapered Square end mill	1	2	25	2'30"	4	Right	Right	E

d)

NO	Tool ID	Tool	Helix angle	Point angle	Diameter 1	Length 1	Chamfer 1	Diameter 2	Length 2	Chamfer 2	Diameter 3	Length 3
92511806050900000000000	T9	Flat Step Drill	25	118	6	5	90					
92511806050900802090000	T9	Flat Step Drill	25	118	6	5	90	8	2	90		
925118060509008050901005	T9	Flat Step Drill	25	118	6	5	90	8	5	90	10	5
925118060509008100900000	T9	Flat Step Drill	25	118	6	5	90	8	10	90		
925118060509008100901005	T9	Flat Step Drill	25	118	6	5	90	8	10	90	10	5

Fig. 6. Data tables: (a) types of tool; (b) helical flute reamer; (c) tapered square end mill; (d) flat step drill

5. Experimental results

In the experiments, the tested cutting tools were the radius end mill, tapered radius end mill, twist drill, and step drill. In the practical grinding, the parameters of grinding processes were fixed, 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. The difference of grinding efficiency of the industrial application and the approach and retract sequence are compared, which are proposed in Section 2. From Table 2, experiments results show that the efficiency analysis for the overall machining time was improved up to 10.58%, 9.36%, 4.64%, and 7.52% for grinding the radius end mill, tapered radius end mill, twist drill, and step drill, respectively. Thus the proposed grinding processes can save the overall machining time effectively. Furthermore, for a tool designer who has sufficient knowledge on cutting tools, the search 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 search system is combined with the tool grinding software. However, the time is depended on the designer's familiarity with tools in degree.

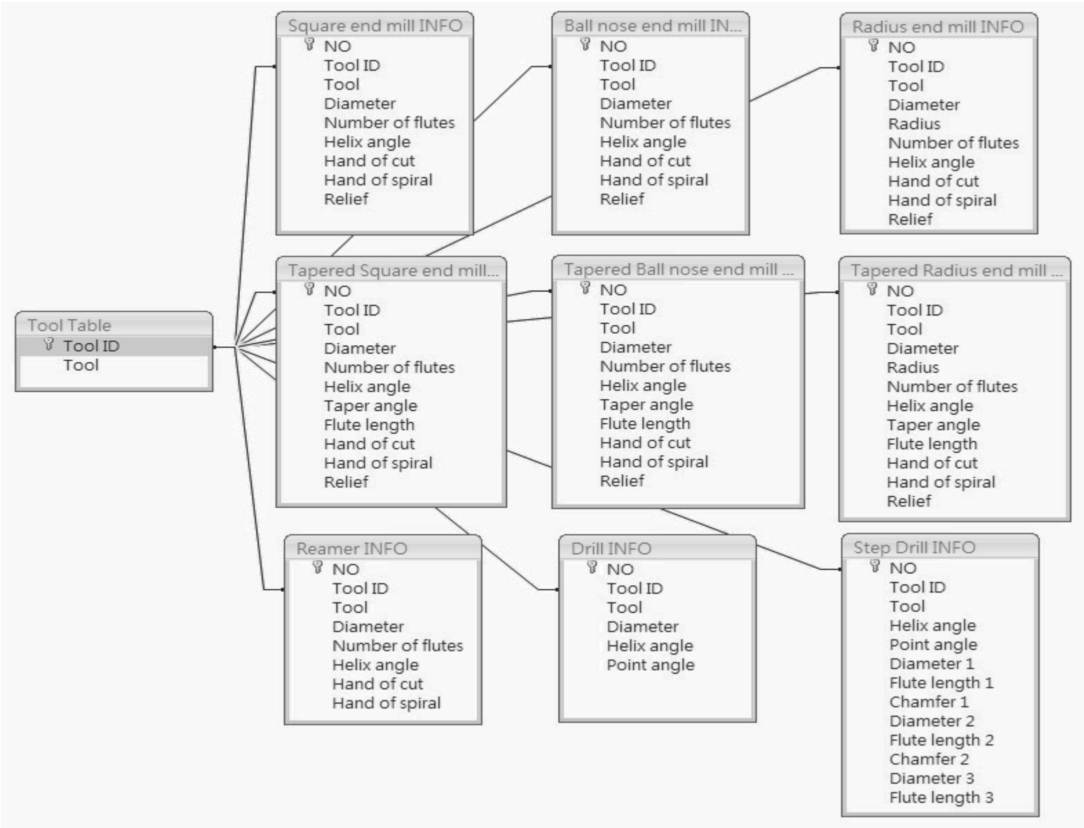

Fig. 7. Relational diagram of data tables of tools

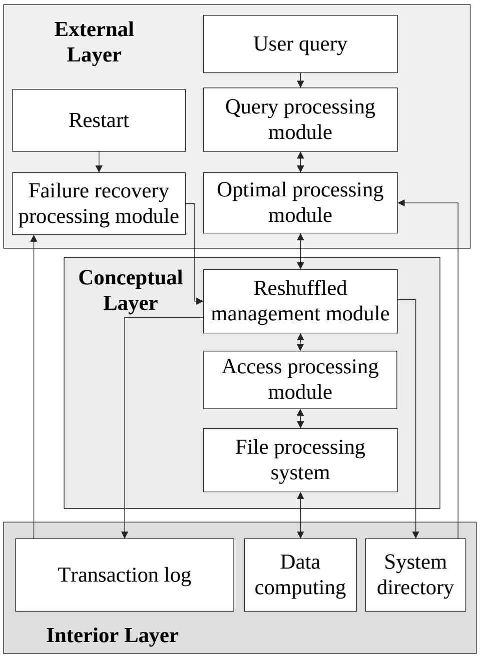

Fig. 8. Flowchart of search system

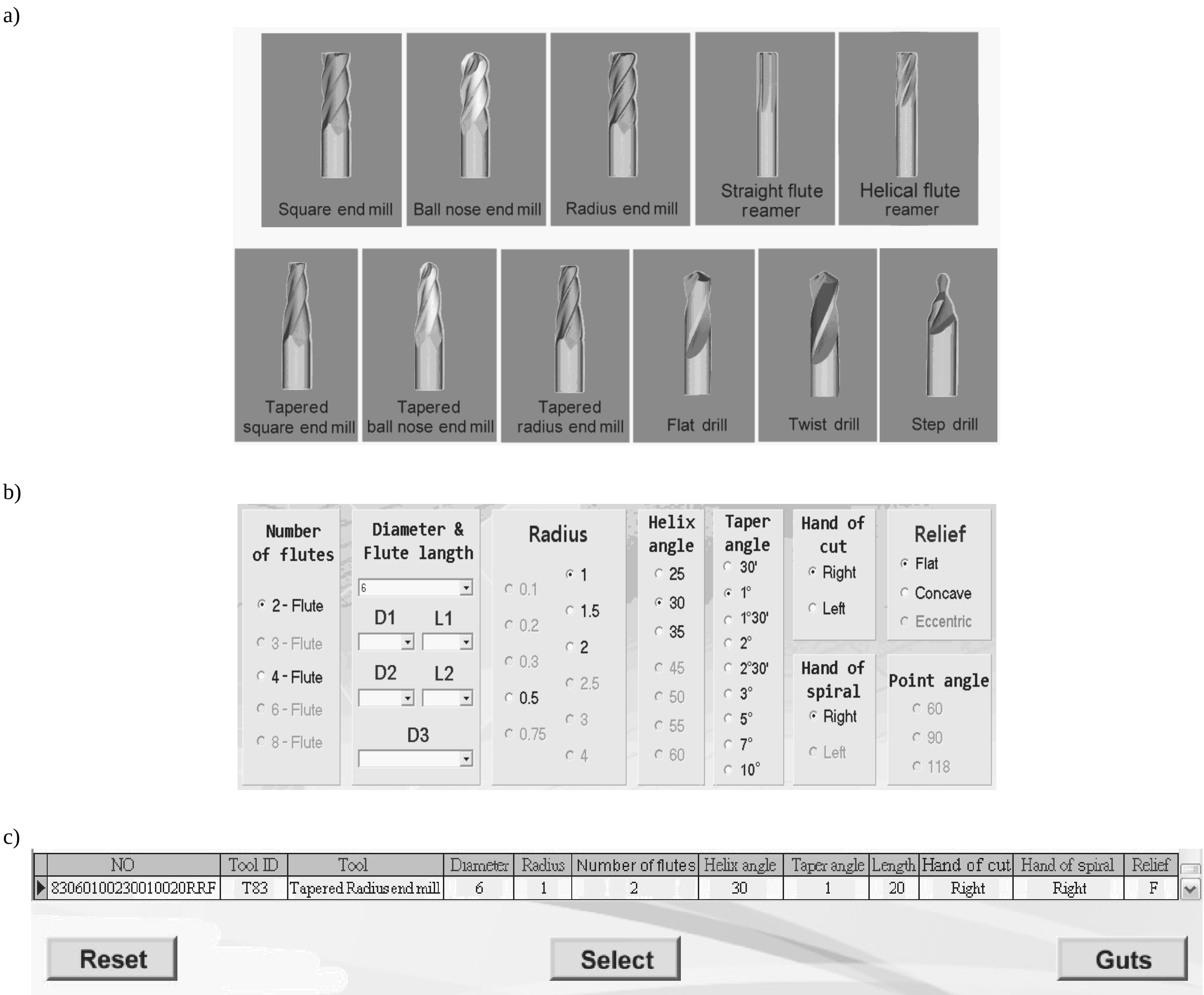

Fig. 9. Human machine interfaces: (a) types of tool; (b) characteristics of tools; (c) search result for a tapered radius end mill

Table 2.
Efficiency analysis of overall machining

Item	Cutting tools for testing							
	8 mm 0.5R radius end mill with four-flute		8 mm 0.5R tapered radius end mill with four-flute		8 mm twist drill with 118° point angle		6-10-12 mm step drill with 118° point angle	
	Grinding processes in industry	Proposed Grinding processes	Grinding processes in industry	Proposed Grinding processes	Grinding processes in industry	Proposed Grinding processes	Grinding processes in industry	Proposed Grinding processes
Machining time	539 s	482 s	609 s	552 s	798 s	761 s	2846 s	2632 s
Saving of approach and retract time	57 s		57 s		37 s		214 s	
Efficiency improved of overall machining	10.58 %		9.36%		4.64%		7.52%	

6. Conclusions

This paper has developed the database and search system for the tools, and the complete planning and analysis of grinding processes for reamers, tapered end mills, and step drills. A five-axis CNC tool grinder was used to grind a radius end mill, tapered radius end mill, twist drill, and step drill via the proposed grinding processes. From the grinding results, the following conclusions can be obtained:

1. There was no collision phenomenon in the approach and retract procedures of each axis.
2. A total of 20270 data of cutting tools were established in the tool database system.
3. The efficiency for the overall machining time was improved approximately up to 10.58%, 9.36%, 4.64%, and 7.52% for grinding the radius end mill, tapered radius end mill, twist drill, and step drill, respectively.
4. It is obvious that the search system with open architecture of the tool grinding software has more flexibility and convenience in designing new cutting tools. Moreover, the time of new tools design and the change of production line can be reduced.
5. The rules of the tool coding system can be used to solve difficulties of tool data management for tool manufacturers.

Acknowledgements

The authors gratefully thank the financial support from the Department of Industrial Technology of Ministry of Economic Affairs, Republic of China under SBIR project 1Z960331.

References

[1] H. Schulz, T. Moriwaki, High-speed machining, Annals of the CIRP 41 (1992) 637-643.

[2] H. Schulz, S. Hock, High-speed milling of die and molds – cutting conditions and technology, Annals of the CRIP 44 (1995) 35-38.

[3] R.C. Dewes, D.K. Aspinwall, A review of ultra high-speed milling of hardened steels, Journal of Materials Processing Technology 69 (1997) 1-17.

[4] L.A. Dobrzański, K. Gołombek, J. Mikuła, D. Pakuła, Cutting ability improvement of coated tool materials, Journal of Achievements in Materials and Manufacturing Engineering 17 (2006) 41-44.

[5] S. Dolinsek, J. Kopac, Mechanism and types of tool wear; particularities in advanced cutting materials, Journal of Achievements in Materials and Manufacturing Engineering 19/1 (2006) 11-18.

[6] S. Malkin, Grinding Technology Theory and Applications of Machining with Abrasives, Society of Manufacturing Engineers, Dearborn, Michigan, 1989.

[7] W. Eversheim, H.J.J. Kals, W. Konig, C.A. van Luttervelt, J. Milberg, A. Storr, H.K. Tonshoff, M. Weck, H. Weule, W.J. Zdeblick, Tool management: the present and the future, Annals of the CIRP 40 (1991) 631-639.

[8] W.L.R. Ip, K.W. Cheng, I.K. Hui, T.S.F. Chan, Dynamic tool management in FMS – a practical approach, Proceedings of the IEEE International Conference "Systems, Man and Cybernetics", Vancouver, 1995, 120-125.

[9] M. Özbayrak, R.B.R. De Souza, R. Bell, Design of a tool management system for a flexible machining facility, Journal of Engineering Manufacture 215 B (2001) 353-370.

[10] G. Svinjarevic, A. Stoic, J. Kopac, Implementation of cutting tool management system, Journal of Achievements in Materials and Manufacturing Engineering 23/1 (2007) 99-102.

[11] M.V. Ribeiro, N.L. Coppini, An applied database system for the optimization of cutting conditions and tool selection, Journal of Materials Processing Technology 92 (1999) 371-374.

[12] F. Cus, B. Mursec, Databases for technological information systems, Journal of Materials Processing Technology 157-158 (2004) 75-81.

[13] United State Cutting Tool Institute, Metal Cutting Tool Handbook, Industrial Press, 2004.

[14] TOP WORK Industry Co., Ltd., GUTS Operational Manual, 2005.

[15] J.Y. Chen, B.Y. Lee, C.H. Chen, Planning and Analysis of Grinding Processes for End Mills of Cemented Tungsten Carbide, Journal of Materials Processing Technology 201 (2008) 618-622.

[16] J.Y. Chen, W.Y. Lin, B.Y. Lee, C.H. Chen, Development of database and searching system for tool grinding, Journal of Achievements in Materials and Manufacturing Engineering 26/2 (2008) 159-162.

[17] P. Rob, C. Coronel, Database Systems: Design, Implementation and Management, Seventh Edition, Thomson, Boston, 2007.