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Procedia Engineering 100 (2015) 1062 – 1067

Procedia Engineering

www.elsevier.com/locate/procedia

25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2014

An Implementation of Web-Based Machining Operation Planning

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Abstract

This paper introduces a machining operation planning system for practical use in small and medium sized manufacturers. The system passes through two stages: manual input of required information and semi-automated generation of an operation plan. At the first stage, removal volumes out of a workpiece and their reference details on the part drawing are translated into the specific machining features manually. The operations to be performed for each feature are then selected from the operation list related to the feature. At the second stage, the cutting tool for each operation is determined with its proper cutting conditions by using a rule-based algorithm and retrieving a machining database gradually updated. The web interface makes it possible for the manufacturers to keep a record of their machining practice in the database and obtain the favorable data from the various sources when needed. An example is shown to demonstrate the usefulness of the system.

Peer-review under responsibility of DAAAM International Vienna

Keywords: Process planning; Machining operation; Machining feature; Web-based system

1. Introduction

Process planning in machining involves a series of decision making activities to link design and manufacturing, i.e., from identifying removal volumes out of a workpiece, selecting the best fit machining methods, and determining the most appropriate machines and tools to efficiently sequencing the methods [1]. Process plans are created based on experience, in the first place, but it is foreseen that an expert system might be constructed to replace the human [2]. Tremendous effort has been made in developing CAPP (Computer Aided Process Planning)

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Peer-review under responsibility of DAAAM International Vienna
doi:10.1016/j.proeng.2015.01.467

systems [3,4,5], yet, it still remains in the conceptual stage, and the benefit of CAPP in the real industrial environment is still to be seen [6]. Upon our investigation into the practical use of the CAPP systems intended for more than 20 manufacturers, most of the systems seem to be hard to hold a concrete place in small and medium sized manufacturers. The manufacturers who mainly produce the parts with a relatively small number of machined volumes could understand the part drawings and select the machining methods easily and quickly by experience. But they still spent much time to determine the proper tools and cutting conditions to be used in the limited machines based on the handbook data provided by tool makers. To sum it up, a software system targeting operation planning, as part of process planning, would be useful for them rather than a comprehensive CAPP system.

This paper introduces an operation planning system which consists of preparation and execution stages. The preparation is made by manual input of the machined shapes with their set of operations. This stage depends on the human process planner's proficiency and expertise completely. Then the execution recommends an operation plan automatically and allows for the human process planner to improve it interactively with using the various machining data. Recommendation rules and a machining database are constructed in this work based on the knowledge and data collected from several manufacturers as well as tool makers. This system adopts the feature-based approach and is implemented on the web as shown in Fig. 1. Thus different users can share a great number of actual field data with each other as needed. But the data management for personalization and globalization is beyond the scope of this paper.

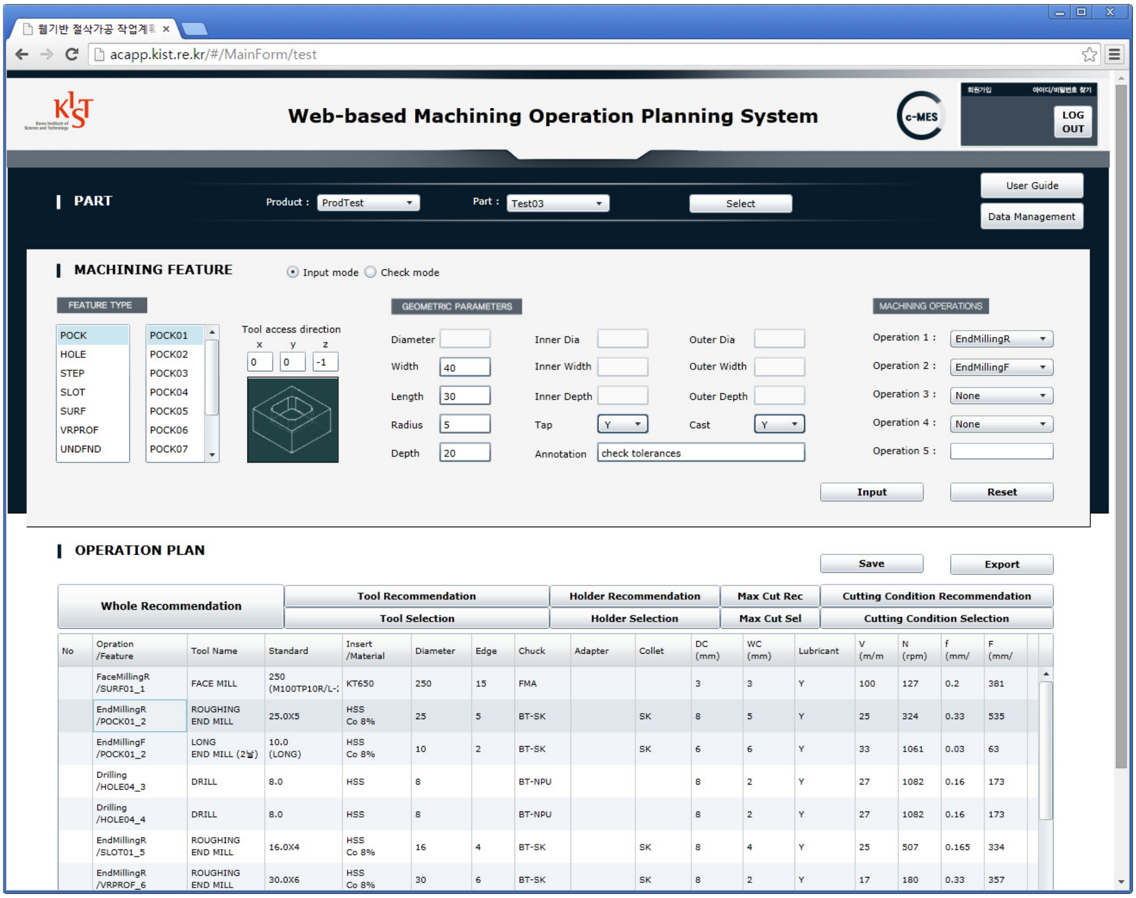

Fig. 1. A web-based machining operation planning system.

2. Input of machining features and operations

A machining feature takes a crucial role in process planning since it can be regarded as the shape of the removal volume through a cutting process, which represents some manufacturing attributes of a part [7]. After the part is selected with its material information for operation planning, geometry and tolerance information of the machined volumes should be represented as the machining features. A specific feature library suggested by [8] and updated by this work is accepted, in which the machining features are categorized as seven classes: POCK, HOLE, STEP, SLOT, SURF, VRPOCK, and UNDFND. Fig. 2 shows the basic 27 features and such parameters of POCK01 feature as width, length, depth, radius, and so on. VRPROF has a free profile, for which milling operations can be assigned while UNDFND may not be machined. In order to identify the features to be machined, a user should select the corresponding feature type with each machined shape on the part drawing and input its parameters free from mistakes. The parameters include not only geometry information but also operation related information such as tap, cast, and considerable remarks. Then the relevant set of operations to be performed can be assigned to each feature by the user. Hole making operations (drilling, boring, reaming, counterboring, countersinking), end milling, and face milling are currently available. Boring, end milling and face milling are specified into either rough or finish respectively. These procedures are dependent on the user's experience and may seem to be tedious. But small effort and time are actually required with simple instructions.

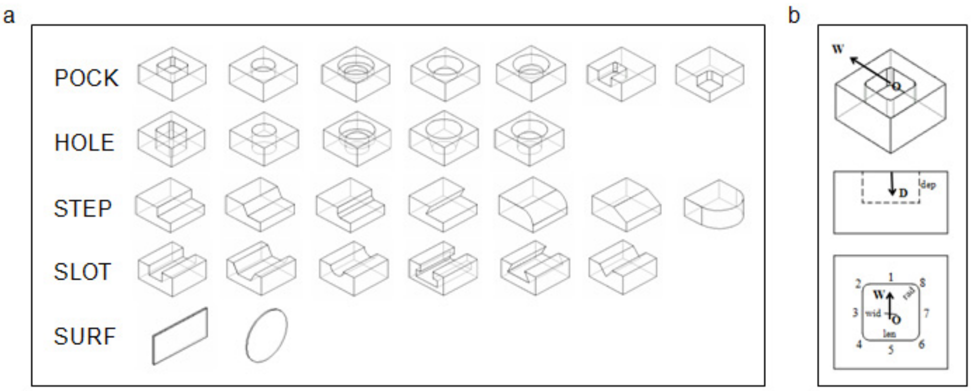

Fig. 2. (a) basic features; (b) feature parameters of POCK01 feature.

3. Generation of operation plan

An operation plan includes a cutting tool, tool holders, and cutting conditions for each operation. Once the operations are given with their related feature information, the system can generate the operation plan automatically based on the rule-based recommendation algorithms and the machining database. The algorithms could be achieved from the knowledge of the experienced engineers and the handbook data provided by several tool makers. The collected data are also stored in the relational database. This way of constructing the system architecture has been regarded as general since [9].

In operation planning, a proper cutting tool should be determined first. The type of an operation and the hardness of the workpiece are considered at macro level and the type and geometrical information of the feature is compared with the standard information of cutting tools at micro level. In cases of face milling and boring operations, a cutter insert is also determined. Relevant tool holders such as chuck, adapter, and collet can be recommended in addition as needed. Then depth of cut and width of cut are calculated using the tool diameter and feature geometry. Appropriate cutting conditions for each cutting tool such as velocity and feed are retrieved from the database finally and the corresponding rpm and feed rate are calculated as well.

The user can change the recommended plan to his favorable one interactively. Fig. 3 shows parts of GUIs for accessing the cutting tool database and modifying cutting conditions easily. This interaction is useful especially for the VRPROF and UNDFND features since it is difficult to generate the plans for them automatically. After the final review is completed, the operation sheet is exported to an MS Excel file to utilize it in various formats.

All the functions to generate the operation plan can be carried out individually as well as at once. In any case, the precedence relations of decision making processes are not violated in the system. For example, unless a cutting tool is not selected, no cutting conditions can be generated.

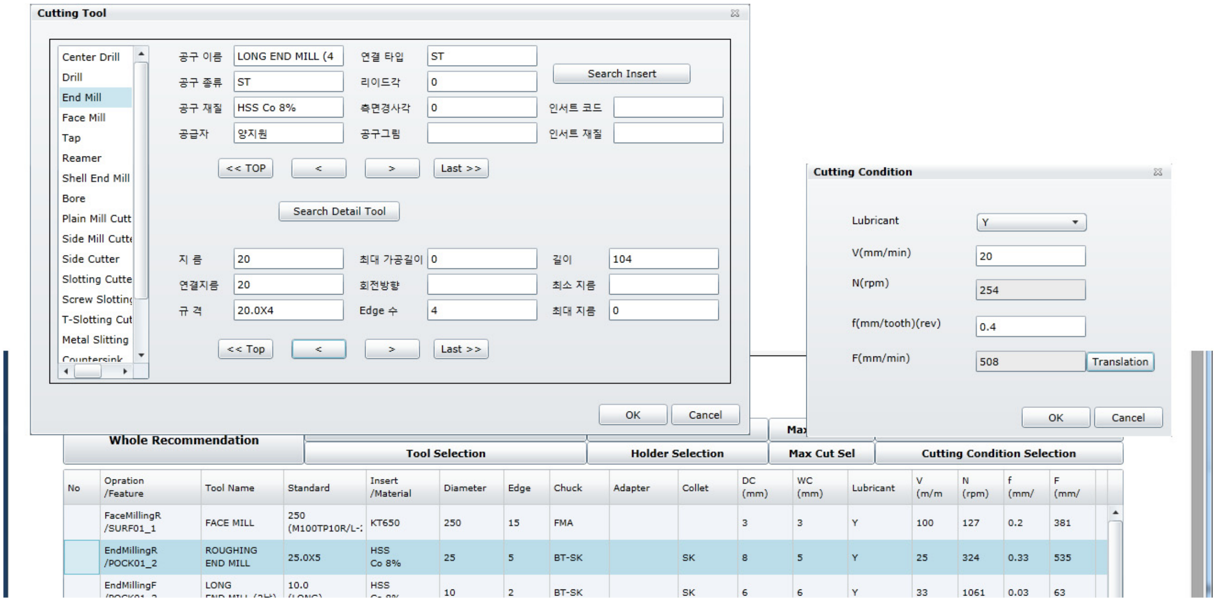

Fig. 3. Interactive modification of cutting tool and cutting conditions.

4. Case study

A case study is done for an example part shown in Fig. 4. The material is SM45C and seven machining features are supposed to be completed by 11 operations. All the geometry information and types of operations for the features are input manually. The time for preparing these input data is not considerable. Tolerance information is excluded in this case since the user can grasp the appropriate operations intuitively.

Fig. 5 shows the result of the automatic operation planning. In accordance with the rule-based algorithm, the cutting tools with the maximum allowable diameters for the features are recommended first. Then their corresponding machining parameters are retrieved sequentially. However this result may not be reliable in certain manufacturers yet. Thus the thorough review by their field engineers should be carried out to revise the plan interactively for practical use. For example, FaceMillingR/SURF01_1 (rough facemilling operation for SURF01_1 feature) in Fig. 4 may be performed under the increased velocity and decreased feed to achieve its higher quality.

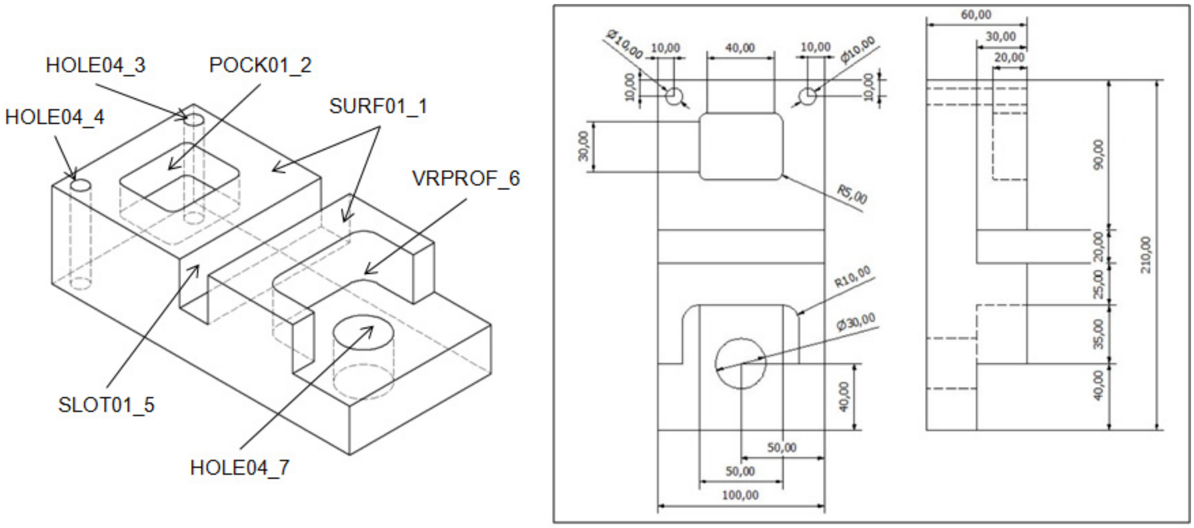

Fig. 4. An example part.

No ▲	Opration /Feature	Tool Name	Standard	Insert /Material	Diameter	Edge	Chuck	Adapter	Collet	DC (mm)	WC (mm)	Lubricant	V (m/m	N (rpm)	f (mm/	F (mm/
01	FaceMillingR /SURF01_1	FACE MILL	250 (M100TP10R/L-:	KT650	250	15	FMA			3	3	Y	100	127	0.2	381
02	EndMillingR /POCK01_2	ROUGHING END MILL	25.0X5	HSS Co 8%	25	5	BT-SK		SK	8	5	Y	25	324	0.33	535
03	EndMillingF /POCK01_2	LONG END MILL (2날)	10.0 (LONG)	HSS Co 8%	10	2	BT-SK		SK	6	6	Y	33	1061	0.03	63
04	Drilling /HOLE04_3	DRILL	10.0 (SSD100)	HSS	10		BT-NPU			8	2	Y	18	572	0.2	114
05	Drilling /HOLE04_4	DRILL	10.0 (SSD100)	HSS	10		BT-NPU			8	2	Y	18	572	0.2	114
06	EndMillingR /SLOT01_5	ROUGHING END MILL	16.0X4	HSS Co 8%	16	4	BT-SK		SK	8	4	Y	25	507	0.165	334
07	EndMillingR /VRPROF_6	ROUGHING END MILL	30.0X6	HSS Co 8%	30	6	BT-SK		SK	8	2	Y	17	180	0.33	357
08	EndMillingF /VRPROF_6	LONG END MILL (2날)	30.0 (LONG)	HSS Co 8%	30	2	BT-SK		SK	7	2	Y	39	413	0.158	131
09	Drilling /HOLE04_7	DRILL	8.0	HSS	8		BT-NPU			8	5	Y	27	1082	0.16	173
10	EndMillingR /HOLE04_7	ROUGHING END MILL	25.0X5	HSS Co 8%	25	5	BT-SK		SK	8	5	Y	25	324	0.33	535
11	EndMillingF /HOLE04_7	LONG END MILL (2날)	30.0 (LONG)	HSS Co 8%	30	2	BT-SK		SK	7	0	Y	39	413	0.158	131

Fig. 5. An operation plan generated automatically for the example part.

5. Concluding remarks

This paper described a web-based machining operation planning system briefly. The system was devised to realize the benefit of CAPP for the small and medium sized manufacturers in practical. According to their requirements, process planning tasks are classified into the interactive and automated ones. While what the human could do easily and intuitively (i.e., interpretation of a drawing and selection of operations) is performed interactively, what gave the human a relatively hard time (i.e., generation of an operation plan) can receive some assistance from the automated capabilities on the system. The advantages in using it over the other systems or none could be summarized as follows:

- Easy and quick identification of machined shapes and their operations
- Automated generation of a basic operation plan and its efficient revision
- Opportunity to share the different operation plans of various manufactures
- Possibility of expanding the application ranges to a variety of the shapes to be manufactured
- Capability of managing manufacturer's own knowledge and data systematically

Despite of these advantages, the limitations still remain. Most of all, the system missed the machine capacity out. As this information plays a crucial role in confirming the operation plan, the system should accept it. For example, a recommended velocity has to be lower than the maximum speed of available machines at least. Otherwise, the velocity should be calibrated by the system, or a different tool with the proper velocity should be recommended. The developed system is currently introduced on a trial basis to several manufacturers. A variety of feedbacks including actual data are expected to be obtained to update the rules and machining database. The knowledge and data management schemes omitted in this paper should be also enhanced to reuse the previously generated data.

Acknowledgements

This work was supported by the grant from the Industrial Core Technology Development Program (Contract Number: 10033163) of the Ministry of Trade, Industry and Energy of Korea.

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