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DEVELOPMENT OF EXPERT SYSTEM-BASED COMPUTER AIDED PROCESS PLANNING FOR PRODUCTION COST ESTIMATION

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ABSTRACT

In industry, estimation of production cost plays important roles since it would affect to product price. Over estimation of production cost would effect to over product pricing and it would decrease ability of the product to compete in the market while under estimation of production cost would effect to profit lost. Production cost estimation must be carried out based on detail analysis of production activities. Hence, it is very hard for common production operator to do that. However, experienced production operator, or expert production operator, could identify the required process activities that were involved to produce a product or a part. Discussing about human experts, even though they can analyses using their intuition, but they can't perform fast computation with high accuracy and they can't work twenty four hours per day, seven days per week. This paper elaborates the development of Expert System-based Computer Aided Process Planning (ESCAPP) for production cost estimation. Focus of this study is on common production process which is milling process. A case study was solved using proposed ESCAPP to explain its performance when being used to evaluate production cost of a part.

***Keywords**: Expert System, Computer Aided Process Planning, milling process, production cost estimation*

1. INTRODUCTION

One of the common problem to be solved in industry is estimation of production cost for the basis of product pricing. Inaccurate production cost estimation leads to over or under product costing. The over product costing would reduce ability of the product to compete in the market while under product costing leads to profit lost. Therefore, the estimation of production cost of a product or part must be carried out based on required production processes and their cost to manufacture the product or part (Tang et al., 2012).

However, process for estimation of production cost is very complicated (Koonce et al., 2003). Cost for every required manufacturing process must be identified thoroughly. Besides, the production cost estimation must be obtained before production is executed (Jung, 2002). Such works couldn't be held by common production operators. Therefore, intervention from experienced production operators, or expert production operator, is required in estimating the production cost.

Fast analysis on production process encourages the development of Computer Aided Process Planning (CAPP), where manufacturing processes planning would be arranged by computer and could be explained in detail. CAPP is a bridge between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) that developed to decide manufacturing processes to be executed (Saidah et al., 2002; Vidal et al., 2005). CAPP must be developed based on experiences of production operators. Hence, knowledge acquisition from experienced production operators is important issue in CAPP development.

In other field, called Artificial Intelligence (AI), there is a technique called Expert System (ES), where decisions were taken based on experts knowledge that were represented by IF-THEN rules and supported by facts that were stored in a database. In CAPP, several facts about cutting tool, machine, machining process and material could be stored in a database while experiences of production operators could be represented in the form of IF-THEN rules to be stored in computer system. Therefore, ES is very potential to be used to develop CAPP application. This study elaborates the development of ES-based CAPP for production cost estimation. Further, the proposed system is called ESCAPP. To be more focus, this study just focus on machining process that usually occurred in a manufacturing system, which is milling process.

2. RELATED STUDIES

There are several related studies conducted by previous researchers that would be elaborated in the following sections. Lee et al. (2013) have developed a CAPP application for hole making in a shape engine with refer to ocean safety standard. Such study aims to coordinate all of machining operations to increase the process efficiency. The machining procedure is started from setting of the hole places until manufacturing operations sequencing. The study shows that the use of CAPP could increase manufacturing planning efficiency up to 60%.

Ipek et al. (2013) have developed an ES for material selection with manufacturing system approach. Such ES is dedicated for car bumper, flywheels and human body implants product. Two chaining process in ES namely forward and backward chaining has been combined in order to get result. The proposed ES is able to provide list of material alternatives to produce products as mentioned above.

Lee and Lee (2009) have investigated a rule-based system to recommend parameters for cutting in a CNC machine with ball end mill cutting tool. Parameters to evaluate performance of the proposed rule-based system is reduction of manufacturing lead time and product quality and the study shows that there is reduction for manufacturing lead time up to 19% and the quality of the product could be improved.

Singh and Sekhon (2005) have developed an AutoCAD-based CAPP for metal sheet forming. A new technique for knowledge representation, which use Object Oriented Programming technique, is introduced. There are more than 150 rules in the proposed CAPP and forward chaining is used as the inference engine. The proposed CAPP system is able to optimise process planning for metal sheet forming in the situation that involves jigs and fixtures selection, measurement and several dies processes.

Vidal et al. (2005) have developed a CAPP application for decision support to optimise parameters in milling operation. The parameters optimisation is carried out with subject to material type, geometry and roughness, and also machine and cutting tools. Application of the proposed CAPP could reduce manufacturing lead time up to 35%.

3. ESCAPP DEVELOPMENT

General structure of the proposed ESCAPP is shown in Figure 1, which also explains about interaction between components in the ESCAPP.

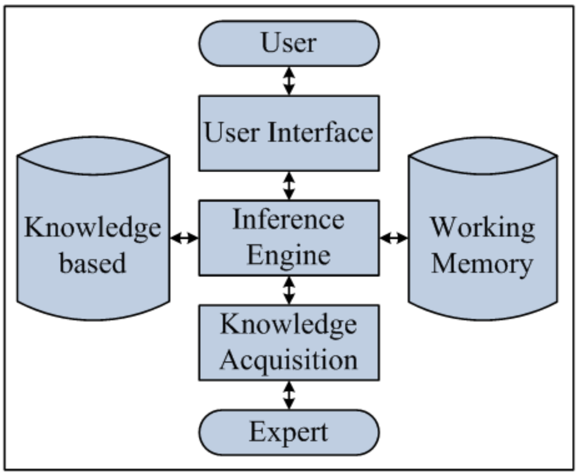


Figure 1. General structure of ESCAPP

3.1 Data Extraction

In ESCAPP development, data is extracted from field study on milling process, literatures and technical specification of several cutting tools and materials. The first extracted data is feature, and there are four type of features, namely plain, stair, slot and pocket, extracted and stored in a table. However, the table is expandable, a new data could be inserted. The second extracted data is type of material and the specification. The data about material is stored in a table with 6 fields which are material ID, material type, hardness, modulus young, tensile strength and cutting tool material ID.

The next extracted data is milling cutting tool and there are three tables used to store the data. The first table has 2 fields which are material ID and cutting material, the second table has three fields which are cutting tool type ID, cutting tool type and parameter ID. The third table has 9 fields which are parameter ID, cutting tool type ID, diameter, lambda value, number of tooth, tool wide, price, cutting tool material ID, and tool life. Entity Relationship Diagram (ERD) of the tables is shown in Figure 2.

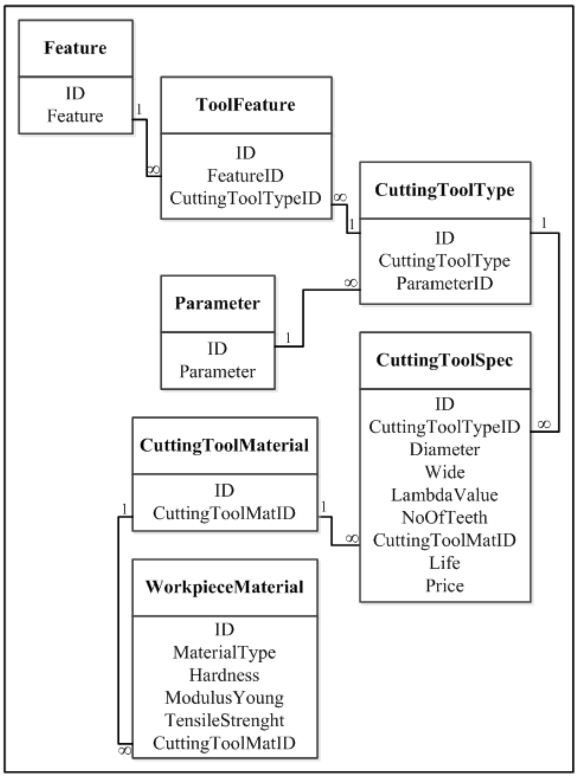


Figure 2. ERD of the Tables in the ESCAPP

3.2 Knowledge based System (KBS)

In the proposed ESCAPP, the KBS is used to process input data from the user. In the KBS, there are several procedures to select cutting tool material, define cutting tool type, select cutting tool specification, recommend machining parameter and estimate production cost. Following sections explain in detail every procedures.

3.2.1 Cutting Tool Material Selection

Cutting tool material selection procedure is used to define the cutting tool material based on work piece material type. Parameter of the selection is quality of the surface after cutting which is defined by the expert.

3.2.2 Cutting Tool Type Selection

In milling process, a feature could be formed by several cutting tool type. Cutting tool type selection procedure aims to provide several alternatives of cutting tool type based on the feature that entered by the user to the ESCAPP system.

3.2.3 Cutting Tool Specification Selection

Every type of milling cutting tool has dimension and detail specification to form a feature. Cutting tool specification selection procedure aims to select cutting tool specification based on milling process and some constraints entered by the user. Such constraints includes feature dimensions and constraints for machining parameters which are cutting speed, feed per tooth, depth of cut and width of cut. Besides, there are constraints for cutting technique which are full and partial cutting. Full cutting technique means that the cutting tool feeds the material's surface once, while partial cutting technique means that the cutting tool feeds the material's surface several time until the feature is finished formed.

3.2.4 Machining Parameters Recommendation

This procedure aims to recommend several machining parameters which are cutting speed, feed rate and material removal rate. After machining parameters recommendation, then the procedure would estimate the processing time. Further, such processing time would be used as one of the basis for production cost estimation. Equation 1 shows the cutting speed formula.

$$v = \frac{\pi.D.n}{1000} \qquad (1)$$

Where:

v = *Cutting Speed* (m/minute)
D = Cutting tool diameter (mm)
n = *Spindle Speed* (rpm)

Feed rate is the moving of the cutting tool that touching the work piece in a minute. Equation 2 shows the formula to calculate feed rate.

$$f = f_1.z.n \qquad (2)$$

Where:

f = *Feed Rate* (mm/minute)
f_1 = *Feed per Tooth* (mm/Tooth)
z = No of tooth in the cutting tool

Material removal rate is the lost volume because of milling process in an interval of time. Value of material removal rate could be calculated using Equation 3.

$$MRR = w.d.f \qquad (3)$$

Where:

MRR = *Material Removal Rate* $(mm^3/minute)$
w = *Width of cut* (mm)
d = *Depth of cut* (mm)

Estimation of processing time is calculated based on a cutting for every features with Equation 4.

$$t = \frac{Vol}{MRR} \qquad (4)$$

Where:

t = Processing time (minute)
Vol = Lost volume (mm^3)

3.2.5 Production Cost Estimation

Estimation of production cost is carried out by accumulating cost to process every feature. Equation 5 shows the formula to calculate cost for every features.

$$Cost = \frac{Cutting\ tool\ price}{T}\ x\ t \qquad (5)$$

Where:

$Cost$ =Production cost (Rp/feature)
T =*Tool Life* (minute)

4. CASE STUDY

To test the performance of the ESCAPP, a case study is proposed. Part to be produced is shown in Figure 3 while detail data about the work piece is shown in Table 1.

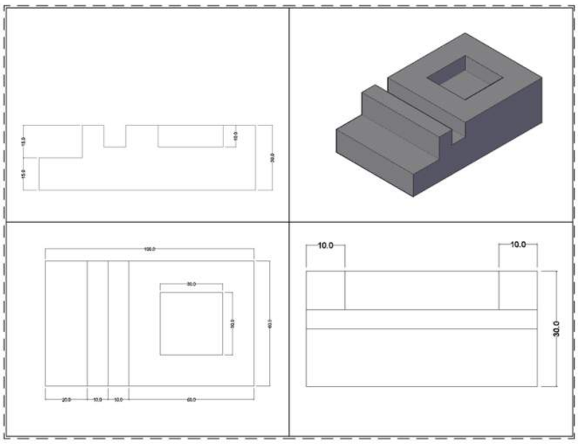


Figure 3. Part for the Case Study

Table 1. Detail Data About Work Piece

Work piece material	Aluminium Alloy			
Overall dimension (mm)	100 x 60 x 40			
Feature	Plain	Stair	Pocket	Slot
Dimension (mm)	100x60x10	60x20x15	30x30x10	60x10x10
Operation type	Full	Partial	Partial	Full
Cutting speed (m/min)	60	120	120	60
Depth of cut (mm)	2	2	2	2
Width of cut (mm)	-	2	2	-
Feed per tooth (mm)	0.1	0.1	0.1	0.1

Figure 4 depicts the user interface of the proposed ESCAPP when being used to analyses the part while Figure 5 depicts routing sheet as the output of the proposed ESCAPP.

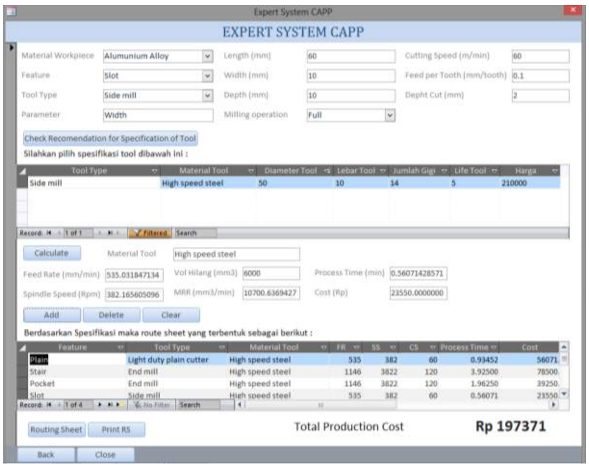
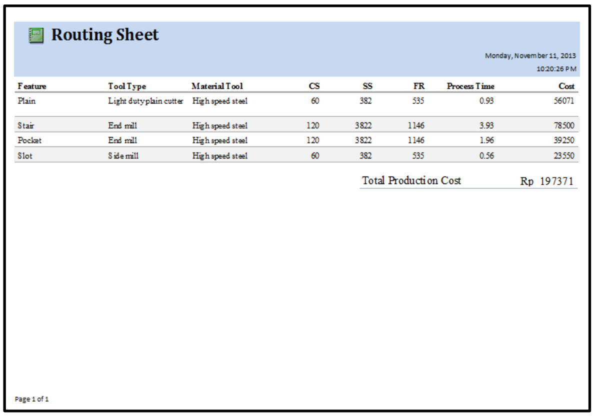


Figure 4. User Interface of the ESCAPP



Routing Sheet

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Feature	Tool Type	Material Tool	CS	SS	FR	Process Time	Cost
Plain	Light duty plain cutter	High speed steel	60	382	535	0.93	56071
Stair	End mill	High speed steel	120	3822	1146	3.93	78500
Pocket	End mill	High speed steel	120	3822	1146	1.96	39250
Slot	Side mill	High speed steel	60	382	535	0.56	23550

Total Production Cost Rp 197371

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Figure 5. Routing Sheet as the Output of the ESCAPP

Since the proposed ESCAPP is an ES then validation of the result is leaving to the expert. Based on the expert opinion, the estimated production cost is reasonable, hence, it could be claimed fairly that the proposed ESCAPP is able to provide valid result.

5. CONCLUSION

Development of ES-based CAPP could be carried out through data extraction, knowledge representation in a KBS and user interface development. In this study, required data to be extracted is data about material, cutting tool and machining process. Based on a case study, the proposed ES-based CAPP which is called as ESCAPP is able to provide valid result.

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AUTHOR BIOGRAPHIES

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