A SOFTWARE PROTOTYPE APPLICATION FOR MACHINING OPTIMIZATION OF INVOLVED CUTTING PARAMETERS IN TURNING PROCESSES A WORK IN PROGRESS

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ABSTRACT

In machining industries, the selection of sets of cutting parameters; cutting speed (v), feed (f), and depth of cut (d) do not put much concern on optimization. In practice, they are even set intuitively or by looking at manual reference table. The study commences with constructing a software based optimization tool. The application software optimizes cutting parameters based on production time and cost for turning operations. The development of the software application captures the idea of product development process with the prototype itself assigned as the product being developed. Product specifications and product feature are derived to meet the requirements. Database of cutting tools geometry, cutting tools' materials (allowable maximum v and f), stock-workpiece geometry, workpiece material properties (amongst others, yield strength, shear strength, modulus of elasticity, unit power, and Brinell hardness), and machine type characteristics are developed using GNU/PostgreSQL database. Java programming language is used to develop the software product. To develop the prototype application, a modeling effort of the software architecture is performed by using GNU/Umbrello, a UML – Unified Modeling Language application. The implementation of process optimization in this application is based on Taylor's Tool Life formula. Iterations are performed to provide the suitable cutting parameters based on cutting power, cutting force, allowable beam (workpiece) deflection, manufacturing cost and time. The functionally-tested application has made it a prototype with prospect in becoming a very helpful tool later on for machining operators to find a set of optimized cutting parameters with consideration of several machining constraints.

Keywords: *turning operation, cutting paremeters, optimization, product development, prototype software application*

Introduction

In this era of globalization, today's industries struggle to put big concern and consideration about productivity, quality, and safety. Kirby (2010) pointed that today's manufacturers hope to quickly and effectively set up and optimize processes associated with new and existing processes to attain success and remain competitive. Engineers and production personnel may utilize various methods and industrial technologies to achieve the optimization of a process to meet the company's needs.

Apparently, people did not really pay attention to one of necessary things need to be done, namely optimization in manufacturing, specifically machining process. Many of machining conditions set intuitively. Although a reference table is used, a large number still disregards about constraints in the system, for example the condition of the factory equipment, production time, rate, cost, and other factors.

Nevertheless now, a lot has recognized that the impact of optimization in real world affects the enhancement of the industries itself. In the end, optimization in manufacturing is becoming a focus for competitive advantage and profitability. Zuperl and Cus (2000) even stated that the optimization of cutting conditions is the crucial component in planning of machining processes. Therefore, it has become part of the key of industrial success.

Actually, there has been numerous research studies conducted in order to optimize manufacturing system in terms of using traditional and modern techniques as technology evolves more modern during the time. However, these techniques seem to be difficult to be applied by machine operators in factories. Therefore, it is an opportunity to develop an uncomplicated and handy application to be used by machine operators in order to select the best optimum cutting conditions to achieve manufacturing optimization.

Literature Review

A. Process Optimization in Manufacturing

According to Pauling (1960), one of the most fundamental principles in humans' world is the search for a condition of a finest state. In terms of economy, there is a favor to maximize profit and sales and to minimize costs to be as low as possible. Therefore, as Neumaier (2006) stated before, optimization is certainly one of the oldest of sciences which even extends into daily life. People like Friedberg (1958) or even Robbins and Monro (1951) pioneered these important research fields in optimization. Optimization algorithms often iteratively evaluate solution candidates in order to approach the optima. A few of popular methods like evolutionary algorithm, genetic algorithm, ant colony optimization, particle swarm optimization, simulated annealing optimization, and simplex method optimization are generally reviewed.

This goes the same with the world of manufacturing. Speaking of optimization Ganesan et al. (2011) voiced that the main optimization in manufacturing system, especially machining process falls to optimization of machining parameters, namely cutting parameters is one of the key performances of any process planning. Most of the objectives are to minimize production cost, to minimize production time, to maximize production rate, and even to maximize the products' quality.

According to Wiley (2002), three most prevalent machining operations fall to turning, milling, and drilling operations. There has been numerous optimization methodologies applied to these machining industries. For instance, Choi and Bricker (1996) offered some information regarding an optimization methodology for the optimization of the multi-pass face milling process. Binary coded genetic algorithm (GA) was chosen as the methodology to minimize the unit production cost along with the presence of several nonlinear constraints. Panchal, Khanna and Dixit (2000) stated that developing a neuro-fuzzy control scheme could do selection of feed and speed in a single pass turning. The objectives were to maximize quality and minimize production cost. On the other hand, Yildiz and Ozturk (2006) a hybrid enhanced genetic algorithm (HRGA) that is developed for the determination of cutting parameters considering minimum production cost under a set of machining constraints. These examples pictured how experts have conducted optimization techniques in manufacturing industries.

B. Application Software Development Technology and Realization

Hill (2004) appointed that application software could be described as end user software, which is used by end users to accomplish a variety of different tasks. The most common feature for application software would be user interface that displays graphical elements called icons to represent familiar objects and a mouse that controls a pointer on the screen that is used to select items such as icons. Another feature is the use of windows which is simply a rectangular area that can display a document, another program menu, or simply a message. Besides, in order for application software to do any specific job, a sequence of instructions has to be given to computer. This set of instructions is called a computer program. According to Pierce (2007), high level language is used in building programs for application software to help the user to get the computer perform the tasks. Classes in program are also part of this technology. As stated by Hurts (1997), a class provides a template or prototype from which objects are created, so it describes a collection of variables and methods in form of functions. In addition to that, for a program, there has to be compiler and interpreter.

Proboyekti (2004) explained that another technology that is being part of application software should be database enclosing data structure used to store, query, and retrieve information. Some of successful application software has been applied to real industries, specifically manufacturing industries. One of them, Feng and Hattori (2008) discussed that dry machining can be cost effective, therefore these researchers decided to build a cost model using the technology of software.

C. Application Software Development from Product Development Aspect

There is an argument saying that software development is more analogous to new product research and development than it is to assembly line style manufacturing as it involves innovation, discovery, and artistry. He supplemented his argument that considering agile methodology in product development, factors like cost, schedule, requirements and quality should be taken into account.

Standish (1994) mentioned that the most common cause of failed projects falls to missing or incorrect requirements. Hence, it is crucial to define client or user requirements carefully. In terms of developing product, there should be product design proposed or suggested. Hence, after requirements have been gathered, the components needed for the application development software are abstracted into a design model using flowcharts or state diagrams as per Simpson (2008).

Mellon (2005) depicted that defining software architecture, which comprises of structures of the software itself, together with the elements, the externally visible properties of those elements, and the relationships among them was seen essentially for the construction of software system. Software architecture fulfills the functional testing of software development on the word of Jenkins (2005). Then, the software is considered ready to be developed. The methodologies offered in actual fact for creating software were Dynamic Systems Development Methodology (DSDM), Waterfall shape methodology, V-shaped methodology, and even Agile Methodology.

Most importantly, Victor Szalvay (2004) mentioned that optimization activity could be done by using application software which is built based on product development process.

Methodology

The core of the methodology stands basically at product development phase since the final result of this work would be a prototype application which is able to perform calculations in finding the best optimum sets of cutting parameters in machining process. For the time being, the prototype application implements trivial; roughing and facing turning operations' optimization.The reason why these two processes are considered because the rate of material removal in these processes are high, leading to high cutting force, high cutting power, and likewise high beam deflection. It is believed that these factors are the ones which affect time and cost the most. Figure 1 depicts the prototype application as a product that is being developed using product development process.

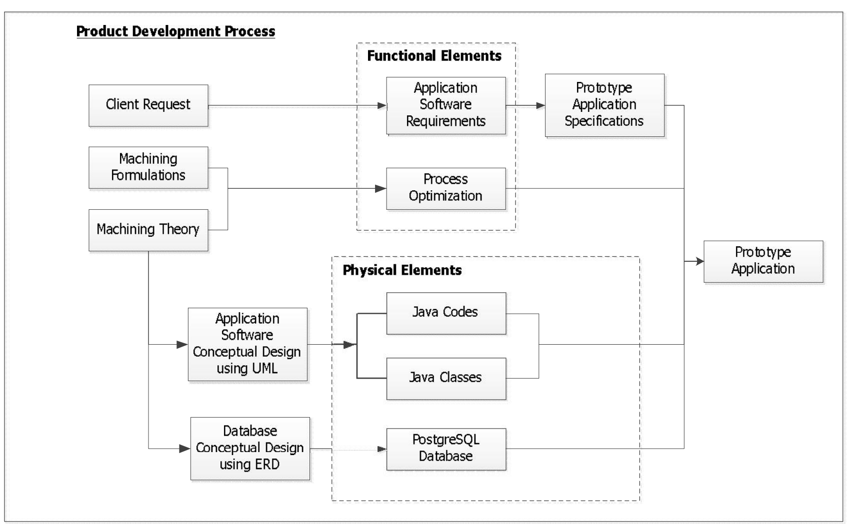

Figure 1. Prototype Application Development Flowchart (Perdana, 2012)

Product development basically means a set of activities beginning with a perception of opportunity and ending with the 'delivery' of product into the market. The phase begins with exploring theory of machining together with formulations contained in it. The theory of machining leads to conceptual design of the prototype application which is divided into two parts; computer programs and concrete database. Instead as the same time, stakeholders' requirements on the prototype application are adjusted with client request. These requirements are assigned as functional elements of the prototype application. Moreover, they also lead to specify the prototype application detailed specifications. On the other hand, the conceptual design leads to the development of physical elements of the product. Functional elements assigned to physical elements constitute product architecture. With complete architecture shown in and detailed specifications, the prototype application can be successfully constructed to become in this case, a product.

The answer to the question of how it is really constructed is by realization. For the Computer Programs are coded using Java programming language with NetBeans 7.11 from Oracle as compiler. In contrast, the database is built in forms of tables consisting of required stored data using Structured Query Language (SQL) with PGAdmin III as the development tool.

Nevertheless, in terms of the production process aspect, despite the utilization of machining theories, there is a requirement for several types of data such as; data of work geometry, work material, cutting tool, and machine specification. These collections of data are the ones that will be stored in the database and be used for process optimization calculations using Taylor's Tool Life formulations. All of the steps shown in Figure 2 are coded using Java. When the program has finished running, optimum sets of cutting parameters are obtained for each turning process.

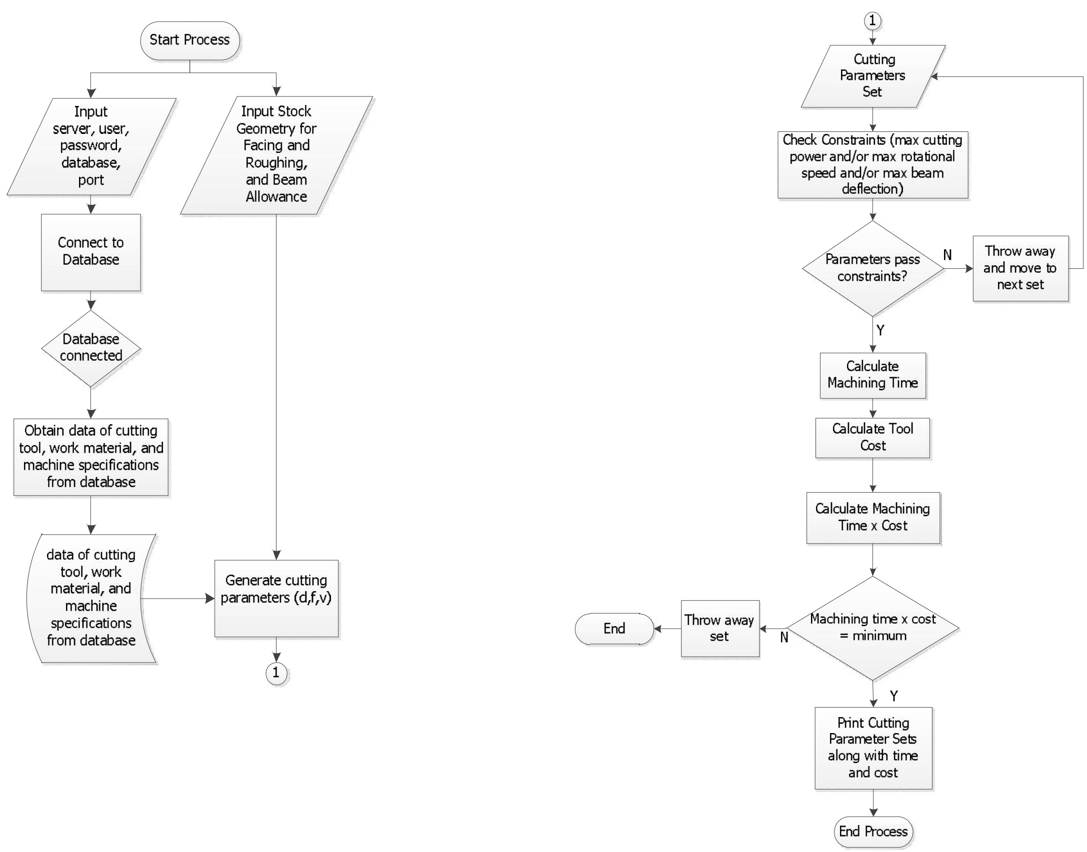

Figure 2. Process Optimization Flowchart (Perdana, 2012)

The shown formulas needed for the calculations are the main formulas for the constraints; cutting power, spindle speed, and beam deflection, and also the formulas to calculate machining time and tool cost. The other time and cost involved in production are not measured as they stay constant in adverse of machining time and tool cost.

$$vT^n = C \quad (1)$$

$$F_C - F_U \times f \times d \quad (2)$$

$$P_c = \frac{F_c\, v}{60} \quad (3)$$

$$N = \frac{1000\, v}{\pi\, D_o} \quad (4)$$

$$\delta l\ (Facing) = \frac{F_t\, L}{E\, A}$$

$$\delta l\ (Roughing) = \frac{F_t\, L^3}{3\, E\, I} \quad (5)$$

$$T_m\ per\ unit = \frac{n\, L}{fr} = \frac{\pi Do\, n\, L}{1000\, fr} \quad (6)$$

$$C_T\ per\ unit = \frac{T_m}{T} \times C_T \quad (7)$$

$$vMux - \frac{C}{[(\frac{1}{n} - 1)\, T_t]^n} \quad (8)$$

$$vMin = C\, (\frac{n}{1-n} \cdot \frac{C_o}{C_o\, T_t + C_t})^n \quad (9)$$

When the prototype application has successfully been designed and built, the run of the prototype application's way of working is distinctly visualized step by step. This step is basically called functional alpha (α) testing. Also, there would be analysis on factual simulation model constituents of the prototype applications. The developed design model obtained using reverse engineer tool is compared with former conceptual design of all constituents. Nevertheless, in order to make sure that the prototype application fulfills the need of finding the best optimum parameters for both facing and turning process, a validation process is required. The sets of cutting parameters obtained should optimize time and cost, not merely either one. As, one of the cutting parameters considered, cutting speeds (v) processed from the happening process optimization should be in between of these calculated cutting speeds; vmax (cutting speed which minimizes time only) and vmin (cutting speed which minimizes cost only). When that situation occurs, the prototype application is said to be validated.

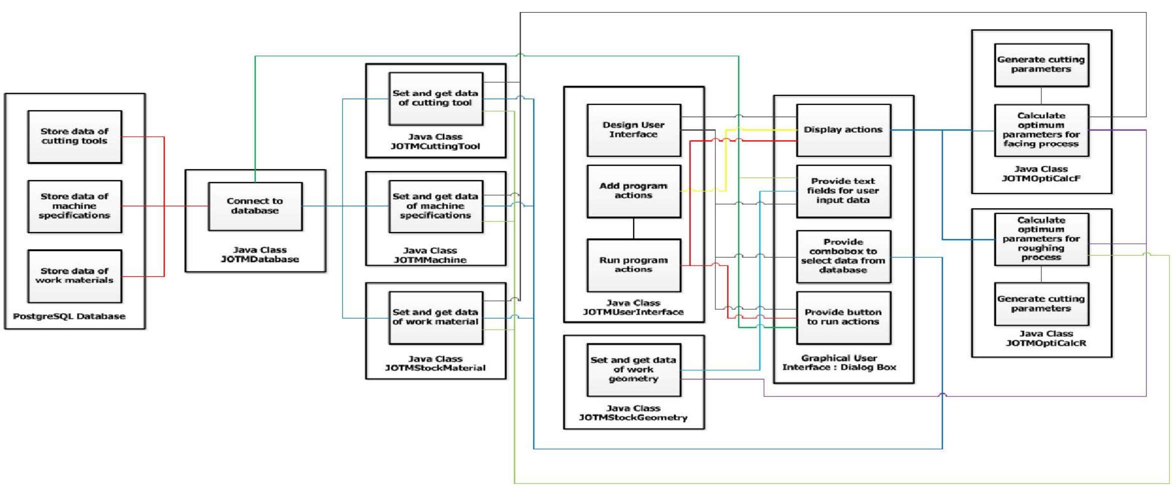

Figure 3. Prototype Application Architecture Schema

Result & Discussion

There is a differentiation of results of this study. In terms of product, prototype application software has been developed successfully. In terms of overall result, optimum sets of cutting parameters for turning process are attained. However, beforehand, every step of the product development process has an individual result. The prototype application architecture is pictured in Figure 3 below.

The prototype application's architecture shows that the prototype application itself contains 8 physical chunks shown in bigger outer black boxes which comprise of Java classes and concrete database, all together having 19 functions pictured as small black boxes. The interfaces of each physical element to others are in Java codes.

	machinetype character(50)	motorpower numeric	motorefficiency numeric	spindlespeed numeric	distancebetweencentre numeric	swingoverbed numeric
1	Gap Bed Lathe - M300/635	2200	0.80	2500	635	330
2	Gap Bed Lathe - M300/1000	2200	0.80	2500	1000	330
3	Gap Bed Lathe - CDE6240A/1000	7500	0.80	1400	1000	400
4	Gap Bed Lathe - CDE6240A/1500	7500	0.80	1400	1500	400
5	Gap Bed Lathe - CDL6241/1000	4500	0.80	2000	1000	410
6	Gap Bed Lathe - CDL6241/1500	4500	0.80	2000	1500	410
7	Gap Bed Lathe - CDL6251/1500	5500	0.80	1600	1500	510
8	Gap Bed Lathe - CDS6266B/2000	7500	0.80	2000	2000	660

	cuttoolid character(20)	material character(20)	insertshape character(25)	rakeangle numeric	reliefangle numeric	n numeric	C numeric	maxd numeric	maxf numeric	maxv numeric	toolcost numeric
1	CNMG 090304-MF1	carbide	rhombus 55°	12.5	12.5	0.25	500	3.81	1.25	300	2000
2	CNMG 090308-MF2	carbide	rhombus 55°	12.5	12.5	0.25	500	3.81	1.25	300	2000
3	DNMG 150408-M1	carbide	rhombus 35°	27.5	27.5	0.25	500	5.15	1.25	300	5000
4	DNMG 150408-MF1	carbide	rhombus 35°	27.5	27.5	0.25	500	5.15	1.25	300	5000
5	SNMG 120408-M1	carbide	square	0	0	0.25	500	5.15	1.25	300	3000
6	SNMG 120409-MR4	carbide	square	0	0	0.25	500	5.15	1.25	300	3000
7	TNMG 220416-M3	carbide	triangle	15	15	0.25	500	5.15	1.25	300	5000
8	TNMG 270612-M3	carbide	triangle	15	15	0.25	500	6.35	1.25	300	5000
9	WNMG 080408-M1	carbide	irregular triangle	10	10	0.25	500	5.15	1.25	300	7000
10	WNMG 080408-MF2	carbide	irregular triangle	10	10	0.25	500	5.15	1.25	300	7000

	type character(50)	yieldstrength numeric	shearstrength numeric	modelasticity numeric	unitpower numeric	brinellhardness numeric
1	alumunium	28	30	69000	0.7	100
2	cast iron	275	220	138000	1.6	250
3	steel	500	186	209000	2.8	300
4	titanium	350	400	117000	1.2	330

Figure 4. Database Tables for Data Stored

Conversely, Figure 4 describes the database tables of cutting tool data, machine specification data, and work material data created using SQL. Each table contains various types of related data.

Previously, it has been explained that the prototype application has mainly two core components, explicitly a database to store data and application programs. When the product architecture was final, these components could effectively be built until it became a prototype application. Alpha (α) testing was subsequently done using data available from user case and catalogue for testing the prototype application. A case study is made for Alpha (α) functional testing of the prototype application. The screenshots are presented at Figure 5 - 8.

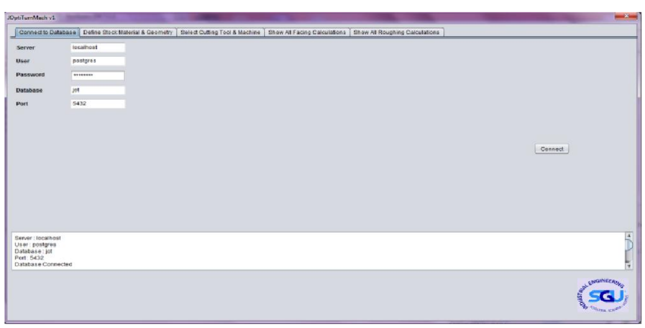

Figure 5. Screenshot of Connect to Database Tabbed Menu

Figure 5 shows the first tab of the application software where the user should put in several inputs in order to be connected with the database. Instead, Figure 6 pictures the second tab which is the menu where the user should input the work geometry and select the work material used in the machining process. Though the diagrams are not in real scale, it gives a representation of the happening case.

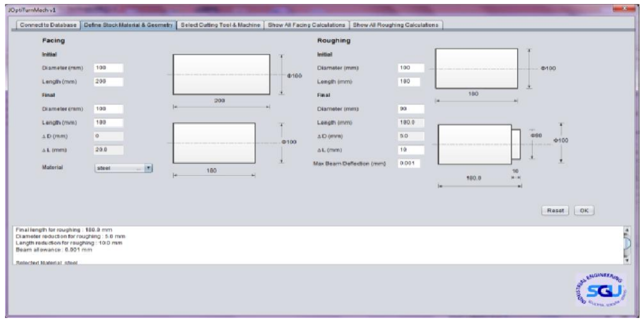

Figure 6. Screenshot of Work Geometry and Material Tabbed Menu

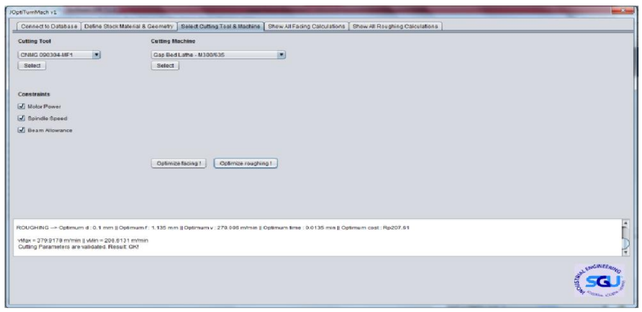

Figure 7. Screenshot of Select Cutting Tool & Machine Tabbed Menu

Figure 7 implies the tab where the user has to select the cutting tool and machine, as well as the machining constraints one wants to consider for the turning process. Figure 8 and Figure 9 just portray all the generated parameters and calculations involved in obtaining the optimum sets of cutting parameters.

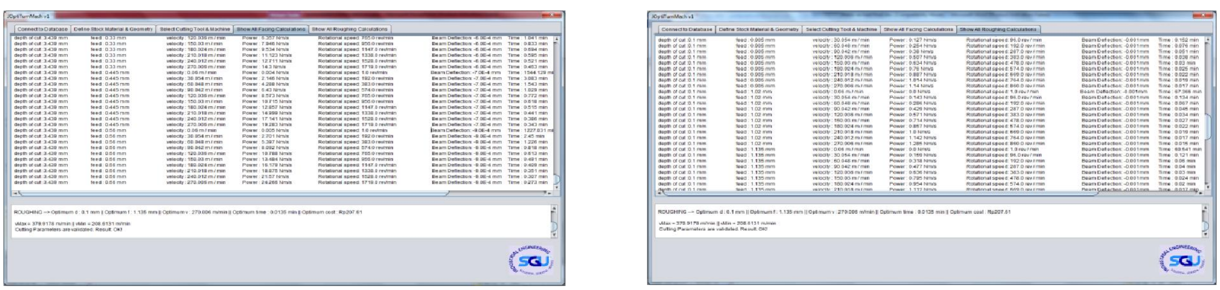

Figure 8. Screenshot of Show All Facing& Roughing Calculations Tabbed Menu

The calculations of the two limits; v_{max} and v_{min} are done within the program. In this case study, it is proven that the prototype application developed is valid and is able to produce true results. In addition to that, the design model Java codes in Java classes and database present are then regenerated using GNU/Umbrello 2.8 and Microsoft Visio 2010 so that it could be compared with the former conceptual designs. Figure 10 and Figure 11 picture both of the real design models.

Conclusion & Recommendation

Every manufacturing organization has assets which are needs for optimizing its production system in terms of producing good quality products, achieving maximum production rate and reducing production costs. It is understood that process optimization has a significant impact on production process.

In terms of product development, this prototype application is considered as a product which is built based on conceptual design constructed and numerous requirements adjusted with factual stakeholder. Finally, the prototype application which is constructed using the idea of user-friendly could provide a result of optimized cutting parameters which are already validated.

Not saying that this study is already perfect, there are still further actions to be done. Firstly, process Optimization could be done using other techniques; Genetic Algorithm & Linear Programming as these techniques are supported with the present condition. Secondly, there are more machining operations factors to be considered; constraints, type of machines, type of machining operations, etc. In addition to those two, there is a prospect of using open sourced components to speed up development process. Also, the product architecture could be improved. Last but not least, the database could still be further developed related with other supporting activities; cutting tools, material preparation, costing, process plan, fixtures – work holdings, etc.

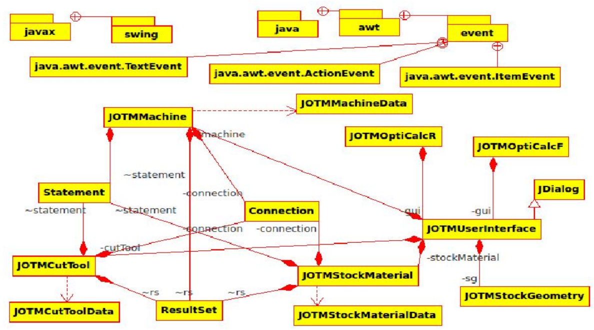

Figure 9. Design Model of Java Classes

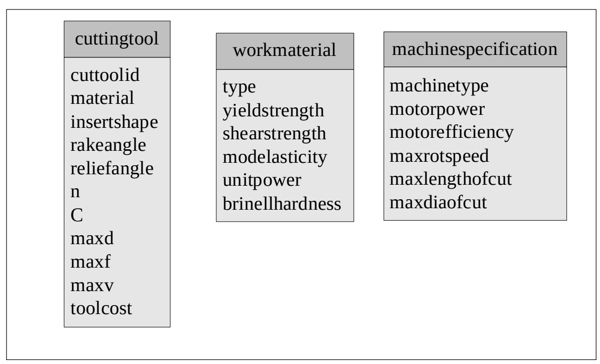

Figure 10. Design Model of Database

Notation List

v = cutting speed, m/min
f = feed, mm
d = depth of cut, mm
F_c = cutting force, N
P_u = unit power, N/mm^2
P_c = cutting power, N/mm^2

References

Abdulkareem, S., U. J. Rumah, and A. Adaokoma, (2011). "Optimizing Machining Parameters During Turning Process." *International Journal of Integrated Engineering*, Vol. 3 No. 1, pp. 23-27.

Aggarwal, A. and H. Singh,(2005). ”Optimization of Machining Techniques – A Retrospective and Literature Review.” *Sadhana,* Vol. 30, 6, pp. 699–711.

Groover, M. P., (2006). ”*Fundamentals of Modern Manufacturing (Materials, Processes, and Systems) - Third Edition.”*, John Wiley & Sons, Inc.

Jenkins, N., (2005). “How to Make Software - An Introduction to Software Development.”, Creative Commons.

Perdana, K. (2012), "*Prototype Application Development for Machining Optimization of Involved Cutting Parameters in Turning Process*", Bachelor Thesis, Department of Industrial Engineering, Swiss German University, Tangerang, Indonesia.

Srinivasan, K. & D. Fisher, (1995). “Machine Learning Approaches to Estimating Software Development Effort.”*IEEE Trans. SE*, Vol. 21, No. 2, pp. 126-137.

Szalvay, V., (2004).*“An Introduction to Agile Software Development.* “Bellevue: Danube Technologies, Inc.

Weise, T., (2009).*“Global Optimization Algorithms, Theory and Application.”* Germany: it weise.de.