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Early Manufacturing Cost Estimate For Mechanical Parts

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Abstract

In manufacturing environment cost estimates process is made in all stages of product development from research to final product. Good estimating techniques and procedures are necessary for each manufacturing stage. When properly implemented, these techniques produce acceptable operational estimates that are useful to management for decision-making.

In this research, an algorithm is developed to build system is called FBMCE (Feature-Based Manufacturing Cost Estimate) to incorporate making decisions integrating design, process planning and manufacturing for cost estimate purposes. The FBMCE system has been tested on product (Shaft 8E - 200) in State Company for Electrical Industries and showed promising results.

Keywords: cost estimation, feature-based, process planning

الخلاصة

عملية تخمين الكلفة في البيئة التصنيعية تمر في كل مراحل تطوير المنتج من مرحلة البحث الى مرحلة المنتج النهائي. ان تقنيات وخطوات التخمين الجيدة ضرورية في كل مراحل التصنيع. وهذه التقنيات عند تنفيذها بشكل مناسب، فانها تؤدي الى تخمين مقبول لمصاريف التشغيل والتي تفيد باتخاذ القرارات.

في هذا البحث تم تطوير خوارزمية لبناء نظام يدعي FBMCE (تخمين كلفة التصنيع بالاستناد الى السمة) والذي طور لاتخاذ القرارات حول التكامل بين التصميم وتخطيط العملية والتصنيع لغرض تخمين الكلفة. تم اختبار النظام على المنتج (Shaft 8E - 200) في الشركة العامة للصناعات الكهربائية حيث اظهر النتائج المرجوة منه.

1- Introduction

Most Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) tools are applied to improve detailed design and detailed manufacturing planning, but not conceptual design, which usually does not include functions, behaviours, form, structure, tolerances, and surface conditions that determine manufacturing methods and cost [1].

In design engineering research, some researchers have proposed methods for cost estimation, material process selection, and basic manufacturing engineering processes and technology. Nevertheless, computer-aided tools for integrated conceptual design and process planning are still far from being satisfactory in real-world applications [2]. The reason is a lack of theoretical foundations to characterize the process of early product design and the integration of various functions and technologies for effective product design[1,2]

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Figure (1) illustrates many stages of communication that can exist when establishing interoperability between design and process planning. In cost estimation, some of the recent researches are the following: - Mark Alan described a methodology whereby companies can improve product cost estimation at the conceptual design phase, using intelligent searching and arrangement of existing accounting data to enable designers to access the activity cost information more readily. The design decision support framework is illustrated by applying it to a typical problem in aerospace composites manufacturing [3]. Azhar *et al* developed a system which could integrate the cost estimation and cost control processes. Such integration enables the transfer of cost estimation data automatically to the cost control process. Therefore, complete information regarding the cost status of the project can be accessed at any time [4]. Weustink *et al* presented a generic framework for cost estimation and cost control in product design and illustrated with a sheet metal example [5]. Roy *et al* described a methodology for developing Cost Estimating Relationship (CER) that explicitly consider and capture both quantitive and qualitative design times during the (CER) development process [6]. Narcyz Roztocki described that the Integrated Activity-based costing (ABC) and Economic Value Added (EVA) System. It is useful not only for manufacturing companies, but also for companies from the service sector. The ABC component of this integrated system will help the companies to trace overhead cost, while the Economic Value Added component will help them trace capital cost [7]. Park and Simpson proposed a production cost model based on a production cost framework associated with the manufacturing activities. The production cost model can be easily integrated within optimization frameworks to support a Decision-Based Design approach for product family design. As an example, the production cost model is utilized to estimate the production costs of a family of cordless power screwdrivers [8].

The main goal of this research is to design a system which describes the integration of design, process planning and manufacturing for cost estimation purposes using a feature-based costing technique (FBC) Such system includes the determination of manufacturing process.

2- <u>Cost Estimating Methodologies</u>

Cost model for a manufacturing component or system can have several purposes. The required output of a cost estimating method depends on the purpose for which it is to be used. There are various cost estimating methodologies used throughout industry. These include: Traditional method, Parametric method, Feature-based costing method, Case-based reasoning method and Neural-network-based method [9].

There is no available research on how the integration of design, process planning and manufacturing for cost estimation purposes is made using a feature-based costing technique (FBC).

3- <u>Feature-Based Costing (FBC)</u>

The integration of design, process planning and manufacturing for cost estimating purposes using a feature-based modeling approach can be possible, although it is not yet fully developed with respect to cost engineering. Through the use of features, products can be described as a number of associated features, such as holes, flat faces, groove, slot… etc [10], as shown in Figure(2).

Each product feature has cost implications during production, the more features a product has the more manufacturing and planning required. Therefore, choices regarding the inclusion or omission of a feature impact the downstream costs of a part and eventually the life cycle costs of the product. Other reasons for using FBC are that the same features appear in many different parts and products, so the basic cost information prepared for a class of features can be reused. Manufacturers should have numerous past geometric data that can be related to features [10].

4- Methodology

Design and Development of Automated Feature-Based Manufacturing Cost Estimate System (FBMCE) is developed as an approach to computer aided process planning to link design phase with manufacturing phase. This helps the designer to explore alternatives at early design stage. Feature-Based costing techniques are used from development to production to determine the manufacturing cost for mechanical parts. Although there have been several reported researches on cost estimation for mechanical products.

The architecture of the developed FBMCE system consists of six modules, shown in figure (3).

4-1 Feature Description Module.

In this phase the part is described as rotational or prismatic and all features are classified into holes, slots, pockets…etc. Each feature is classified into sub-classes and the user identifies the dimensions and tolerances for each feature, and output results are geometrical information in other applications.

4-2 Process Selection Module.

This module starts with geometrical information that is driven from the feature description form to select the suitable processes for each feature and the system selects the specific process with capabilities of tolerance.

4-3 Machining Parameter Selection Module.

The selection of process parameter depends on the tool material, work piece material, tool diameter. Since there are a wide number of material, diameter and depth of cut combination, the storage of process parameter requires a large database.

4-4 Tooling Cost Module.

The cost of the tooling is the cost of the cutting tools and the prorated cost of any special jigs and fixtures used to hold the workpiece. The cost of the cutting tool per unit depend on both of the cost and life of the tool.

4-5 Material Cost Module.

This module starts with specifying the type of the parts shape (rotational, prismatic) for the purpose of calculating material cost which can be defined as the value of the material necessary for producing a piece of product.

4-6 Cost Estimation Module.

This module starts with calculation of production time, cost rate, machining cost and cost of a machined unit, which depends on calculation of tooling cost and material cost. Finally, the manufacturing cost of product can be calculated.

The estimate selling price per unit is established by adding a markup/profit to the total cost per unit. The percent markup must cover all operating expenses (wages, rent, advertising, etc.) and provide some margin of profit. The block diagram explain estimate selling price per unit is shown in Figure (4).

5- The FBMCE System Testing

To examine and test the capabilities of the developed system are carried out through selecting mechanical part, which is considered as an example for testing the system. The part design models selected are taken from the real world problem chosen from the manufacturing environments of State Company for electrical Industries, which are shown in Figure (5). The interaction with the system and the results output will be given as follows: -

1- Providing the needed information, which is considered essential data to feed the system mechanism, the system contains three types of database: Machine-Operator, Customer-Parameter and Tools database this is illustrated in Figures(6).

2- Selection of the type of part shape and entering the major dimension of part parameters, after that the type of material is entered to the design model through selection from user. In this case the material type of the test part is steel, this is illustrated in Figure (7).

3- The output results of the system in the feature description stage include representation of all information required in other stages in FBMCE system. The output results through the system window include feature type, sub-feature, feature dimension such as (length, diameter, radius, etc), topological information (tolerance, surface finish). By feeding the system with the required information it becomes possible to select the process and machining parameters. The output results are illustrated in Figure (8) through the system window.

4- After generating all manufacturing information about the select design model and generating a plan sheet, the user enters the machine number. In this case the part needs multi machine to manufacture, this is illustrated in Figure (9). Then calculate the tooling cost and machining cost, this is illustrated in Figure (10).

5- Calculate total cost of machined unit, manufacturing cost estimation and selling price. The final outputs of the FBMCE system as shown in table(1).

Table (1): The final outputs through FBMCE system	
Material Cost	**0.427 $**
Tooling Cost	**0.343 $**
Machining Cost	**0.556 $**
Total Cost of Machined Unit	**1.327 $**
Manufacturing Cost Per Unit	**1.605 $**
Estimate Selling Price $ Per Unit	**2.07 $**

6- <u>Conclusions</u>

Cost has become a major business driver in many industries. It is observed that there is a lack of understanding about the process to cost estimate in the design stage of a product. This research presents a business case to understand the principles of 'Cost Estimating' within the manufacturing industries. The main goal of this research is focused on the development and implementation of the integration between design, process planning and manufacturing for cost estimate purpose using feature-based costing.

This paper describes FBMCE system is developed to face the need to improve the linkage between CAD and CAM through applying automated process planning technique and automated cost estimate techniques. The FBMCE system to help planner and manufacturing engineering to select manufacturing process, determine machining parameters, and estimate manufacturing cost for products.

The FBMCE database system can provide refinements that would not be possible for an engineer to handle. For example, tool type, tool materials, and materials conditions can easily and quickly be factored into cost, thus making the estimate more accurate and reliable.

Computer estimates are very consistent and therefore more accurate. Estimates can be adjusted higher or lower, as needed, or observed from previous cost estimates. More details can be incorporated into an estimate because of computer-details that might be tedious and time-consuming if done by hand can be done quickly and accurately on computer.

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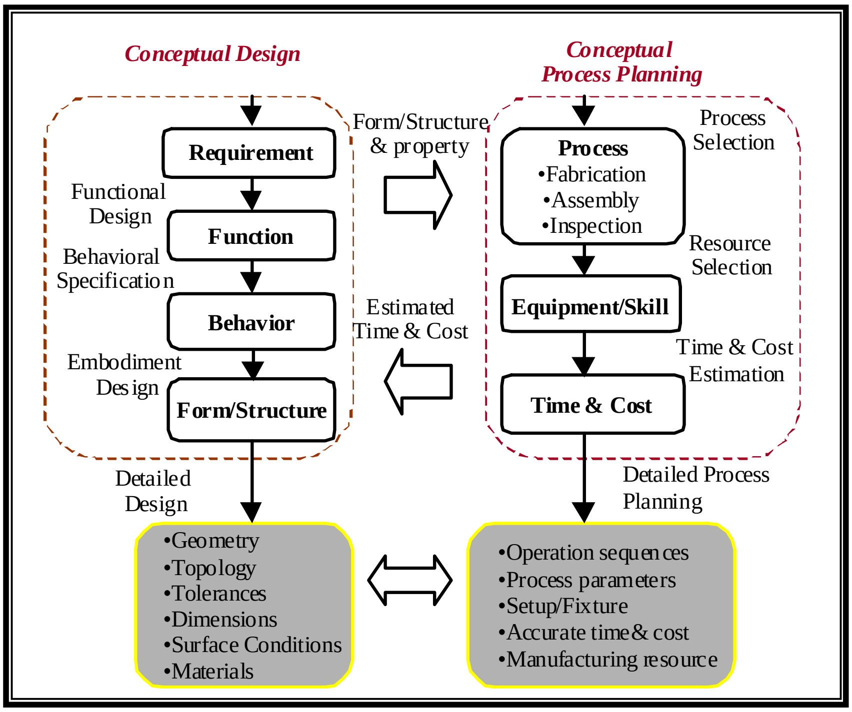

Figure (1): Design and process planning message exchange for integration [1].

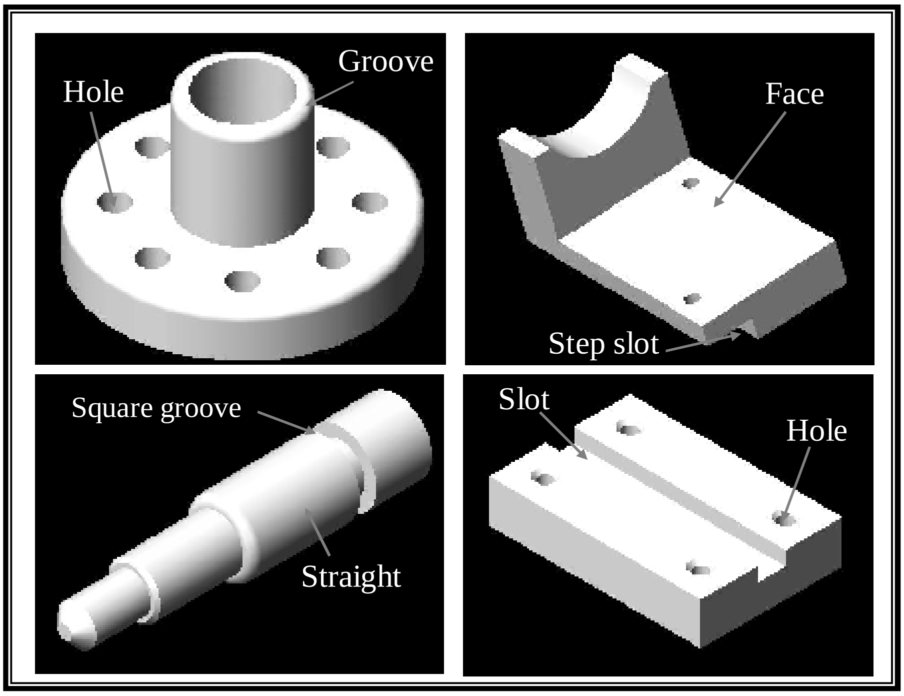

Figure (2): Examples of different views on features

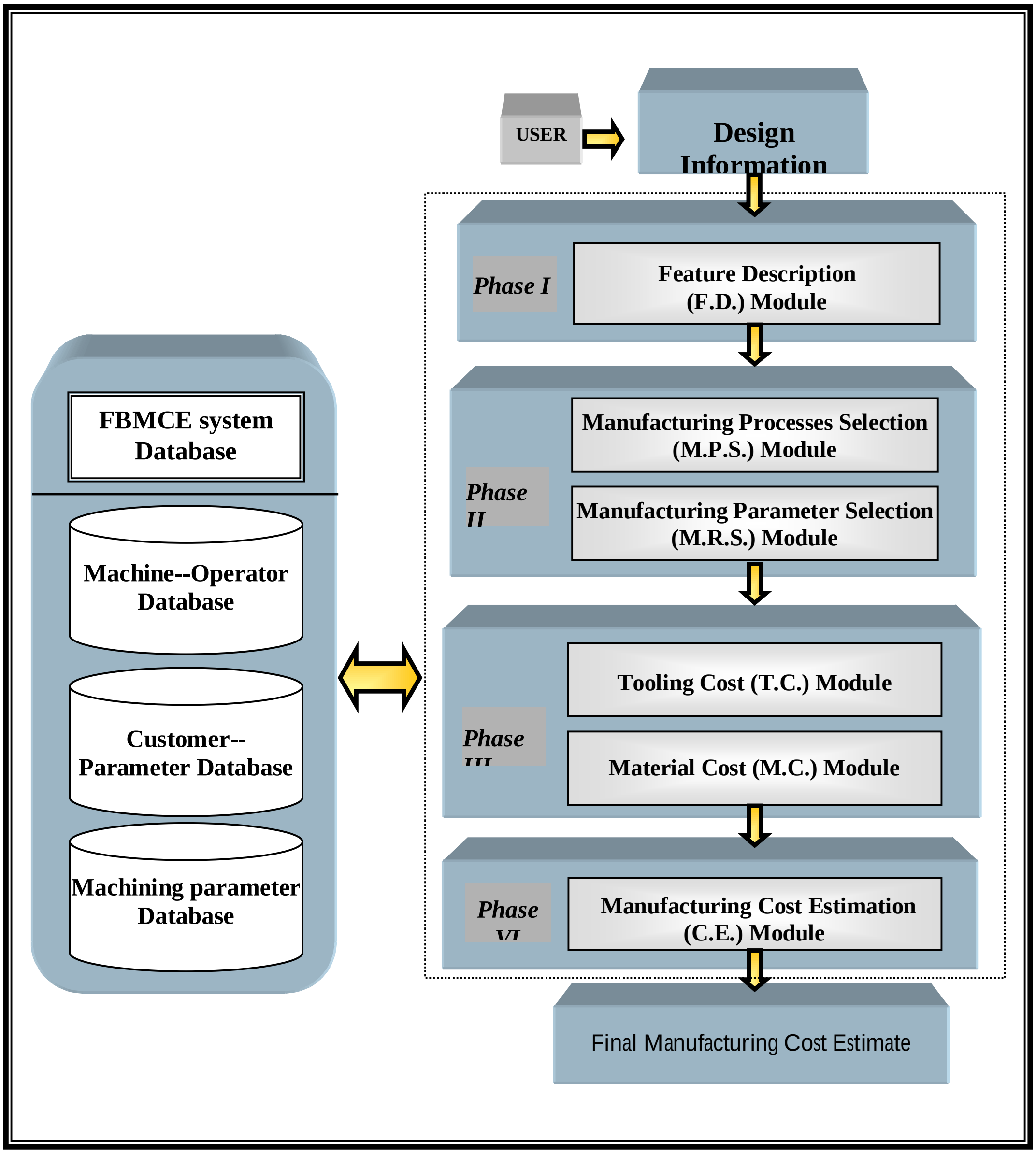

Figure (3): FBMCE system architecture.

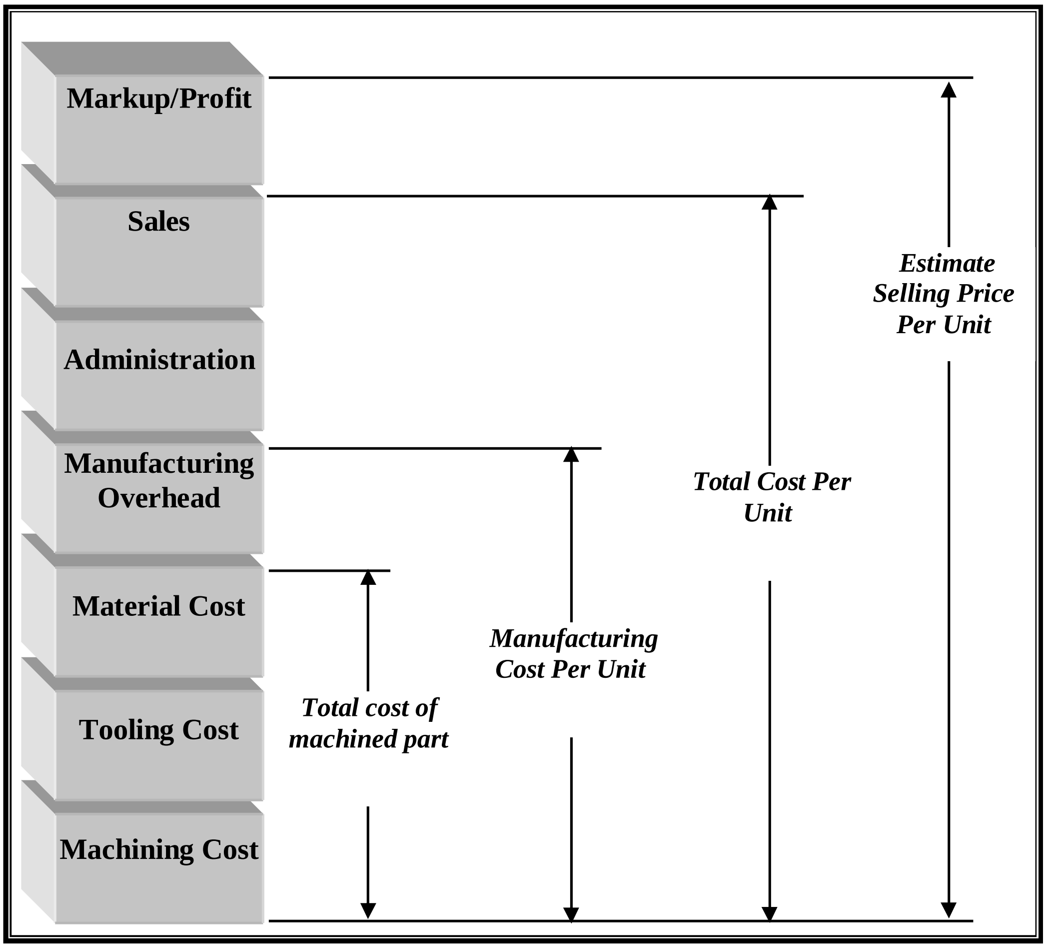

Figure (4): Block diagram explain estimate selling price per unit

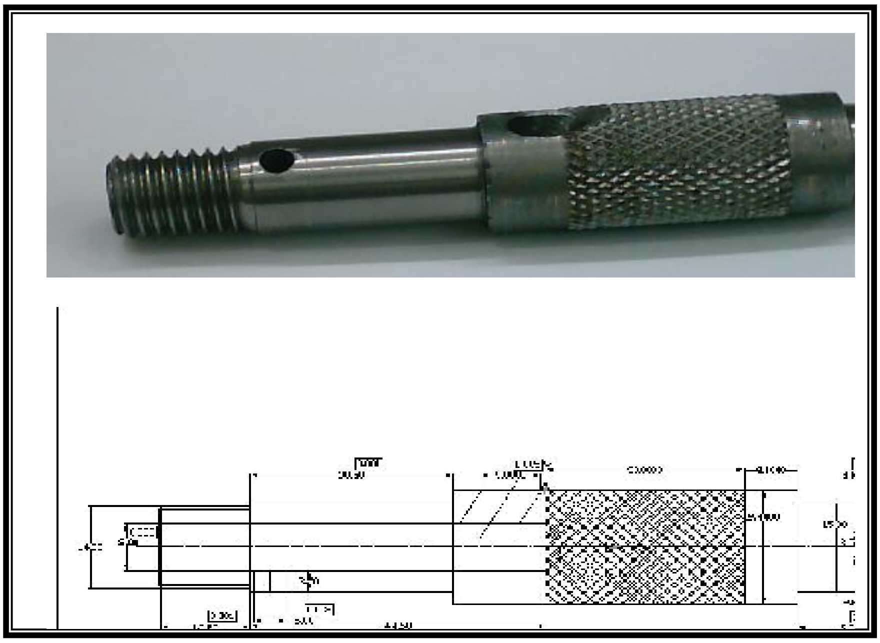

Figure (5): Shift (8E-200)

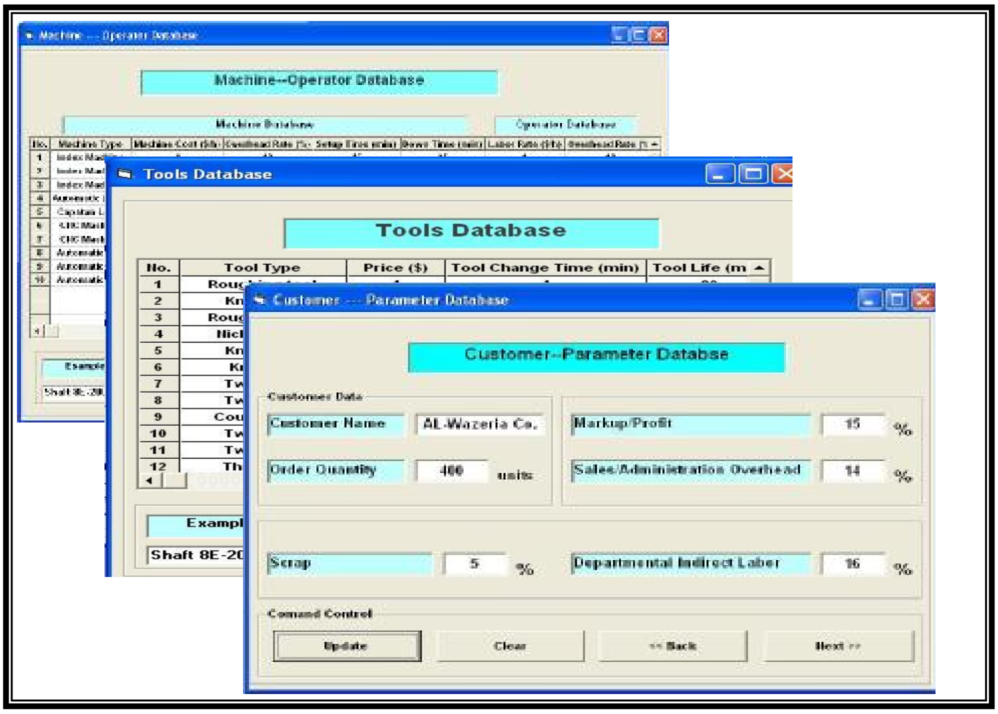

Figure (6): The machine-operator, tools and customer-parameter database Screen

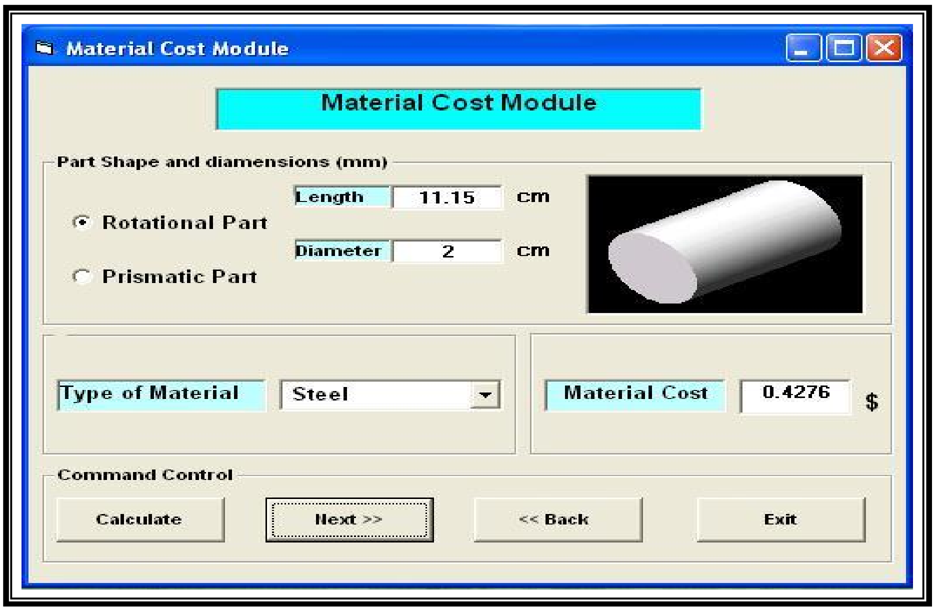

Figure (7): The output results by material cost module screen.

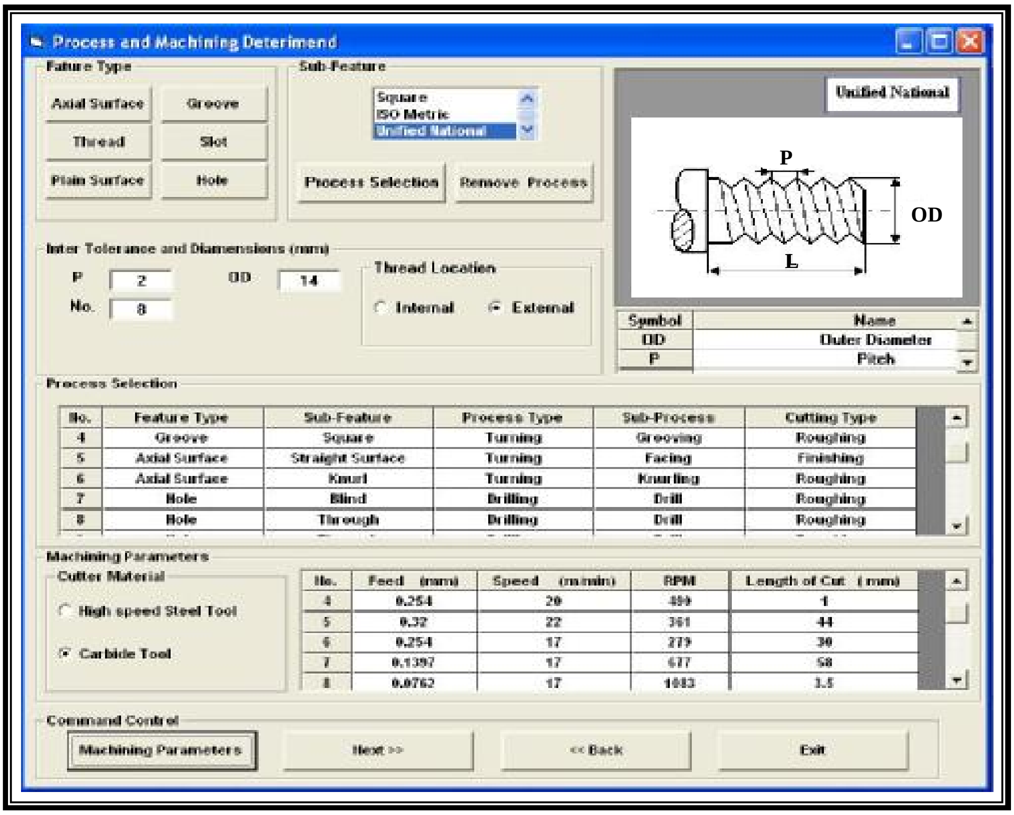

Figure (8): The output results by process and machining determined screen.

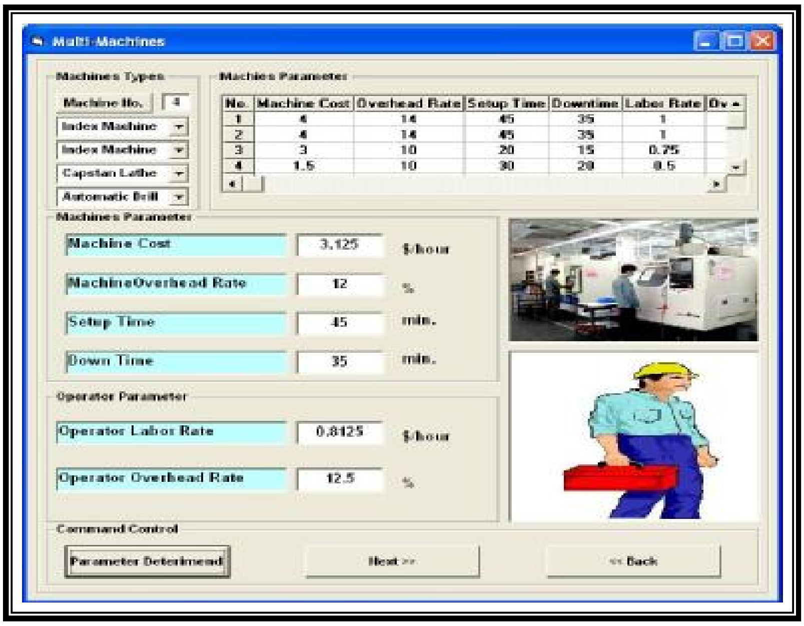

Figure (9): The output results by multi-machines screen.

Figure (10): The output results by tooling cost and machining cost screen.

Appendix

Production time formula [11].

$$T_{unit} = T_m + T_i \qquad \text{(1)}$$

where:

T= machining time ……………min

T_i = idle time ……………………min

Machining time formula [11].

For drilling: Blind hole $T = \dfrac{H + 0.3D}{F * N}$, Through hole $T = \dfrac{H + 0.3D}{F * N}$ ………… (2)

For milling: $T = \dfrac{L}{F * N * No}$ ………… (3)

For turning: $T = \dfrac{L}{F * N}$ ………… (4)

where:

T = machining time………………(min)
L = length of cut…………………(mm)
H = hole depth.. …………..(mm)
F = Feed per revolution………(mm/rev)
N = rpm……………………………(rev/min)
D = drill diameter……………….(mm)
No = number of gear teeth.

Revolution per minute formula [12].

$$N = \frac{1000 * S}{3.14 * D} \qquad \text{(5)}$$

where:

N = RPM…………………………(rev/min)
D = Diameter of work, cutter….(mm)
S = cutting speed………………..(mm/min)

Idle time formula [13].

$$T_i = t_{set} + t_{hand} + t_{down} + t_{change} \qquad \text{(6)}$$

where:

t_{set} = total time for job setup divided by number of parts in the batch.

t_{hand} = time the machine operator spends loading and unloading the work on the machine.

t_{down} = downtime lost because of machine or tool failure, waiting for material or tools.

t_{change} = prorated time for changing the cutting tool. It can be calculated by using the following formula:-

$$\textbf{T Changing} = \textbf{Tool change time} * \frac{t\ Cutting}{Tool\ life} \quad \text{.........................(7)}$$

Material Cost formula [12].

$$M.C. = V * D * P \quad \text{.............................. (8)}$$

where:

M.C. = Material Cost…..…..…..(\$)
V = Volume of workpiece…….(mm³)
D = Density…………………...…(Kg/mm³)
P = Price…………...………......(\$/Kg)

Tooling Cost formula [12].

$$T.C. = C_t * \frac{T_m}{T_L} \quad \text{.........................(9)}$$

where:

T.C.=Tooling Cost…………..…..(\$)
C_t = Cost of a cutting tool……...(\$)
T_m = machining time …………..(min)
T_L = Tool life…………………….(min)

Machining Cost formula [13].

$$C_m = C_r * T_{unit} \quad \text{.......................... (10)}$$

where:

Cm=machining Cost………..…(\$)
C*r* = cost rate……………….… (\$/min)
T *unit* = production time…..…(min)

Cost rate formula [13].

$$Cr = \frac{1}{60}\left[\frac{M(1+OHm)}{100} + \frac{W(1+OHop)}{100}\right] \quad \text{..............................(11)}$$

where:

M = machine cost…………………. ..(\$/hour)
OH_m = machine overhead rate…….. (%)
W = labor rate for operator……….. (\$/hour)
OH_{op} = operator overhead………... (%)

Total cost of machined part [13].

$$C = M.C. + T.C. + Cm \quad \text{..........................(12)}$$