Computer -aided Machine Tool Selection (Numerical or conventional) with respect to Cost Assessment (CAMTS)

By

I. M. Elewa
Assoc. Prof. Dr. in Indust. Prod.Eng. Dept.
Faculty of Eng. Mansoura Univ.

الملخص العربي

استخدام الحاسب الالى فى اختيار ماكينة التشغيل (الرقمية أو التقليدية) بالنسبة لتكلفة المنتج

لاتستخدم الماكينات الرقمية فى الانتاج الغزير ولكن تستخدم بنجاح فى تشغيل المنتجات ذات الاعداد الصغيرة والمتوسطة وذلك فى معظم المصانع ولقد كان لظهور هذة الماكينات الفضل فى تقليل تكاليف الانتاج فى بعض الصناعات مثل صناعة اجزاء محرك الطائرات وفى بعض الصناعات الهيدروليكية وصناعة ماكينات التشغيل : ولقد ظهر من الدراسة النظرية ان هناك بعض من المميزات لتلك الماكينات وهى المرونة الكاملة فى التشغيل والدقة العالية وقصر وقت التشغيل ...الخ

إن هذا البحث يشتمل على دراسة نظرية وتطبيقية تم اجراءها فى المصانع الحربية وذلك بانتاجمنتج معين واستخدام النظام الجديد لتبرير اى من الماكينات الافضل هل الرقمية ام التقليدية؟ ولقد تم ادخال جميع العناصر المختلفة والمرتبطة بعمليات التشغيل او الخاصة بحساب التكلفة فى برنامج خاص تم كتابتة بلغة (C).

ويقوم النظام الجديد بعد ادخال جميع البيانات المطلوبة باعطاء نتائج اولية عن امكانية تنفيذ المنتج المطلوب على الماكينات المتاحة بالمصنع والمخزنة بملف بيانات خاص بالماكينات وقابل للاضافة فاذا كانت هذة النتيجة تشير الى امكانية الانتاج على كل من الماكينة الرقمية والتقليدية - يقوم النظام الجديد فى هذة الحالة بعمل مفاضلة بين الماكينتين على اساس التكلفة الكلية.

Abstract

Numerical control m/c tools are not intended to compete with mass production process NC techniques are applied most successfully when components are machined in small batches, The machining of small and median quantities is a high cost area of production.

The advent of NC provides a medium for reducing machining costs in low quantity production which is of particular value in certain types of industry engineering. aircraft accessory, hydraulic and machine tools. The study has shown several factors in favor of NC such as full flexibility, accuracy, shorter production time, etc. The present work has an experimental study which carried out in one of the military factories to establish a justification rule for producing a certain product.

The relationship between the variables such as the tolerance required for dimension, shapes, and surface roughness as well as the process capability has been encountered in a special program written in C-language

The availability of producing each feature in the product has been checked for each m/c. If the decision is the two m/C can be produce the product or feature then the cost analysis will takes place.

1. Introduction

Numerically controlled machine tools have become standard features in the manufacturing facilities of today. Since these tools began making their way into industry around 1957, their capabilities have increased greatly. The evolution of the field of numerical control has introduced industry to such concepts as CAD/CAM, flexible manufacturing system and many others (1)

It has been estimated that most manufactured parts are produced in lot sizes of 50 or fewer, small lot and batch production jobs, present the ideal situations for the application of NC This is made possible by the capability to program the NC machine and to save that program for subsequent use in future orders. If the NC programs are long and complicated, complex part geometry, many operations, much metal removal, This makes NC all the more appropriate when compared to manual methods of production. finally, if quality and inspection are important issues (**close tolerances, high part cost, 100% inspection required**), NC would be most suitable, owing to its high accuracy and repeatability. (2,3) Repeatability is the comparison between the same dimensions of each piece machined.

The repeatability of NC is roughly about one-half of the actual positioning tolerances. Repeatability is another important goal of modern NC manufactures and users. The skilled hands of a good machinist are difficult to find. Thus the reliability that was previously built into the hands of the machinist must now be built into the NC machine. (4,5). NC machines provide good position accuracy and repeatability, complex jigs and fixture are not required in all cases. Also, a high degree of quality is inherent in the NC process because of accuracy, repeatability and freedom from operator-introduced variations. In-process quality inspection is seldom required after an inspection of the first part produced. from a new tape, as a check on the programming function (6).

One of the basis functions of economic planning is the determination of lot size. With conventional machining methods, setup costs are high and cannot be calculated with any degree of accuracy, Therefor it is necessary to make a large number of parts for each setup if the unit part cost is to be minimized. With numerically controlled machined the high process predictability ensures accurate cost determinations, and the simplified, low cost setups enables parts to be run in small quantities economically (6,7)

However, there are a multiplicity of factors influencing calculations to establish beyond doubt the most suitable field of applications for NC turning machines (8) In this context it must not be forgotten that improvements in economy are not achieved only by reducing direct production costs. There are quite number of other cost factors which influence economical production without appearing directly as production costs. NC machines have adhesive influence on the overall production flow, the design of production media and the whole chain of events from work preparation to the final inspection. Also, the quality costs are usually estimated to be at least 10-15 % of the product costs. About 60-70% the quality costs are thought to depend on the errors of the produced parts (**geometrical accuracy**) due to insufficient control of the machining process. Even loading of workpieces, automation of tool change, wear of the tool or tool failures, influence product quality when manual supervision is reduced or eliminated (9,10,11,12).

2. The area of comparability

In an economic comparison between two conventional machining processes, say between turning on a center lathe and turning on a capstan lathe, it is a often sufficient to make a direct contrast between the floor-to-floor time for the two processes and select the process needing the least time for production. This comparison is possible if the costs of machine operation and tooling are similar. If the turning and tooling costs are not similar e.g. as between a drilling and a jig boring machines, then the comparison must take into account the costs of each process and not simply the time for each operation.

Making a decision on a basis of time can be done on the shop floor, deciding on a basis of cost requires the use of information which can be supplied by the cost account, and the decision is usually carried out in the planning department. The direct approach outlined above can be used for economic comparison of circumstances surrounding, each of the process are themselves directly comparable. The some administration is shared, the planning procedures are identical, there is no difference in the supporting services to the machine, e.g. tool stores, maintenance, etc. This is not true when comparing NC with conventional machining processes. a moment's through will show differences in the following areas:

a. The preparation work, e.g. programming and tape preparation is not needed for conventional machines:

b. Backing-up services, e.g. pre-set tooling and computer services, may be needed for NC work. (10)

c. Workshop floor facilities, e.g. large amount of jig storage space are not required for NC production.

3. Factors to be considered in the comparability between the conventional m/c and NC.

It is possible to assess certain factors directly in monetary terms. For example, the actual product cost including the cost of labor and over heads attribute able to the process-can be determined. Setting-up costs can be contrasted with the set-up costs of conventional methods, and the value of machining centers can be checked

Many factors which affect costs one way on the other remain unconsidered. To ensure that these factors are not overlooked they are summarized below. The savings made in these areas should always be taken into consideration, and the effect of NC production will not be fully appreciated until the impact in all areas has been evaluated and the different are ; areas inspection costs, the cost of scrap, the machining accuracy, the cost of modification, the tool storage costs, the transportation costs, the machine utilization, the cost of floor space and the work in-progress.

4. Decision making for deciding between NC and conventional machining.

Both NC and conventional machining have their relative advantages and disadvantages. However, it is not always obvious whether a particular part should be processed benefits of NC, only these parts that are appropriate for NC must be processed on it. Currently, there is no universally accepted procedure for deciding on parts to the experience of the process planner and the facilities available within the m/c shop. When the choice between NC and eonventional machine tool is not clear, alternative process plans must be developed for both methods A study was conducted in several of the machine shops to develop a standard scoring system and decision table for determining whether to process a part on a NC or on conventional equipment. (13). In the use of the scoring system, an analysis is made of the physical characteristics shown on the part print and of other known information about the part, such as lot size, lots/year, ... etc.

These factors are assigned weighting values The assigned factors are then summed up, and a decision is made weather to produce the part by NC or by conventional methods, depending on the sum of the factor weights.

The procedure consists of two steps, the first step is concerned with a conditional decision,. if numerical control were to be used, what type of NC machine would it be ? The second step involve a comparison of the relative merits of using conventional processing methods against the particular NC machine selected in the first step. This comparison involves the use of 22 process planning factors that might influence the decision on processing method. Each factor is assigned a value which depends on the part characteristics, the values are added and if the sum exceeds a certain threshold value, NC should be used ; otherwise, conventional machines should be used.

5. Cost comparison ; NC and Conventional machine processes.

To determine weather NC or conventional methods are the most economic in a given circumstances, the calculation made must take into account the factors which have been discussed. To provide a basis for the calculation, it is essential for the relevant data regarding costs to be available and for estimates to be made of the expected times needed for carrying out the various activities, e.g. planning, programming, ...etc. The break-even point can then be determined and the relative economics of the two process assessed.

The data needed for the comparison falls into two distinct parts : (a) Data relating to the time taken for preparing for production setting-up and machining. the data (a) need be determined once only for subsequent calculations, but data (b) must be calculated for each individual component for which an economic comparison of the processes is made

6. The program design.

The program is designed to be used directly by the production engineer personnel. The program requires **IBM pc or IBM compatible**, hard disk **170 MB** and **2MB RAM**, a high resolution card (**EGA card at least**), and color monitor.

The program was designed as friendly system to produce a good interface between the user and the program. The program is written with a high level computer language is namely C.

The user of this program works directly from the detail drawing. This program has the ability to select the suitable machine for each feature according to the specification required as well as the ability to justify the suitable m/c according to the total cost of the product.

The main characteristics of the program are :

1. Detecting the type of the required m/c for a specific component according to ; IT grade (**dimension, form errors, surface roughness**) and the geometry of the component (**Max. diameter, Max. length**).
2. Searching in a store data base files **1,2** where; data base file 1 for conventional m/c and data base file 2 for numerical control (NC).
   - If the answer is yes the two type of **m/C** capable to produce this component then the justification of use which are according to the total cost will takes place. But if the answer is No then return to the main menu.
3. Updating data base stored for both conventional m/C and numerical m/C. The flow chart of this program is shown in Fig. 1. The data file is written with special format and contains required input of the program.

The input of the program is :

- Detecting number from the main menu (**q**).
- The form number (**num**) which contain the operation type.
- The required grade number (**it**).
- Max. diameter (**s1**) and max. length of the workpiece (**s2**).

The flow chart of the total cost has shown in Fig. 2. The main function cost in this program are, The preparation cost, related cost and machining cost and the program is capable to extend for any other type of cost.

The flow chart of justification of use which m/c has shown in Fig. 3 and the output chart showing the break even point (**BEP**) is illustrated in Fig. 4.

the output of the run program and nomenclature showing in appendix I.

7- Practical application.

In order to check the applicability of the created system a certain component has been produce in the military factory as shown in Fig. 5. first the check has been done based on the process capability of each **m/c** (**conv.& Nc**). When the answer is yes, the two m/c are capable to produce this component according to the required specification, then the justification of use which m/c according to the total cost will takes place.

To carry out this justification it was necessary to find out the values of different elements of cost i.e. the preparation cost, the related cost and the machining cost.

The process planning office has done all the required steps, i.e. the process sequence, for both conventional and numerical from which the preparation and the machining cost has obtained as shown in Fig.6 for numerical m/c and in fig Fig. 7 for conventional m/c.

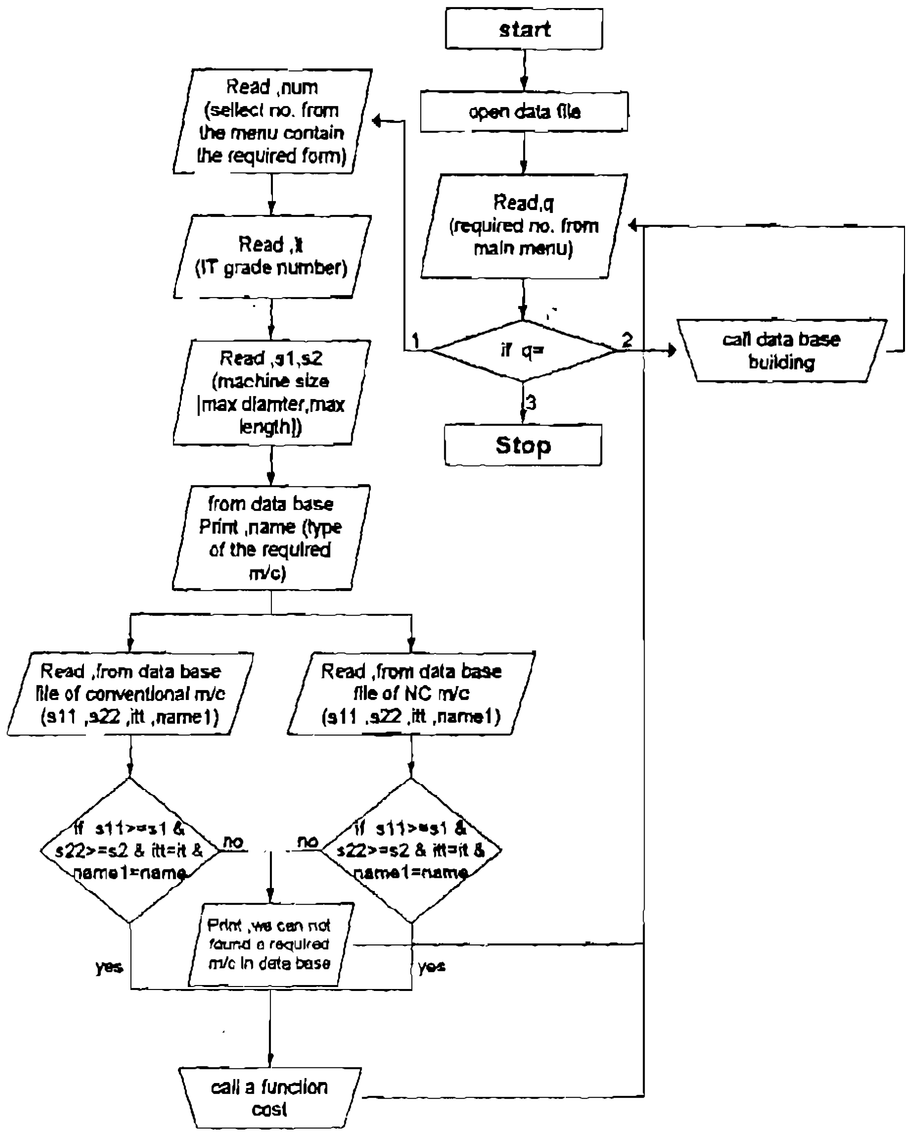


Fig. 1. The flow chart of the main program

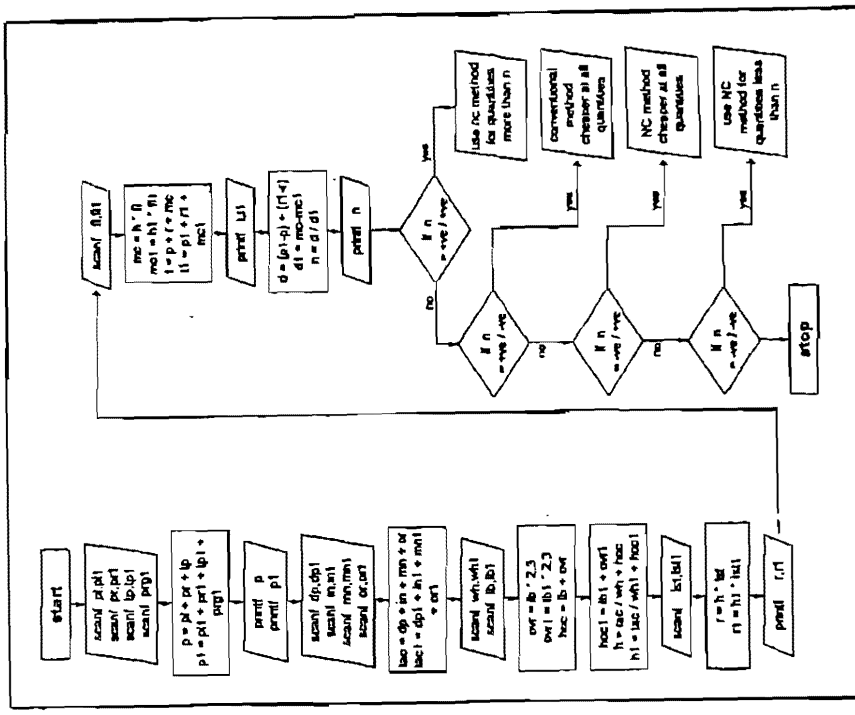


Fig. 3. The flow chart of justification of use m/c tools

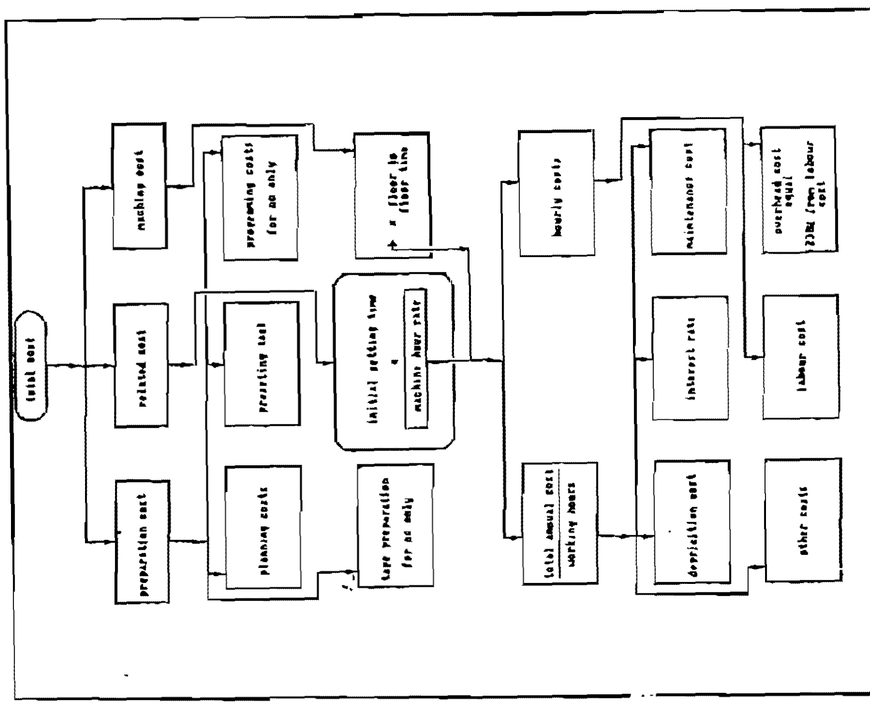


Fig. 2. The flow chart of the total cost

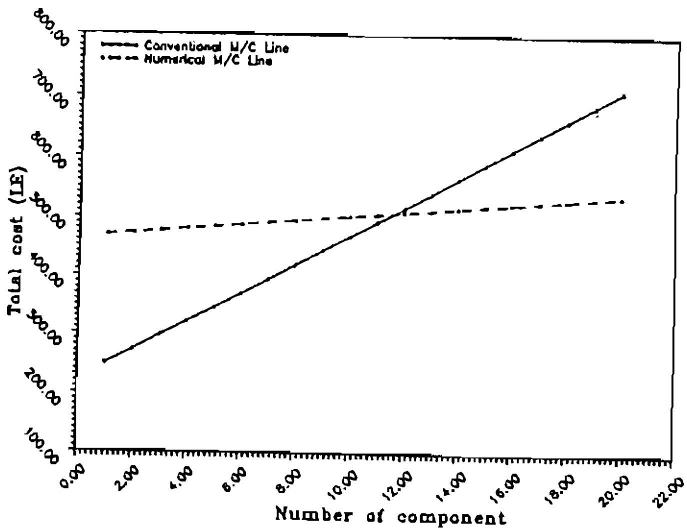
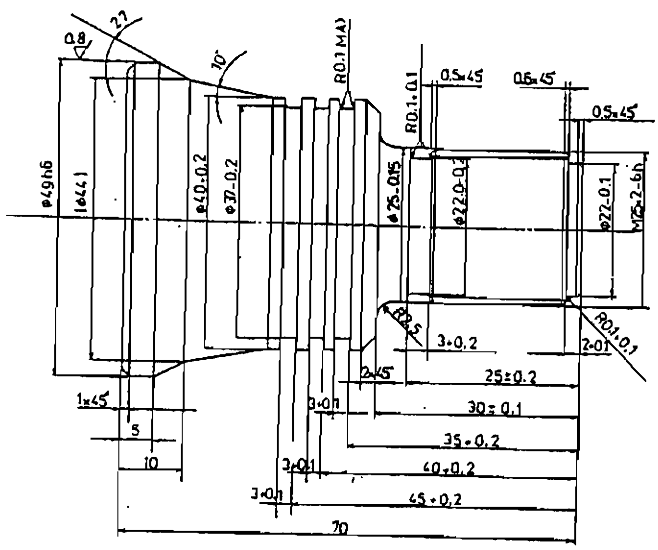


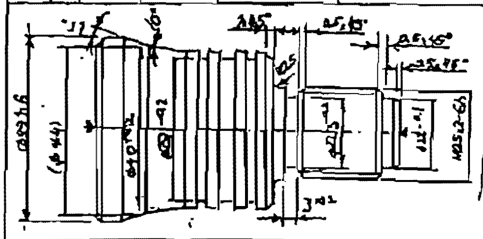
Fig. 4. Output chart showing the breakeven point (BEP)



T10 for Turing
T30 for turing with noze R2.5
T40 Groving
T50 for Threading

Fig. 5. The workpiece geometry which produced using conventional and NC m/cs

TAS	TECHNOLOGICAL PROCESS OF MACHINING			PROJECT No. 1
20	2150	24123	SPT 32 NC.	



Section	Work Description	Speed	r.p.m.	feed	No. Cuts	Name — Dimension	Designation
1.	CLAMP BETWEEN TWO CENTRE.					LIVE CENTRE	ESN 24.32 24
2.	TURN UP TO FINISH ø 22 $^{-0.2}$					TURNING TOOL 20x20 720	ESN 2234 18
3.	TURN ø 25 $^{-0.15}$ WITH RADIUS 2.5 TO LENGTH ± 0.1					TOOL 20 x 20 720	ESN 2234.16
4.	TURN ø 40 $^{-0.2}$ TO LENGTH [45].					TOOL 20x20 720	ESN 2234.16

										Worked out by	Approved	Date
										Technology		
										Tools		

Fig. 6a. The process sheet for operation NO. 20 using NC m/c

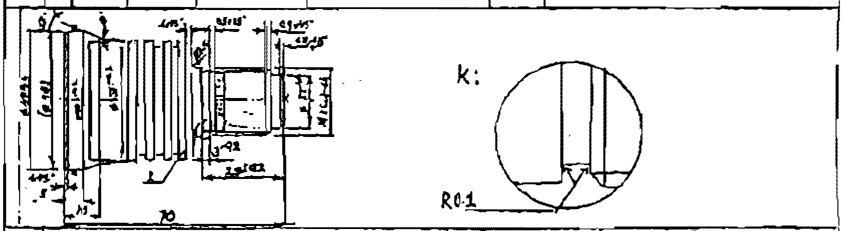
TAS	TECHNOLOGICAL PROCESS OF MACHINING — CONTINUED				PROJECT No. 1	

Section	Work Description	Speed	r.p.m.	feed	No. Cuts	Name — Dimension	Designation
5.	TURN THE ANGLE 10°					TOOL 20x20 P 70	ESN 2234 16
6	TURN THE ANGLE 21° TO LENGTH 1.					TOOL 20x20 P 20	ESN 2234 16
7	TURN STEP BY STEP RECESSES ACCORDING TO THE SKETCH.					RECESSING TOOL 12x8x3	ESN 2234 30
	3 x 3 $^{+0.1}$ TO 37-02						
	1 x 3 $^{-0.2}$ TO 22.5 $^{-0.2}$						
8.	CHAMFER THE EDGES 3x0.5 x 45° ACCORDING TO THE SKETCH 1 x 1 x 45°					TOOL 20x20 P 10	ESN 2234 12
9.	CUT THREAD M 25x2 - 6h.					TOOL 20x12 P20	ESN 2232 70
10.	TURN ø 4445 WITH THE ALLOWANCE FOR GRINDING ±0.1						
11.	CHAMFER THE SHAPEEDGE 1 x 45°					TOOL 20x20 P20	ESN 2224 70
	INSPECTION THE WORKER 100% 120 20 %.					VARNIER CALLIPER	ESN 2234 11

										Worked out by	Approved	Date
										Technology		
										Tools		

Fig.6b.

TAS	TECHNOLOGICAL PROCESS OF MACHINING			PROJECT No. 1
10	3136	04333		



Section	Work Description	Speed	r.p.m.	feed	No. cuts	Name — Dimension	Designation
1	CLAMP INTO THE CHUCK.					TURNING TOOL 16x16 P20	CSN 223412
2	SQUARE UP THE FACE TO LENGTH OF L = 78					VERNIER CALLIPER 150	CSN 251236
3	RECLAMP.						
4	SQUARE UP THE FACE TO LENGTH OF 70.					TOOL 16x16 P 20	CSN 22 3412

Fig. 7a The process sheet for operation NO. 10 using conventional m/c

TAS	TECHNOLOGICAL PROCESS OF MACHINING — CONTINUED			10	PROJECT NO. 1.

Section	Work Description	Speed	r.p.m.	feed	No. cuts	Name — Dimension	Designation
5.	DRILL THE CENTRE DOT					CENTRE DRILL Ø 3.15	CSN 22 11 10
6.	RECLAMP ON LENGTH 5MM AND SUPPORT WITH THE CENTRE					CENTRE 4	CSN 2432 24
7.	TURN Ø 40 -0.2 TO LENGTH 49.					TOOL 16x16 P20	CSN 2234 12
8.	TURN Ø 25.5-0.2 TO LENGTH 30 ±0.1 TO LENGTH 2.					TOOL 16x16 P20, R2.5	CSN 2234 16
9.	TURN Ø 22 ±0.1 TO LENGTH 2					TOOL 16x16 P20	CSN 2234 16
10	TURN STEP BY STEP RECESSES ACCORDING TO THE SKETCH 3x1 ±0.1 TO Ø 34 -0.2					RECESSING TOOL 12x8x2 P 20	CSN 2234 30
	1x3 ±0.2 TO Ø 22.3 -0.2 RADII OF THE TOOL POINT = 0.1						
11.	TURN Ø 15 -0.25 TO LENGTH 22±0.2					TOOL 16x16 P20	CSN 2234 16
12	CHAMFER THE EDGES 3 x 0.5x 45° ACCORDING TO THE SKETCH					TOOL 16x16 P20	CSN 22 34 12
13.	CUT THREAD 25x2 - 6h,					20 x 12 P20 SCREW GAUGE M25x2-6h	CSN 22 34 40 CSN 2540 45
14	TURN 5 10					TOOL 20x12x5 P20	CSN 22 34 30
15.	TURN 27°					TOOL 20x12x5 P20 27°	CSN 2232 10
16	RECLAMP, CLAMP ON Ø 10 10.2						
17	TURN Ø 10 h 8 WITH THE ALLOWANCE FOR GRINDING 0.1					TOOL 20x10 P20	CSN 2231 14
18	CHAMFER THE EDGES 1 x 45°					TOOL 16x16 P 20 VERNIER CALLIPER	CSN 2234 11
	INSPECTION TTO 100 % 10 %						

Fig. 7b.

All the information required for the cost justification has been fed to the new system and the output of the system is illustrated in appendix I. The data used in this justification for both conventional and numerical as obtained from the factory are as shown in appendix I.

8. Discussion and Conclusion.

The new system (CAMTS) makes a suitable choice of the m/c tool before constructing the process sheet (**or part program**) for the component. The data base of the system stores the main specification of each m/c as well as the process capability of each. The IT grade corresponding to each operation has been Oslo stored in the data base memory. The system can identify the suitable machines in the workshop or the factory satisfying the specification of the product.

The new system (CAMTS) computes the total cost of a process by finding the cost of each manufacturing operation along the process sheet. It is difficult to assign a specific value to the cost of each manufacturing operation, as it will vary from one manufacturing firm to another and from one country to another. However, it is possible to work with a relative cost for each manufacturing operation as compared with a choose reference operation.

The designed system (CAMTS) proved to easy used and saved a significant amount of time and effort which could be spent to identify the suitable operation and m/c. It can be implemented on a micro processor computer or compatible and it greatly reduces the range of skills required for choice the suitable m/c. Finally, it can be say that, the new system gives the process engineer a tool to aid in determining the most economic process and m/c and it may be, a step in the way of getting a write decision in a short time and produce a complete computer integrated manufacturing (CIM).

9. References

1. GROOVER, M.P. and ZIMMERS, E.W. " CAD/CAM " Computer-Aided Design and Manufacturing prentice, Inc. Englewood clilte, New Jersey, 1984.

2. GROOVER, M.P. "Automation Production System and Computer-Aided Manufacturing " Prentice-Hall, Inc. Englewood clifte, New Jersey, 1980.

3. HEGLAND,D.E. "Numerical Control -Your Best Investment in Productivity " Production Engineering, March,1981, PP. 42-47.

4. Luggen, W. W. "Fundamental of Numerical Control " printed in USA by Nelson Canada, A Div of Inter. Thomson LTD. 1988.

5. EL-Midany, T. T. " Variation of production cost with Batch Size for Turning machines " 2 nd Int. Conf. PEDAC.1983, Alexandria Univ., Egypt.

6. EL-Midany, T. T. and AlMakky. M. Y. " Introduction To Numerical Control of Machine Tools " first Edition, Egypt 1994 PP.353

7. TAKEVCHI, Y. and et al. "Reconstruction of NC Lathe To BTR-DNC By means of a single Boad, 1982.

8. ARNE, N. and MAGNUS, R. "Tolerance Requirements in NC-Turning And Grinding And Suitable Methods of Measuring And Achieving them" proceed of fourth international conf., Manchester, 1988.

9. **Sutherland, G.H., Roth, B., 1975, " Mechanism esign; accounting for manufacturing tolerance and costs in function generalation problem ", J. Eng. Ind. Trans. of ASME, Vol. 98,P. 282-286.**

10. Kwnneth, C.L., Robert. M.C. and Anttany, G.A., 1987, "Manufacturing engineering ecnomics and process" Published by Prentice-Hall, Inc., Englewwod Cliffs, New Jersey.

11. Oswald, P.F., and Blake, M.O., 1989, "Estimating cost associated with dimensional tolerance", Manufacturing Review, Vol. 2., No. 4, P 277-282.

12. Kunnander, A and Sohlenius, G. "Machining Reliability in NC-Turning." Annals of the CIRR, vol. 28, 1979.

13. MARTAIN, S.J. "Numerical Control of Machine Tools " Hoder and Stoughton, London GB. 1979.

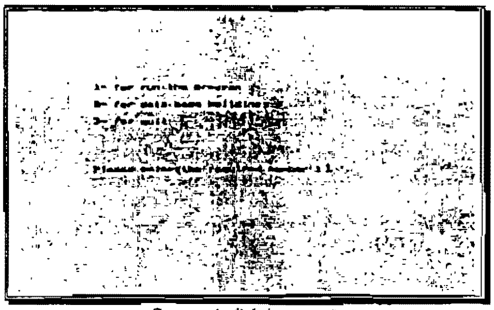
Appendix 1.

Symbol	Definition
pl , pl1	are the planning costs for conventional & numerical control m/cs
pr , pr1	are the presetting costs for conventional & numerical control m/cs
tp , tp1	are the type costs for conventional & numerical control m/cs
prg1	is the programming cost for numerical control m/c
dp , dp1	are the depreciation costs for conventional & numerical control m/cs per year
in , in1	are the interest rate for conventional & numerical control m/cs per year
mn , mn1	are the maintenance costs for the conventional & numerical control m/cs
or , or1	are the others costs for conventional & numerical control m/cs
wh , wh1	are the working hours of conventional & numerical control m/cs per year
lp , lp1	are the labour wages of conventional & numerical control m/cs per day
ist , ist1	are the initial setting time for conventional & numerical control m/cs
fl , fl1	are the floor to floor time for conventional & numerical control m/cs

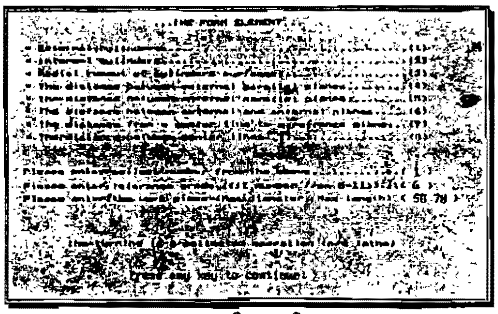
Data of conventional m/c		Data of NC m/c	
Symbol	Value	Symbol	Value
pl	201.0 LE	pl1	201.0 LE
pr	0.045 LE	pr1	0.045 LE
tp	3.0 LE	tp1	42.0 LE
prg	-	prg1	174.0 LE
dp	893.0 LE	dp1	4285.8 LE
in	803.7 LE	in1	4285.8 LE
mn	243.0 LE	mn1	699.0 LE
or	189.0 LE	or1	378.0 LE
wh	1344.0 hr	wh1	1536.0 hr
lp	12.0 LE	lp1	3.0 LE
ist	0.5 hr	ist1	3.0 hr
fl	0.59 hr	fl1	0.223 hr

The data used as obtained from the military factory

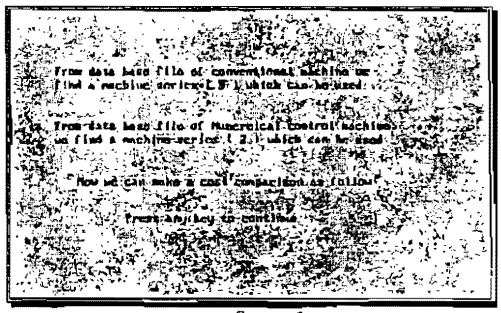
Run of the program



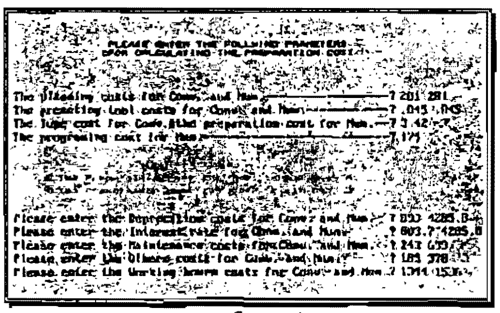
Screen 1. (Main menu)



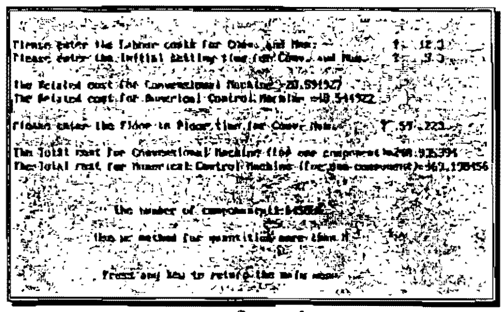
Screen 2



Screen 3

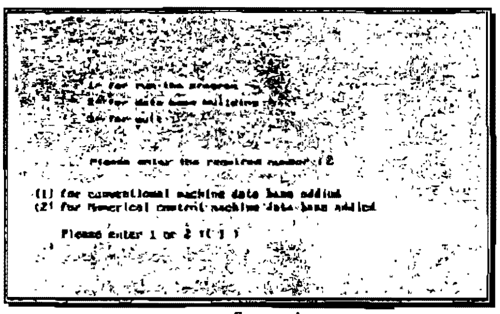


Screen 4

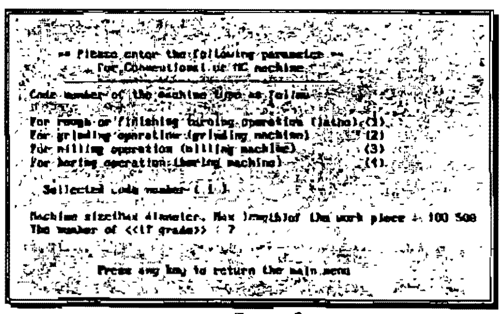


Screen 5

Example of data base updating



Screen 1



Screen 2