CAD/NC INTEGRATION WITH THE OOP SUPORT

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ABSTRACT

Now days: large and small manufacturing companies own several numerically controlled (NC) lathe machines. They are finding that NC/CNC machines can make dramatic saving possible. Certain aspects of NC/CNC shop operations require a high skilled operator level than conventional method. So that the need to develop a computerized technology to support the adoption of these machines and get the maximum benefits that's offer is highly recommended. The present work aims to develop such system that stand over the most modern available technologies to support this task. The system database is used to organize the factory data. The database hold factory lathe machines definition at current state tooling and the available tools and materials with the recommended machining parameters for each machine-tool-material combinations.

The developed system is interactive supported with a powerful graphics package (AutoCAD) which gives the system user the ability to describe the part manufacturing process through direct manipulation of the part and stock in process drawing with the aid of friendly user machining process dialog box. The system offers as output different types of the product documentation files these are the process plan sheet, the computer aided plan description model, and a DXF (Drawing Exchange File) format which may be used to exchange the product information between the CAD/CAM systems. Finally the system postprocessor is used to generate NC/CNC Code (G-Code) files that are necessary to operate the predefined machines to produce the part.

الخلاصة

ان اغلـب شركات التصنيع الصغيرة والكبيرة تمتلك العديد من مكائن الخراطة ذات السيطرة الرقمية . هذه الشـركات وجدت ان استخدام هذا النوع من المكائن يمكن ان يؤدي الى اختزال كبير في الكلفة والجهد . ان بعض عمليات التشغيل في هذه المكائن تتطلب مشغل ذو خبرة عالية مقارنة بمشغل مكائن الخراطة الاعتيادية . وعلـيه اصبح من المهم جداً تطوير تقنيات حاسوبية لاسناد عملية تشغيل مثل هذه المكائن للحصول على أقصـى فـائدة ممكـنة مـنها . هذا العمل يهدف الى تطوير نظام يعكس النظرة المتكاملة لعمليتي التصميم والتصنيع بالوقوف على أحدث التقنيات المتوفرة لاسناد هذه المهمة .

تسـتخدم قـاعدة البـيانات في هذا النظام لغرض تنظيم بيانات المعمل. ان قاعدة البيانات هذه تحتوي على تعاريف مكائن الخراطة بعددها الحالية وبقية العدد والخامات الهندسية المتوفرة مع قيم التشغيل المناسبة لكل مجموعـة اقتران (ماكنة – عدة – معدن) . النظام المطور تفاعلي مسند بحقيبة رسم (AutoCAD) والتي تعطـي مستخدم النظام القدرة على وصف عملية تصنيع المنتج من خلال المعالجة المباشرة لرسم المنتج مع

الخامـــة فـــي زمن التشغيل وبمساعدة واجهات حوار متخصصة بعمليات التشغيل . يوفر النظام عدة طرق لغـــرض توثـــيق هـــذه العمليات وتكون على نوعين . النوع الاول هو وثائق وصفية (رسوم) للعمليات مع النموذج المصنع والنوع الثاني على شكل وثائق نصية مثل وثيقة المسالك التكنولوجية للمنتج أو صيغي لتبادل هـــذه المعلومات مع انظمة التصميم والتصنيع الاخرى تعرف باسم (DXF) . كما يستخدم برنامج المحول الخاص بالنظام لغرض تحويل هذه المعلومات إلى وثيقة نصيـــــة تتضمن الشفرات البرمجية (G-CODE) الضرورية لتشغيل المنتج على مكائن الخراطة المبرمجة .

INTRODUCTION

As a result of development in computer technology and numerical control (NC) systems with associated peripheral devices; the number of NC programming facilities and procedures has been steadily increased .For NC programming the most important criteria is programming with/or without computer support [U. Rembold, 1993].

Automatic or computer aided programming is done largely independent of the manufacturing equipment (processes oriented) and directly solved the task, which is defined in a part program. The general purpose digital computer assists the programmer in defining the operation to be performed by the machine tool, in order to produce a part. Each of the parts programmer (pp) and computer do part of the job. The main objective is to reduce the amount of effort and man – hours required by a parts programmer in programming the job, by turning much of the details over the computer, the pp describes the operations to done interactively (dialog oriented) which are interpreted by the computer to produce instructions as a result of the requirements utilizing the part programmer description as input. The computer adds and converts this input into the language required by the particular NC machine for which the program is being prepared [Groover, M. P., 1989].

The interconnection of CAD (Computer Aided Design) and NC programming systems is an important step toward CIM (Computer Integrated Manufacturing). The term CAD/NC programming is used to describe the generation of work piece data for NC using CAD database implemented by the designer. CAD/NC coupling is a CAD/CAP (Computer Aided Planning) in the narrower sense [U. Rembold, 1993]. Here are some researches concerning the above outlined principles of NC programming:

A. J. Adnan [2001]. developed CAM (Computer Aided Manufacturing) system to generates G-code for CNC lathe machine on three stages. The first stage generates the necessary sub programs (as Canned Cycles) depending mainly on the radii deference values between the part and the blank to machine the stock material sequentially. Second stage used to define other lathe process such as drilling, threading, etc. the third stage compute the actual machining time. The system defines the proper machining parameters feed, speed, etc. automatically.

A. B. Al-Hadithi [2001], integrates CAD and CAM through the developed IFBPP (Intelligent Feature Base Process Planning). IFBPP system basically consist of two systems, manufacturing feature knowledge-based system to extract and recognize manufacturing features from CAD database to automate link between CAD and CAPP (Computer Aided Process Planning), automated process planning knowledge based system to generate manufacturing information represented as process plan-sheet to automate the link between CAD and CAM. The researcher use the hybrid approach for knowledge representation by combination of rule-based and frame-based approaches employs comprehensive geometrical reasoning and process plan for symmetrical parts. The IFBPP system is written using visual basic language supported by AutoCAD 2000 package.

The approaches used by the above researchers to define rotational parts machining processes on lathe machines can be applied successfully to very limit rang of turning feature (simple) geometry and the extension of these approaches to include more complex parts can be considered a very difficult task.

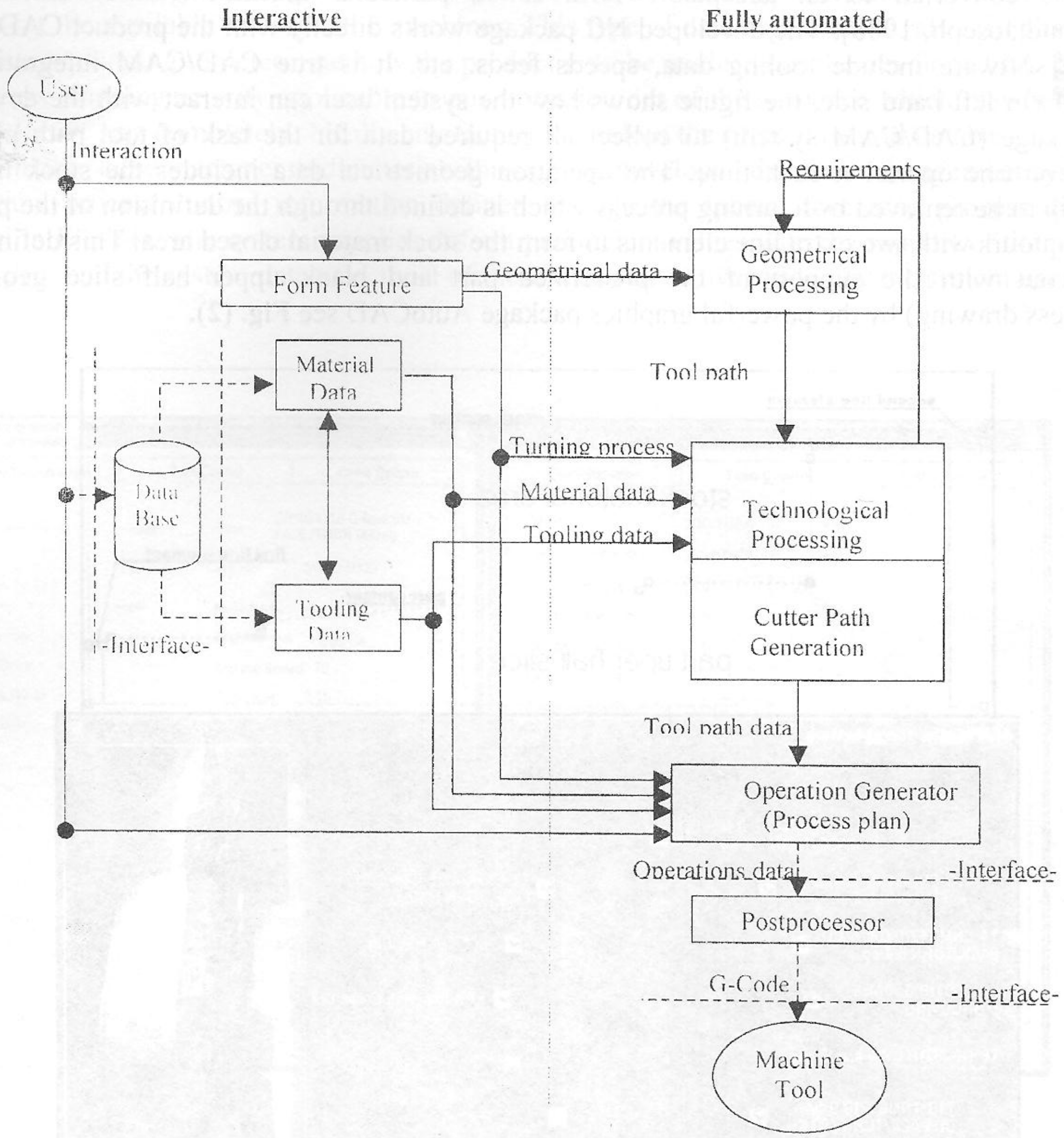
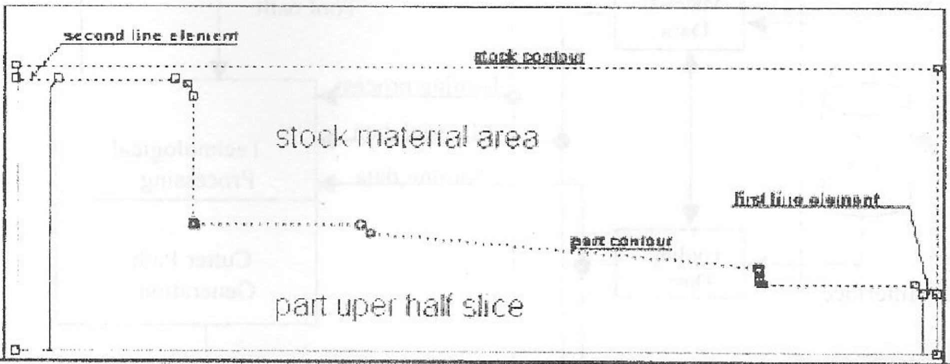


Fig. (1) Integrating design and manufacture (present work)

* The figure did not show the interface to the CAD system.

NC PROGRAMING USING THE DEVELOPED CAD/CAM SYSTEM

In general. Part programming for NC production comprises the collection of all data required to produce the part, the calculation of a tool path along which the machining operations will be performed, and the arrangement of those given and calculated data in a standard format, which could be converted to an acceptable form for a particular machine control unit (MCU) [Y. K. and Joseph, 1988]. The developed NC package works directly with the product CAD model and the software include tooling data, speeds feeds, etc. It is true CAD/CAM integration see Fig. (1). On left hand side, the figure shows how the system user can interact with the developed NC Package (CAD/CAM system) to collect all required data for the task of tool path planning applied on one operation each time. The operation geometrical data includes the stock material geometry to be removed by a turning process which is defined through the definition of the part and stock contours with two extra line elements to form the stock material closed area. This definition is carried out with the support of the predefined part and blank upper half slice geometries (in process drawing) by the powerful graphics package AutoCAD see **Fig. (2).**



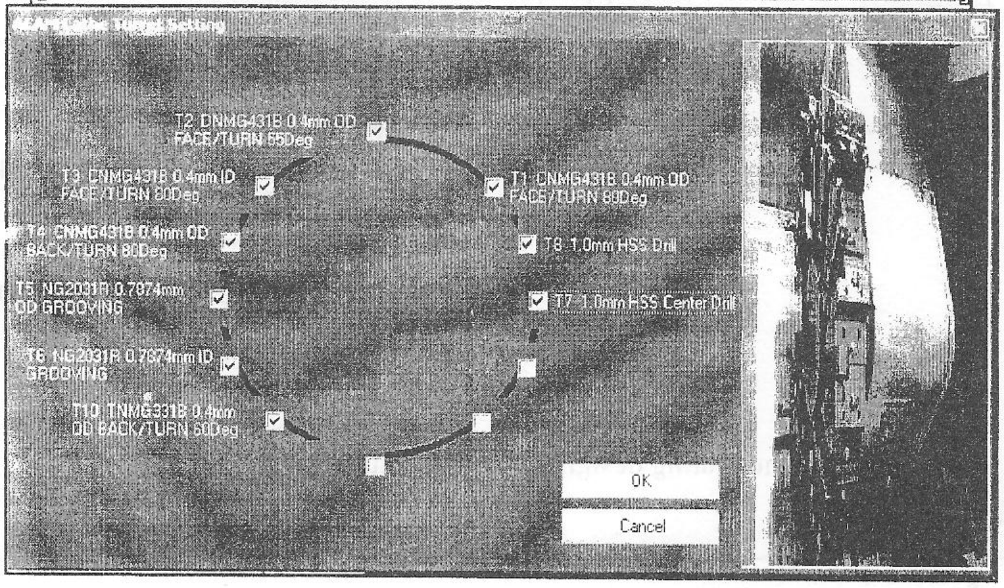


Fig. (3): 12-station machine turrets at setting time (TURRET object)

The system database is organized to simplify the task of defining the remaining necessary information (turning process data, material data, tooling data). The factory lathe drill tools, lathe turn tools and materials are organized in three strongly related tables (relational database). These tools can be assembled on the machine's turrets to define the machines current state tooling see Fig. (3). The turrets are represented as part of the machines specification data which in turn represent the available factory lathe machines. This type of data organization, also simplify the task of process planning to determine how the product is to be made. Thus the developed NC package is a process planning activity applicable to one operation out of the sequence which may be necessary to produce a part completely. Ideally any factory can adopt the offered central database to prototype the available lathe machines and materials through the developed database management system.
Tool and process control information defined through the special formatted process dialog box shown in **Fig. (4).** The system supplies default parameters values with the support of the predefined CAD data and the system database, most of these data can be overridden by the system user.

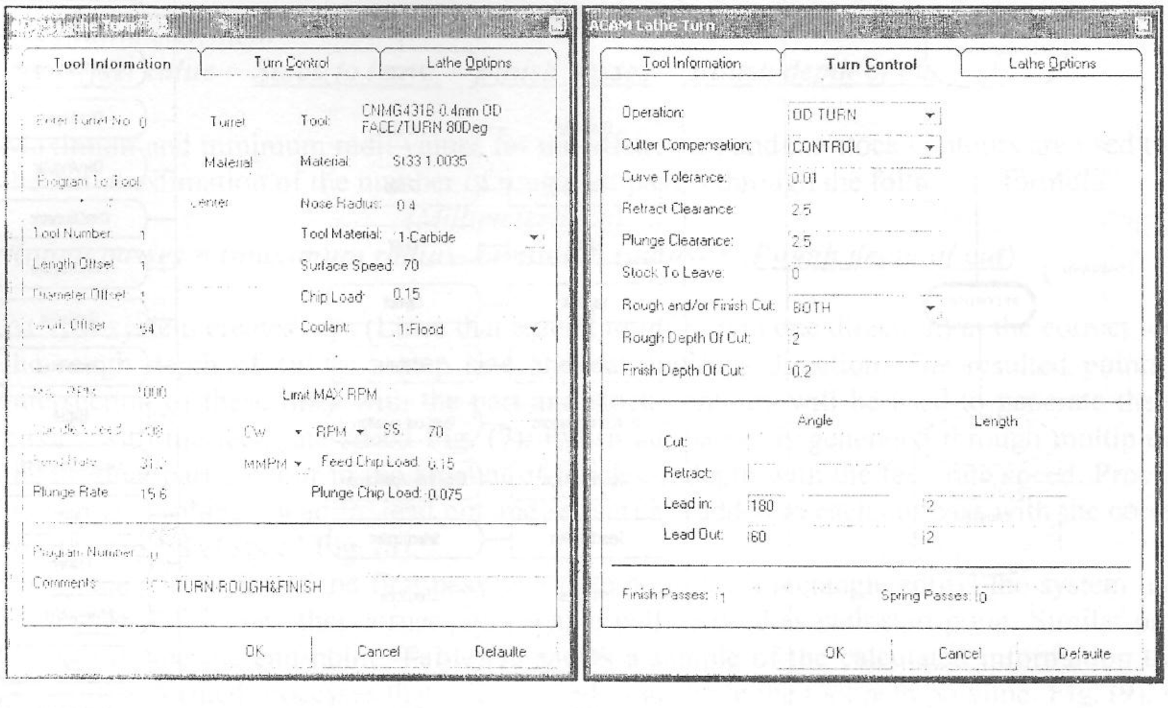


Fig. (4) Lathe Turn tool & Control Information tabs (TURN object)

Last think to be considered here is that visual basic object oriented programming (OOP) language was used in the development of the NC package object model first generation shown in figure(5), which is a composition of several previously defined object models, AutoCAD , ActiveX data object (ADO) and the developed ACAM (Auto-CAM) object models. These objects take its properties values from the system database, CAD data and/or a calculated data (i.e. tool object take its properties from the tools data base. polyline object can be used to represent part and/or tool path geometry).

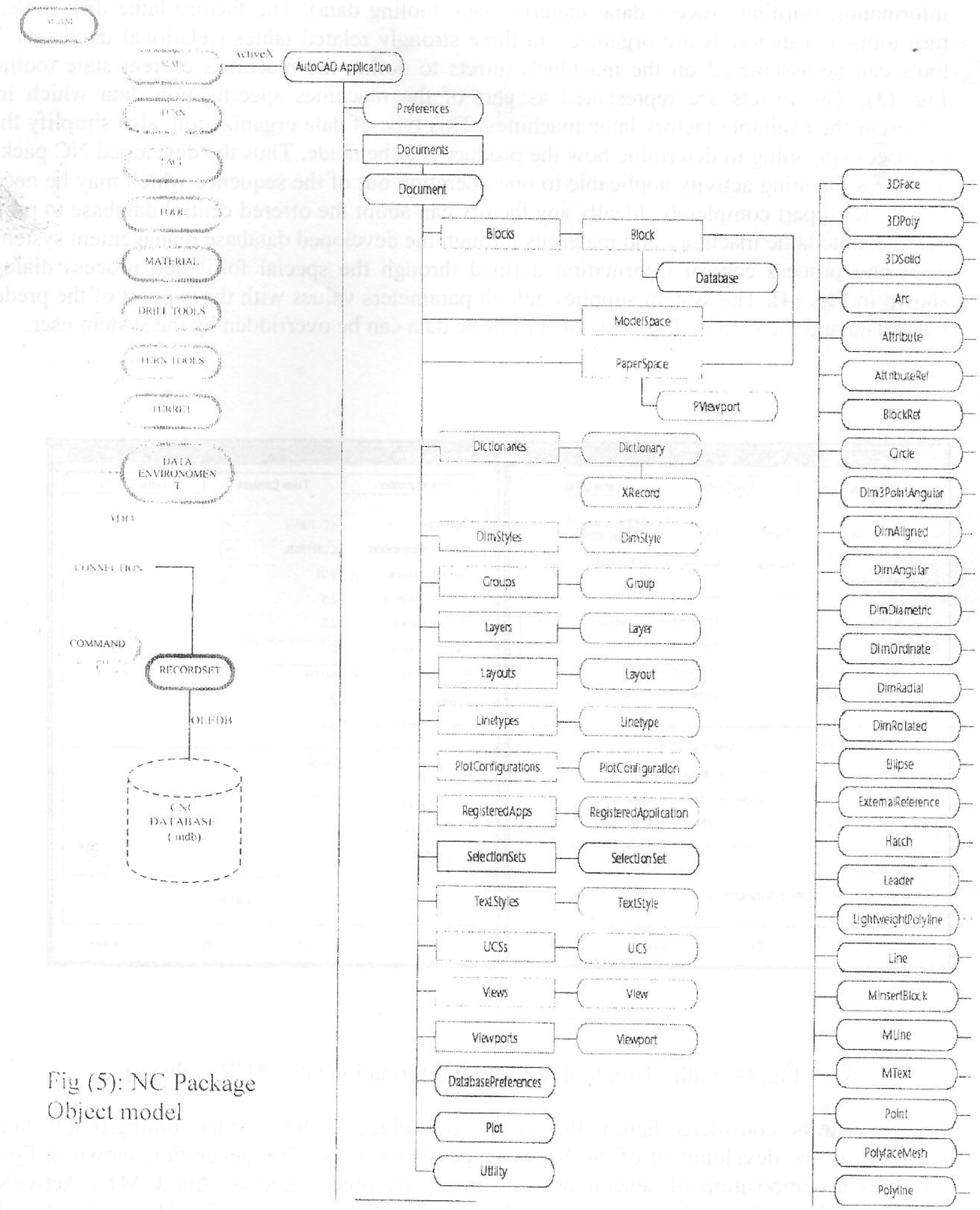


Fig (5): NC Package Object model

PROCESS GENERATION

AutoCAD (the graphics package) play a key role in the geometrical processing of the process information. The following are the mainly used AutoCAD functions:

- The conversion of lines and arcs elements into a single polyline or region (Regions are two-dimensional enclosed areas) entities and vies versa.
- Offset, trim, copy, delete, etc. the drawing entities.
- Boolean functions (intersection and subtraction of the drawing entities).

Fig. (6) shows the Main algorithms for the process generation. To find the correct offset direction (-ve or +ve) for the part contour (polyline) a test region is created from the combination of the original part contour and an offset one. If the result of the subtraction of this region from the part region leads to any reduction in the part area then the tested polyline offset direction is incorrect else the direction is correct.

The correct sign will be used to offset the part contour with the mount as a radius value for the stock to leave for finishing processes calculated using the following formula:

(Millimeter/inch)

Offset value = <u>Stock to leave</u> + <u>Finish passes</u> × <u>Finish depth of cut</u>

Maximum and minimum radii values for the offsite part and the stock contours are used to calculate the initial estimation of the number of rough cut passes through the following formula:

(Millimeter/inch)

Rough passes = (maximum radius- minimum radius) ÷ (<u>Rough depth of cut</u>)

ACAM system creates rays (Lines that extend to infinity in one direction) at the correct levels using the rough depth of cut as a step size and cut angle as direction. The resulted points from the intersection of these lines with the part and stock contours will be used to generate the rough cut passes with the feed rate speed **Fig. (7).** Finish cut passes is generated through multiple offsets to the original part contour in the amount of finish cut depth with the feed rate speed. Process control movements (plunge. lead in, lead out and retract) are added to each cut pass with the corresponding length, angle and speed **Fig. (8).**

Using the start point of the first pass as a base point for a rectangle entity; the system user will be prompt to define the other corner point which will be used as path start point. Similar procedure is used to define the end point. **Table (1)** shows a sample of the calculated information through the previously defined processes that will be used to generate the tool path polyline. **Fig. (9). shows** the final results of the predefined process information.

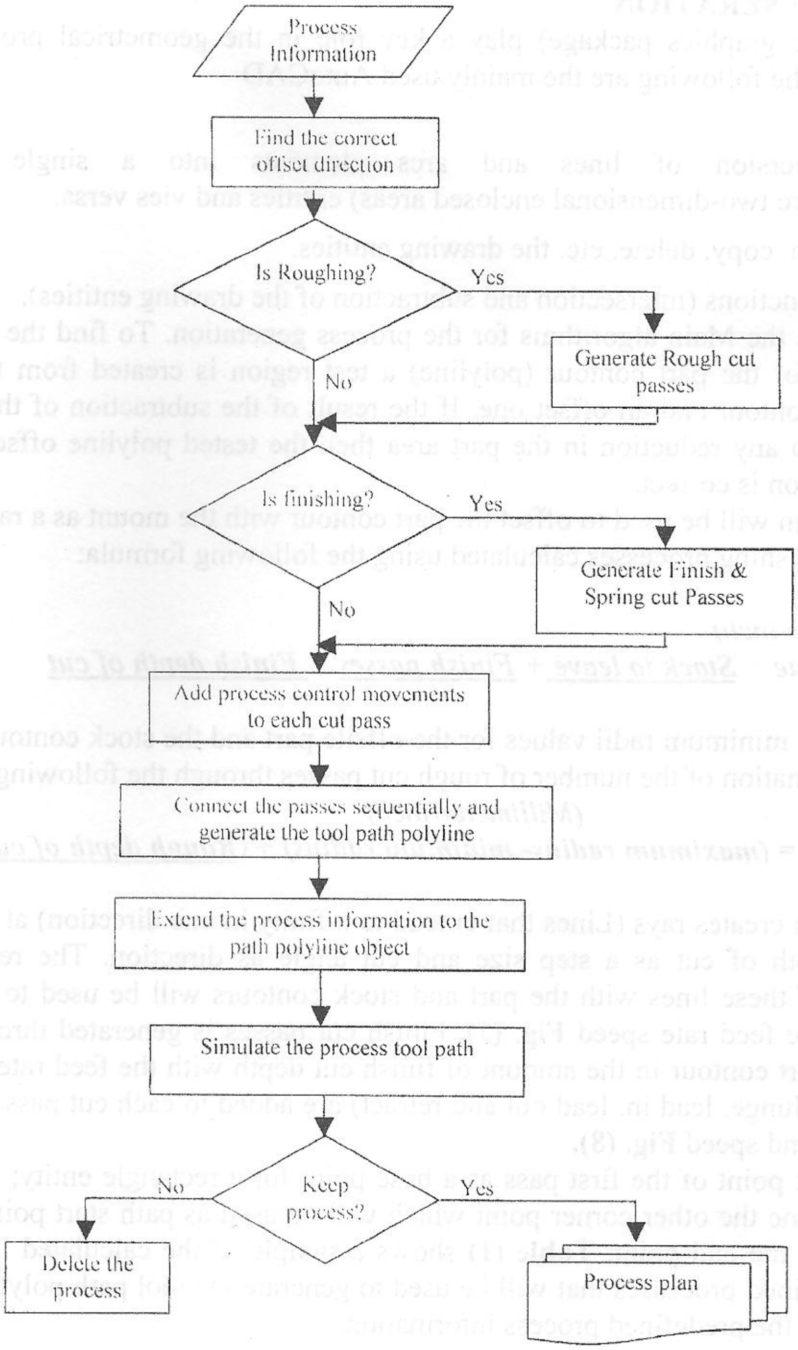


Fig. (6): Main algorithms for the process generation

Table (1) Sample from the tool movement's data.

Sequence/ Vertex	X- coordinate	Y- coordinate	Bulge*	Speed/start width**	Compensation/ end width***
0	10.000	60.000	0.000	0.000	0.000
1	4.540	60.000	0.000	0.000	0.000
2	4.540	53.843	0.000	0.001	0.002
3	4.540	51.343	0.000	0.001	0.002
4	2.540	51.340	0.000	0.002	0.002
5	-161.290	51.340	0.000	0.001	0.002
6	-160.290	53.072	0.000	0.000	0.002
7	-160.290	53.840	0.000	0.000	0.000
8	4.540	53.840	0.000	0.000	0.000
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
154	-28.575	13.200	0.000	0.002	0.002
155	-28.575	15.293	0.389	0.002	0.002
156	-29.155	15.926	0.000	0.002	0.002
157	-98.425	21.986	0.000	0.002	0.002
158	-100.070	23.632	0.000	0.002	0.002
159	-129.675	23.632	-0.414	0.002	0.002
160	-130.175	24.132	0.000	0.002	0.002
161	-130.175	47.625	0.414	0.002	0.002
162	-133.350	50.800	0.000	0.002	0.002
163	-153.988	50.800	0.000	0.001	0.002
164	-152.988	52.532	0.000	0.000	0.002
165	-152.988	53.300	0.000	0.000	0.000
166	-152.988	65.000	0.000	0.000	0.000
167	10.000	65.000			

*the **bulge** can be in one of the following values (0.000, -value or +value) implies that the tool movement from the current point to the ne. one it's (straight, CW arced or CCW arced) movement respectively.

the **speed/start width can be in one of the following values (0.000, 0.001 or 0.002) implies that the tool movement speed from the current point to the next one it's in (**Rapid rate**, **Plunge rate** or **Feed rate**) speed respectively.

***the **compensation/end width** can be in one of the following values (0.000, 0.001 or 0.002) implies that the tool movement from the current point to the next one it's with (no, left or right) tool nose radius compensation.

The generated polyline is an AutoCAD entity. This means that most of the editing function applied to this entity it is now has a manufacturing meaning (editing the polyline means editing the process tool path). Process data shown in the process sheet to the left of **Table (2)** represent the extended data to the tool path polyline. At this stage the AutoCAD drawing document represent a process plan sheet holding all the necessary information to manufacture the part which can be post-processed as CAM document in the DXF file format shown in **Table (2).** In this table the entity section of the DXF file is shown with the polyline entity represents the process tool path and its extended data represents the process information. Extended data are follow the normal entity data started at group code (1001) followed by the system name (ACAM).

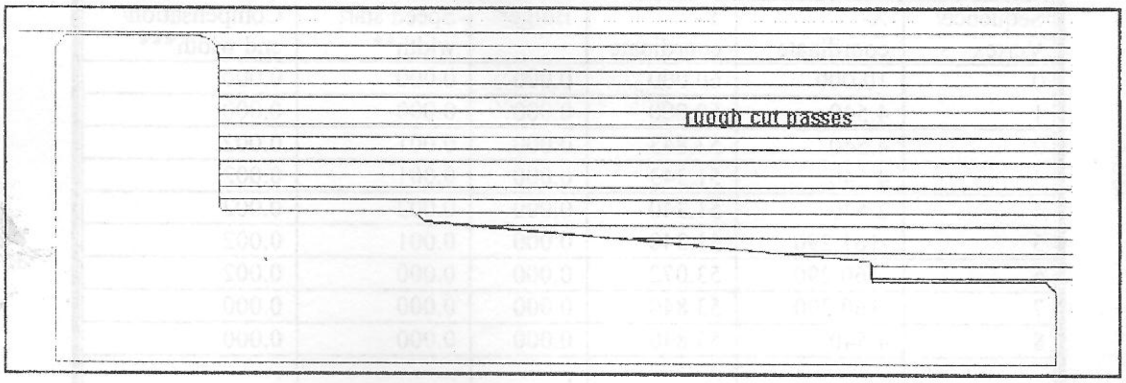


Fig. (7) Rough cut passes

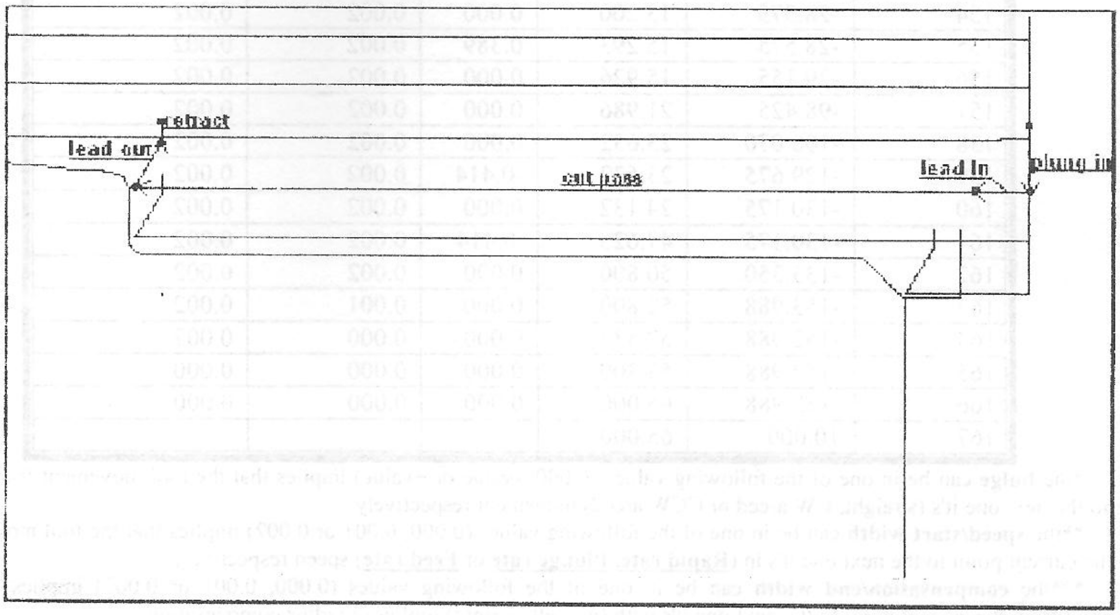


Fig. (8) a cut pass with the control movements

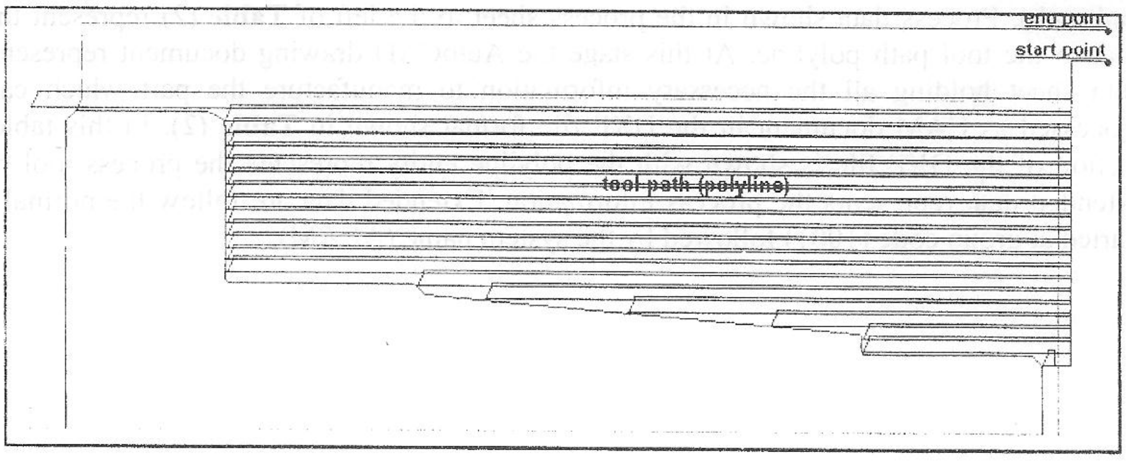


Fig. (9) Process tool path simulations

Table (2) process information data files.

Data groups	Process information sheet <Data description> Data value	DXF File <Group code> Data value	Comments <data description> possibilities of data values
Normal entity data	.	.	
	.	.	
	<vertex X>	*10*	
	-130.175	*-130.175*	
	<vertex Y>	*20*	
	47.625	*47.625*	
	<start width>	*40*	
	0.002	*0.002*	
	<end width>	*41*	
	0.002	*0.002*	
	<bulge>	*42*	
	0.4142135623730951	*0.4142135623730951*	
	.	.	
	.	.	
Entity Type data	*< Application name >*	*1001*	
	ACAM	*ACAM*	
	<control string >	*1002*	
	{	*{*	
	<control string>	*1002*	
	{	*{*	
	<Entity Description>	*1000*	<entity type>
	Operation	*Operation*	Operation, part or stock
	<Comment>	*1000*	
	OD TURN-ROUGH&FINISH	*OD TURN-ROUGH&FINISH*	
	<Operation>	*1070*	<turn operations, face operations>
	0	*0*	(0, 1, 2 or 3), (4, 5, 6 or 7)
	<control string>	*1002*	
	}	*}*	

Table (2) process information data files (continued).

Data groups	Process information sheet	DXF File	Comments
	<Data description> ***Data value***	***<Group code>*** ***Data value***	**<data description> possibilities of data values**
Cutter EX Information Stored in the entity	*<control string>*	***1002***	
	{	***{***	
	<Tool Class>	***1070***	<lathe tools, drill tools>
	0	***0***	(0-4), (0-8)
	<Tool Type>	***1000***	<tool type>
	lathe	***lathe***	Lathe or drill
	<Tool Material Type>	***1070***	< (HSS, Carbide, TIC/TIN CC, CoHSS, TIC/TIN CHSS, Ce., D, or T)> (0-7)
	1	***1***	
	<Tool Tip Radius>	***1040***	
	0.4	***0.4***	
	<Tool Width>	***1040***	
	12.7	***12.7***	
	<Front Angle>	***1070***	
	5	***5***	
	<Back Angle>	***1070***	
	85	***85***	
	<Curve Tolerance>	***1040***	
	0.01	***0.01***	
	<Tip or Center>	***1070***	<tip or centre>
	-1	***1-***	(-1 or 0)
	<Tool Orientation>	***1070***	<turn tools, groove tools>
	1	***1***	(0-7), (20-27)
	<Sides of Insert>	***1070***	
	4	***4***	
	<control string>	***1002***	
	}	***}***	

Table (2) process information data files (continued).

Data groups	Process information sheet	DXF File	Comments
	<Data description> *Data value*	*<Group code>* *Data value*	<data description> possibilities of data values
Cutter Information as Stored in Tool Library	*<control string>*	*1002*	
	{	*{*	
	<Tool Reference Number>	*1070*	
	1	*1*	
	<Comment>	*1000*	
	CNMG431B 0.4mm OD FACE/TURN 80Deg	*CNMG431B 0.4mm OD FACE/TURN 80Deg*	
	<Tool Number>	*1070*	
	1	*1*	
	<Turret Number>	*1070*	
	0	*0*	
	<Length Offset>	*1070*	
	1	*1*	
	<Diameter Offset>	*1070*	
	1	*1*	
	<Tip Radius>	*1040*	
	0.4	*0.4*	
	<Interior Diameter>	*1040*	
	12.7	*12.7*	
	<Orientation>	*1070*	
	1	*1*	
	<Front Angle>	*1070*	
	5	*5*	
	<Back Angle>	*1070*	
	85	*85*	
	<Clearance Angle>	*1070*	
	1	*1*	
	<Sides of Insert>	*1070*	
	4	*4*	
	<Material>	*1070*	< (HSS, Carbide, TIC/TIN CC, CoHSS, TIC/TIN CHSS, Ce., D, or T)> (0-7)
	1	*1*	
	<Coolant>	*1070*	<Off, Flood, Mist, and FLP, FHP, TLP, THP> (0, 1, 2, 3, 4, 5, 6, 7)
	1	*1*	
	<Roughing Depth of Cut>	*1040*	
	2	*2.0*	
	<Finish Depth of Cut>	*1040*	
	0.2	*0.2*	
	<Curve Tolerance>	*1040*	
	0.01	*0.01*	
	<Surface Clearance in X>	*1040*	
	0.25	*0.25*	
	<Surface Clearance in Z>	*1040*	
	0.25	*0.25*	
	<Tool Chip load>	*1040*	
	0.15	*0.15*	
	<Tip/Center>	*1070*	<tip or centre> (-1 or 0)
	0	*0*	
	<control string>	*1002*	
	}	*}*	

Table (2) process information data files (continued).

Data name	Process information sheet	DXF File	Comments
	<Data description> *Data value*	*<Group code>* *Data value*	<data description> possibilities of data values
Tool Chang EX Information	*<Control string>*	*1002*	
	{	*{*	
	<Mat. Reference Number>	*1070*	
	1	*1*	
	<Program Number>	*1070*	
	0	*0*	
	<Sequence Number>	*1070*	
	0	*0*	
	<Tool Number>	*1070*	
	1	*1*	
	<Tool Length Offset>	*1070*	
	1	*1*	
	<Tool Diameter Offset>	*1070*	
	1	*1*	
	<Tool Work Offset>	*1070*	
	54	*54*	
	<Origin X>	*1010*	
	0	*0.0*	
	<origin Y>	*1020*	
	0	*0.0*	
	<origin Z>	*1030*	
	0	*0.0*	
	<Turret Number>	*1070*	
	0	*0*	
	<Coolant Type>	*1070*	<Off, Flood, Mist, and FLP, FHP, TLP,
	1	*1*	THP>(0, 1, 2, 3, 4, 5, 6, 7)
	<Spindle Speed>	*1040*	
	208	*208.0*	
	<Speed Units>	*1070*	<RPM or CSS>
	0	*0*	(0 or 1)
	<Revolution Dir>	*1070*	<CW or CCW>
	0	*0*	(0 or 1)
	<MAX RPM>	*1070*	
	1000	*1000*	
	<Feed Rate>	*1040*	
	31.2	*31.2*	
	<Plunge Rate>	*1040*	
	15.6	*15.6*	
	<Feed Units>	*1070*	<feed per minute or feed per revolution>
	0	*0*	(0 or 1)
	<Units>	*1070*	<imperial or metric>
	1	*1*	(0 or 1)
	<Compensation>	*1070*	<none, ACAM, control or both>
	2	*2*	(0, 1, 2 or 3)
	<control string>	*1002*	
	}	*}*	
	<control string>	*1002*	
	}	*}*	

RESULTS

The ACAM software was written using the Visual BASIC OOP language augmented by ActiveX, which provides very tight integration with AutoCAD. ACAM and AutoCAD both run inside Microsoft Windows (32-bit version). The Windows environment provides the tools needed to manipulate the files that are generated as a result of running ACAM; After ACAM creates the text files containing the process plan sheet, Extended DXF and NC/CNC program. **Fig. (10)** shows the main windows for the NC package the graphics package (AutoCAD) to the right of the figure with the CAP description model of the turned part described in the previous section, to the left is the application program (ACAM) with the three documents described above. ACAM can be started from within AutoCAD. The final goal of ACAM is to transform graphic information in a drawing into an NC/CNC code file. The NC/CNC code file is a text file that can be viewed and changed in the word processor or the text editor.

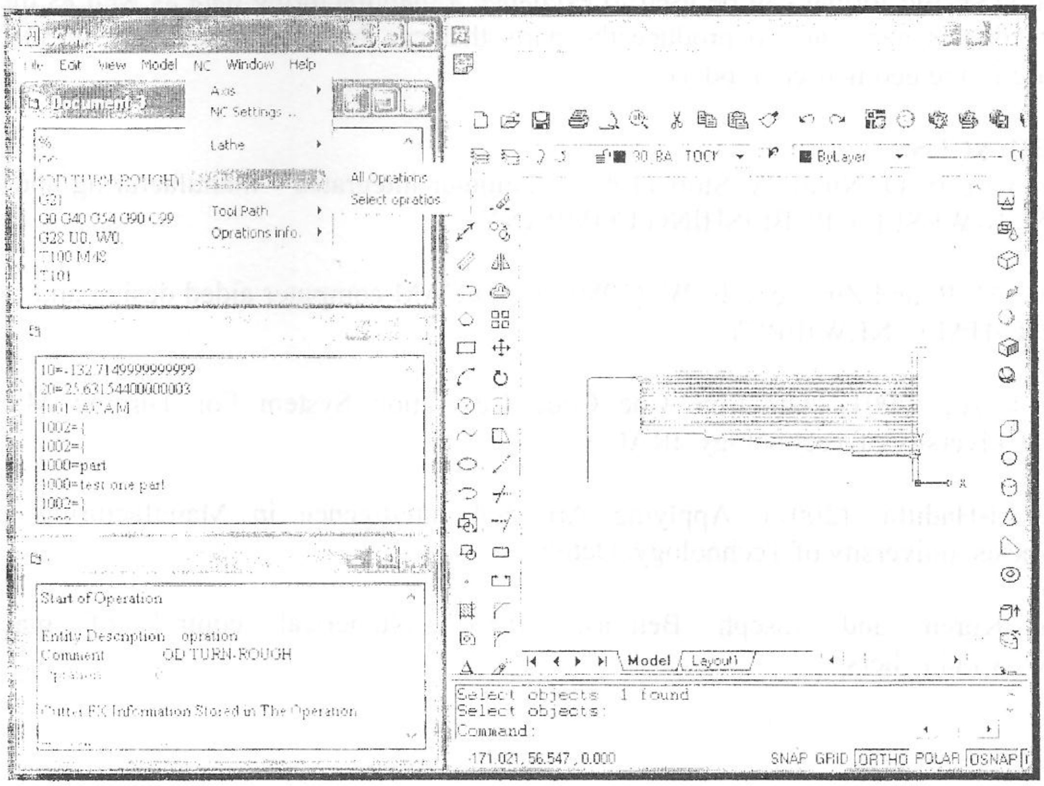


Fig. (10) Main screen of the NC Package

CONCLUSIONS

1- Backup CAM system with a powerful graphics package made the system user know what is going on and helps him to manipulate directly the CAP description model through its graphic picture.

2- The decomposing task of the stock material area to be removed by machining processes is a critical task, so that the definition of flexible way like the developed one to identify these areas purely and correctly made this task easer to be done and eliminate ambiguity resulted from the definition of insufficient geometrical information.

3- Polyline entity represents a powerful geometrical entity to hold such information like a continuous tool path cutting movements. It is easy to generate, edit and extracts the needed movement's information. Also the use of polyline to represents the part and stock geometries have the benefit that is guarantee the elements end points are actually match but its weakness have the benefit that is guarantee the elements end points are actually match but its weakness concentrated in the ability to hold geometrical information for spline curves in spit of it can be used to hold the control points for such geometrical entities.

4- Relational database can be used ideally to reflect the CIM principle. Since it facilitate (accessed and manipulate) the proving of applications programs. As example machine-tools relationship is one to many relationships identifying the machine gives the ability to retrieve the machine information as well as the tools information that were associated with it.

5- The proper documentation for the defined manufacturing processes play a key role to create a unified manufacturing document that can be exchanged between different CADCAM system also it can be used for future addition or modification of a manufacturing process in other wards the direct conversion (concrete integration) from CAD drawing to NC/CNC programs without taken into consideration the importance of CAD and/ CAM systems interfaces leads to go back to the early days of the NC machine program blue print.

6- The DXF file format can be used to exchange a manufacturing data as well as the geometrical data that is necessary to produce the parts that can be described purely in such file format (wire frame geometrical model).

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