Computer Aided Manufacturing (CAM)
A Machining Application

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Abstract:

The aim of this report is to determine optimum machining conditions, though the introduction of the computer programs that aid manufacturing and machining, operations sequences and tool magazine arrangements to manufacture a batch of parts by a CNC machine on a minimum cost basis. The processes of the machining operations, the cutting speed and the feed rate will remain variable decision to each machining operation to choose and setup the candidate tools from a white range available tool of limited quantities. The design and the management of flexible manufacturing systems that can manage the low or high productivity are crucial and important issues. Integrated of many optimized iterative processes of plan and control of a multi-stage and multi-cellular flexible manufacturing system, based on simulation tools cycle time, has been developed and is illustrated. There are several calculation illustrated to find the best operation management method, these methods consider only the contribution of machining time and tooling cycle time and the labouring costs and the time and number of machines are appreciated to reduce the total cost of the production.

1. Introduction:

Computer aided machining is the use of computer, based on software tools that assist engineers and machinists in manufacturing or prototyping product components and tooling, in purpose to create a faster production process and tooling with more precise dimensions and material consistency. Computer aided machining can programming the tools in a way that create possibility to manufacture physical models to be able to use computer aided design (CAD) programs with computer aided manufacturing (CAM), creates real life versions of components designed within a software package. CAM has been considered as a numerical control (NC) programming tool wherein three-dimensional (3D) models of component generated in CAD software which can use to generate G- code to drive numerically controlled machine CNC. The software has developed in many years experience in dealing with, the needs of small, medium and large manufacturing businesses. This design has assist human, easy to learn, and gives the flexibility in managing the operations from quotations through to invoicing, enabling the manufacturer to hit the target of quality, cost, efficiency and delivery.

2. Computer control technology:

Computer controlled technology is an application which applied on product development, to increase access to technology by providing easy way to products with cost effective and work in conjunction with existing computer equipments. Computers control helps many aspects of human’s live such as the control of the products and manufacturing around the world, in the way that obtain possibility to produce ideal products.

2.1 Computer Aided Manufacturing CAM:

Computer aided manufacturing (CAM) has been considered as software converts three dimensions (3D) models generated in CAD into a numerical control programming tools to generate computer numerical control (CNC) code, set of basic operating instructions written in G-Code to drive numerically controlled machines. The code is a programming language that can be understood by numerical controlled machine tools and essentially industrial robots. The code can instruct the machine tool to manufacture a large number of items with perfect precision and faith to the CAD design while the stage at which conceptual designs for new products can be made entirely within the framework of CAD software. The computer Aided Manufacturing takes a step further by bridging the gap between the conceptual design and the manufacturing of the finished product.

2.2Computer Numerical Control machines:

Computer Numerical Control CNC means a computer converts the design produced by Computer Aided Design software (CAD) into numbers. The numbers can be considered to be the coordinates of a graph and they control the movement of the cutter. In this way the computer controls the cutting and shaping of the material. CNC machines cut and shape precisely products such as automobile, aviation, and machine parts.

CNC machines operate by reading the code (G- Code) included a computer controlled module, which drives the machine tools and performs the functions of forming and shaping a piece of material which formerly block in different process. But these machines cut away material from a solid block of metal or plastic which is known by (workpiece) to form the required shape. CNC programmers also referred to as numerical tool and process control programmers, to develop the programs that run the machine tools. Computer control programmers and operators normally produce large quantities of same part, although they may produce small batches or one of a kind of an item. Firms use their knowledge of work and properties of metals with their skill in CNC programs to design and carry out the operations needed to make machined products that meet precise specifications.

2.3Delcam:

Delcam is one of the world's leading suppliers of advanced CAD, CAM solutions for manufacturing industry. Delcam has as range of design, manufacturing and inspection software provides complete, automated CAD, CAM solutions, to take complex shaped products from concept to reality. It is now the largest developer of product design and manufacturing software as the combination of Delcam software has powered growth at toolmaker and precision machinist tooling systems in a number of ways, the most obvious growth is in the size of the machine tools. Delcam such as CAD and CAM hardware and software, includes PwerMILL and PowerSHAPE which are two of the most powerful and highest performance computer workstations operator,

2.4 PowerMILL:

Power MILL is the most leading specialist numerical control of CAM software for the manufacture of the complex shapes typically found in the tool making, automotive and aerospace industries. Key features include a wide range of strategies, including the latest high efficiency roughing, high speed finishing, and 5-axis machining techniques, exceptionally fast calculation times and powerful editing tools to ensure optimum performance on the machine tool. PowerMILL software is used by the toolmakers on the shop floor to produce programs whilst the job is on the machine. This reduces lead time and overhead by allowing machining to be started sooner and programming with reduce cost, while enables programs to be modified or adjusted to suit the cutting conditions with minimize delay.

2.5 Milling tool cutters:

Milling tools are cutting tools used in milling machines or machining centres, they remove material by their movement within the machine which are directly cut from block to make wanted shapes with several features of milling cutter such as several shapes and many sizes, however these tools are availed with a choice of coatings, as well as rake angle and number of cutting surfaces. There are many types of milling cutter that can be used for much different purpose. Each CNC machine has a range of cutting tools and it is very important that all the cutters are setup to exactly to the same length in the part because if this is not done, the material being machined will be machined at incorrect depths.

Modern numerical controlled machine tools can be linked into a centre of collection which called (Cell) of tools that each performs a specified task in the manufacture of a product, whenever the product is passed along the cell in the manner of a production line, with each machine tool (i.e. welding and milling machines, drills, lathes etc.) performing a single step of the process, while for the sake of more convenience, a single computer which is known as the controller, can drive all of the tools in a single cell on CNC machine, up to the information applied by software.

2.6 Property of Cutting Tools:

Cutting tools for milling mild steel are made from solid carbide with high quality and precision with paramount tight tolerances and urgent deadlines are the norm. In the metal working industry, cutting tools must keep their cutting edge that is how product companies provide the tools properties. Tools do not last forever at cutting speeds less than those speeds that cause them to collapse, because they wear out either by steady growth of wear flats or by the accumulation of cracks leading to fracture, this called file cycle time for cutting tool. To improve cutting tool life and improve properties by using the latest technology and highest quality will extent the tools life.

Cutting tool life cycle has great relationship with milling models in CNC machines; the tools has its cost which effects the cost of milling, also exchange time to use a new tool instead of the tool that run out of its life, cost time and the down time for changing tool must be appreciated during the calculation of productivity.

2.7 Fixture of workpiece:

The fixture of workpiece is a scheme that contacts the rigidity between the workpiece and fixture elements which contributes in the dimensional accuracy achievement. There are different specific hydraulic and pneumatic or manual dedicated fixture for CNC horizontal and vertical machining centres and other CNC machines. The precision value or tight tolerance machining is vital and the clear positioning understanding may influence location accuracy of a workpiece, so the major attempt is to eliminate displacements and rotations of the workpiece that occur under the influence of clamping, cutting, and locating (contact) forces. A complete investigation of the relationships between location accuracy and those factors is essential to obtaining an improved fixture design, reducing the cost of fixture implementation and increasing the production efficiency, to maintain location accuracy and avoid workpiece slippage, as well as to determine the clamping effects, force analysis on the fixture-workpiece system is necessary. When a workpiece is clamped in a fixture, the contact forces between the locators and the workpiece develop at the locating points. These contact forces cause deformation of locators and the workpiece at the contact regions.

In this case (project part), the CNC machines has hydraulic manual dedicator fixture, which allow horizontally fix the first side of the block easily, the hydraulic force prevent the workpiece from slipping or detaching from the locators the reaction forces on the locators. The second side of the workpiece fixed in a different fixture, as its not block shape anymore, so that, the fixture must have clamps to locate inside the edges of the part and the fixture must have a pin to go inside the pre-hole inside the first worked side of the part to prevent the workpiece form slipping or detaching from the locators. There is a necessity to make a new work-plane for the second side of the workpiece by the PowerMILL program to let the tools to recon the new starting point of milling. The most reaction force must locate on the pin which located inside the hole, because the high value of reaction force on inside edge may slightly effect deflection which cost inaccuracy in production.

3. A practical Application of CNC:

This application is a project which has been given as assignment.

The theory of the project:

ProMachine Ltd are medium size machining company that won an order from a major automotive gearbox manufacturing to supply a centrifugal weight component that is to be used in an automatic gearbox for large military vehicles.
Directorate require a clear and concise justification that outlines the equipment needed to manufacture and quality the component based on sound cost and technical engineering issues.
The centrifugal weight component is to be manufactured in two phases. The component has initial volume requirements of 500 pre weeks increased after six months to 2500 per week.
The raw material is certificated mild steel and is supplied in the form of pre-sawn blocks that are 130mm × 80mm × 45mm. there is design licence for minor modifications to be specified to suit manufacturing methods or for possible fixturing location for the manufacture of high production volumes. General machining tolerances are as follows, and should be assumed unless otherwise stated.
The component specifications are as follows;
General dimensions ±0.15mm
Flatness 0.2mm
Angularity ±0.2□
Hole diameters ±0.05mm
Use a cutting speed of 175m/min for carbide tolls and 50m/min for High Speed Steel tools.

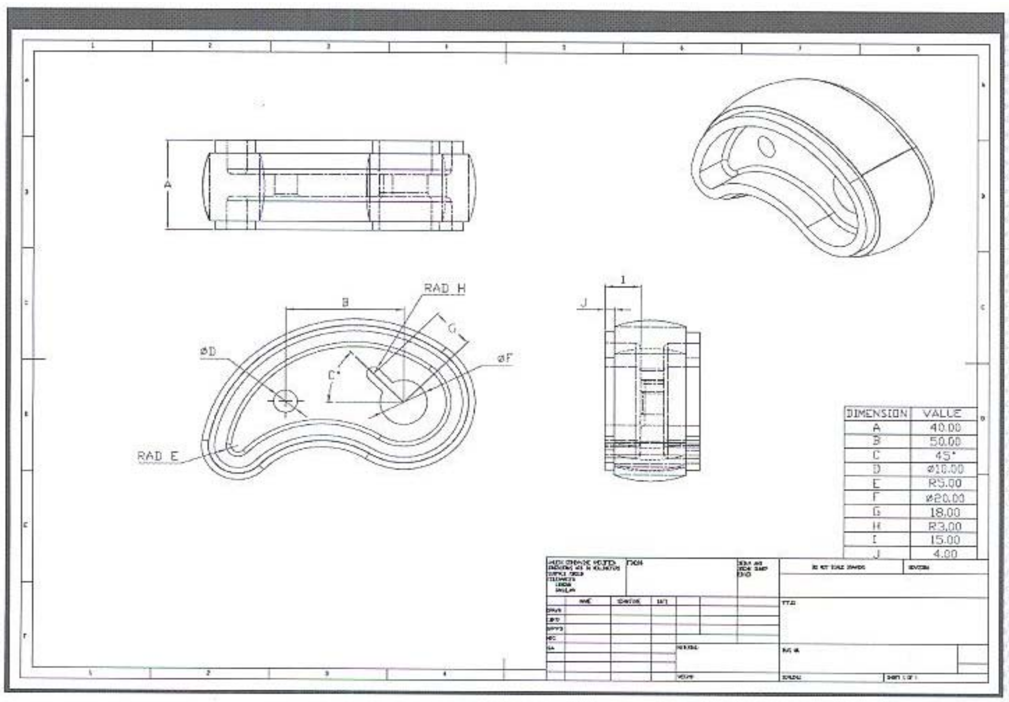

Figure (1): show the component Specification.
The figure obtained from the assignment handout.

3.1 Project implementation:

It is important to establish which activities should be carried out first; subsequently a very detailed analysis of the information required for each activity must be made. So that, Delcam PowerMILL software has been used to demonstrates how cutter paths can be assigned to manufacture bespoke part (model). PowerMILL also writes the G-Code (G-54) within the CN program for each tool sparely and all the tools together which can be transferred to machines to setup them to the tool as it required in any stage, the CNC machines in workshop work by the given G-Code.

Metal Cutting Demonstrations have been given within the workshop where issues such as: material, underlying technological principles, cooling, operational difficulties, and quality aspects, all outlined and discussed.

PowerMILL program has illustrated the part cutting well with the cutting tools. There is a tool magazine attached to each CNC machine with a limited tool slot capacity. .Proper tools for cutting mild steel can be fund from the tool properties list which been given by the cutting tool company manufacturer, table below is an example of tool magazine belong the CNC machines.

Note: All the tools that used within PowerMILL program taken from this table are used with the same name, number, diameter, speed and feeds which are shown in the table below.

Table (1): The list below show a Tooling List for demonstration part manufacture:

Tool number	Tool Name	Spindle Speed rev/min	Feed Rate mm/min		Depth of Cut mm	Stopover mm
			Linear	Plunge		
1	4mm Diameter Ball Nose Slot Drill	7000	4000	1000	2	0.5
2	Centre Drill	5000	0	1000	5	0
3	10mm Diameter Flat Slot Drill	4000	4000	1000	2	3
4	10mm diameter Twist Drill	3000	0	800	…..	0
5	12mm Diameter Ball Nose Slot Drill	6000	4000	1000	3	5

Note: This table obtained from the assignment handout.

These figures bellow illustrates the part of the project within the block, with the cutting tools that been used for remove the material, are drawn by Power MILL program. These figures show how the tools are work on the work piece (model).

Figure (2): shows the first used tool which is Tool Number (5) from the table, it has (12mm Diameter Ball Nose drill), and been used with the same speed and feed as shown in the table. Tool number (5) due to its properties, it has biggest diameter (12mm) and other mechanical properties, used at the first to do the Roughing work on the (Work piece) or the fist side of the part.

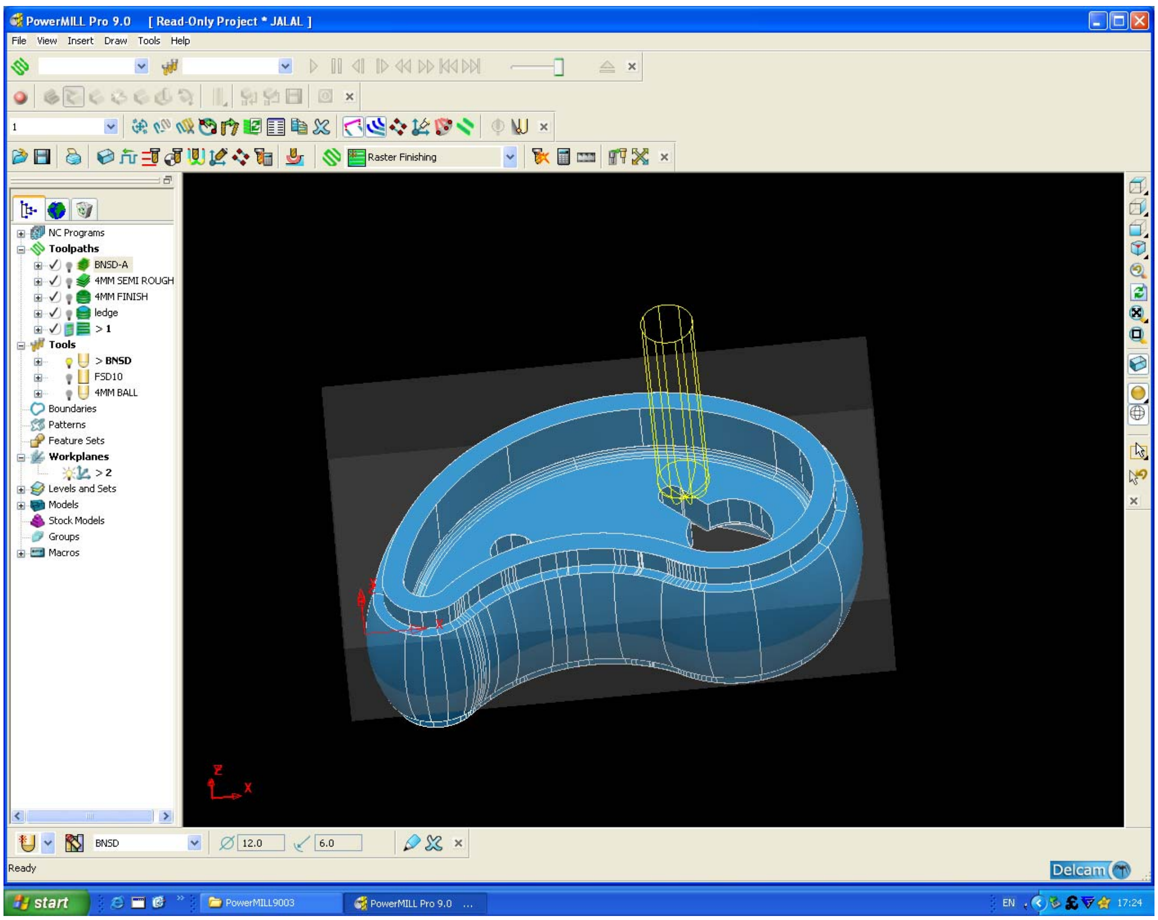

Figure (2): Illustrates the part project within the block with Tool number (5) which is used to first Rough cutting. (Figure obtained from practical programming part project to PowerMILL software.)

Figure (2-A): shows the NC program which includes all G-codes and the time required to first Roughing Tool which is (4.3 minutes). This is the actual time required for the first tool to roughing the model; it is useful to calculating the manufacturing required time for product the parts and can be used in management plane of production. This time required will remind the same for next parts within the same process and the same tool. It can be used to calculate the total time of operating the machine to performing plans and strategies to manage productivity target in the limited times.

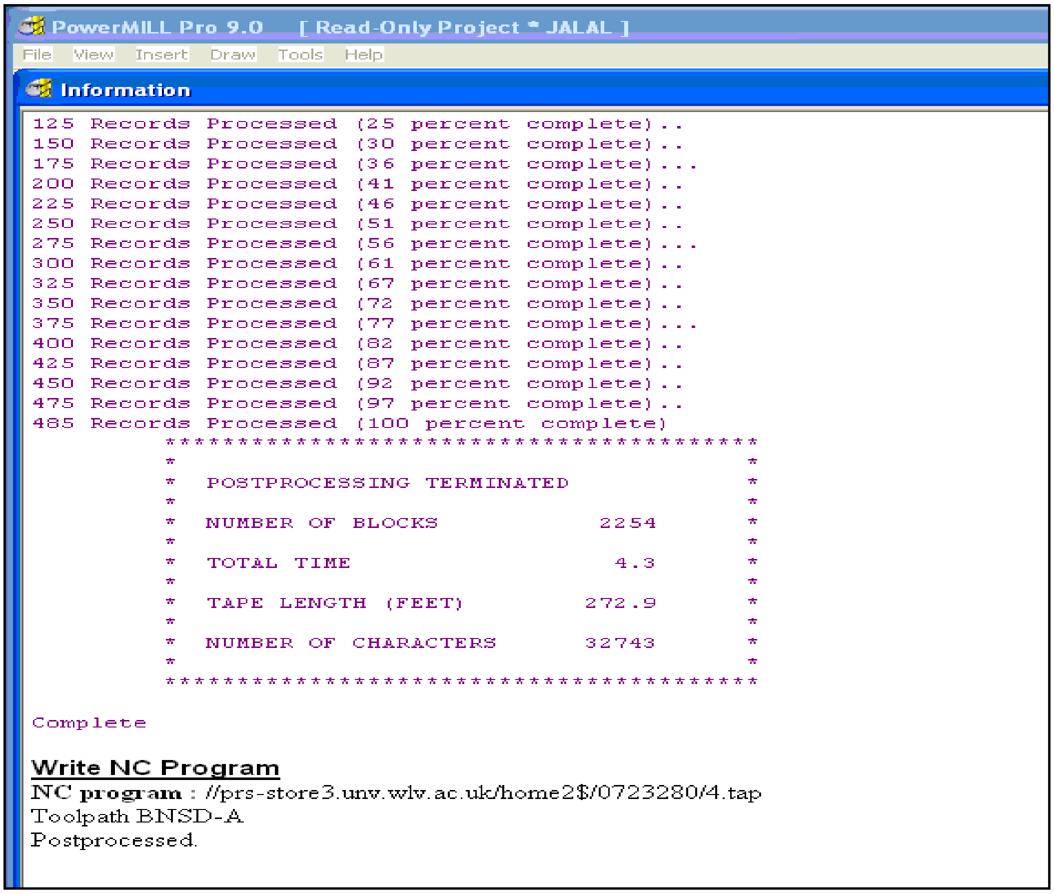

Figure (2-A): shows NC Program, the time cycle for the first Roughing Tool. (Figure obtained from practical programming the part project with PowerMILL software).

Figure (3): shows the part within the block, with tool number (1) from table (1) which named (4mm Diameter Ball Nose Slot Drill) and also used with the same speed and feed that shown in the table. This tool used as secondary area clearance strategy, semi-rough, is process comes just after first roughing to reduce the stocks around the surface of part, this tool works within less tolerance range than the first roughing tool. This will reduce the degree of tool overload and provide a more consistence material removal rate for any subsequent finishing operations.

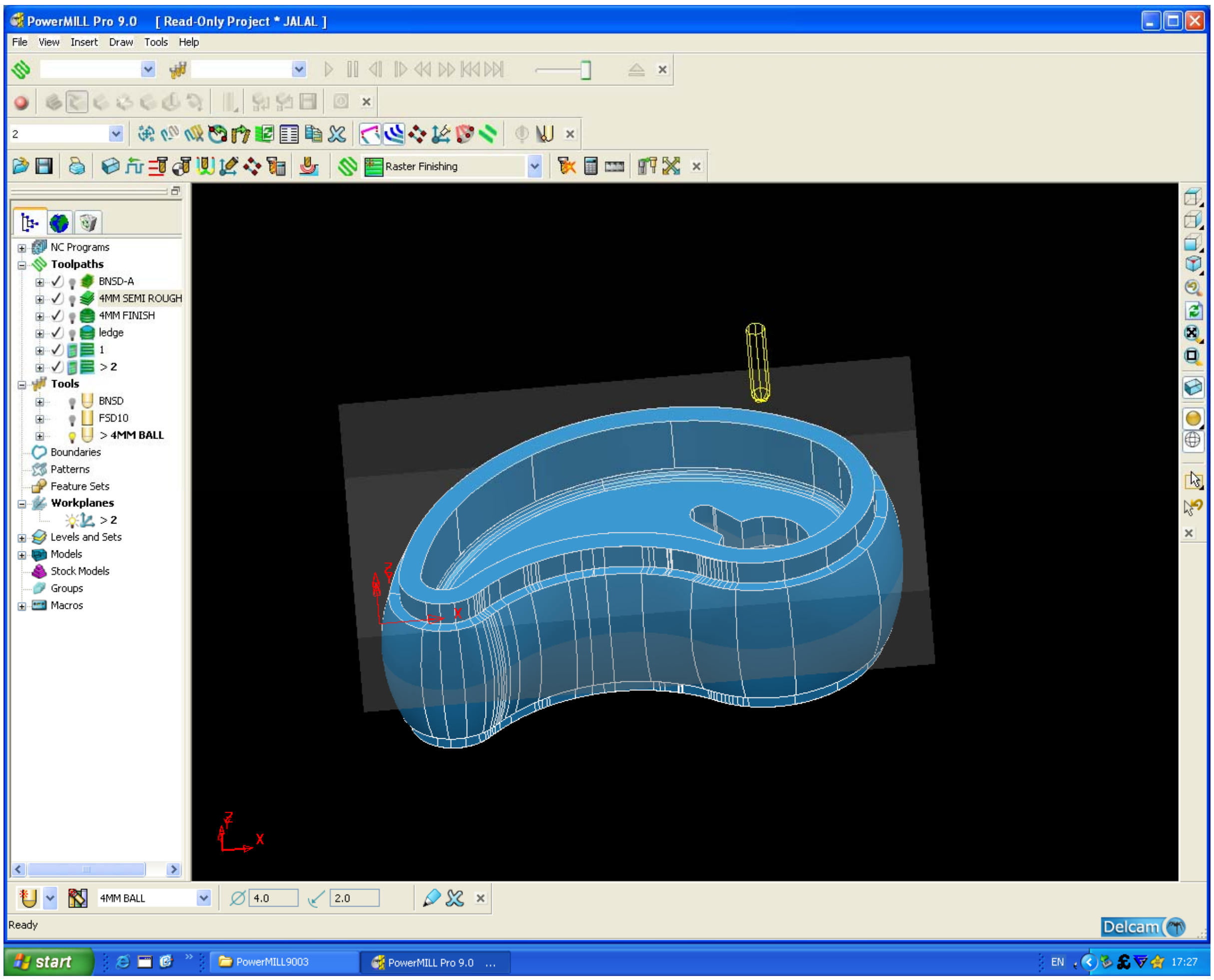

Figure (3): Illustrates the part project within the block with Tool number (1) which is used to Semi- Rough cutting. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (3-A): shows the NC program which includes all codes and the time required to first Semi-Roughing Tool which is 2.7 minutes. This is the actual time required for the second tool to Semi-Roughing the part, it is useful to calculating the manufacturing required time for product the part, also can be used in management plane of production. It remains the same for next parts.

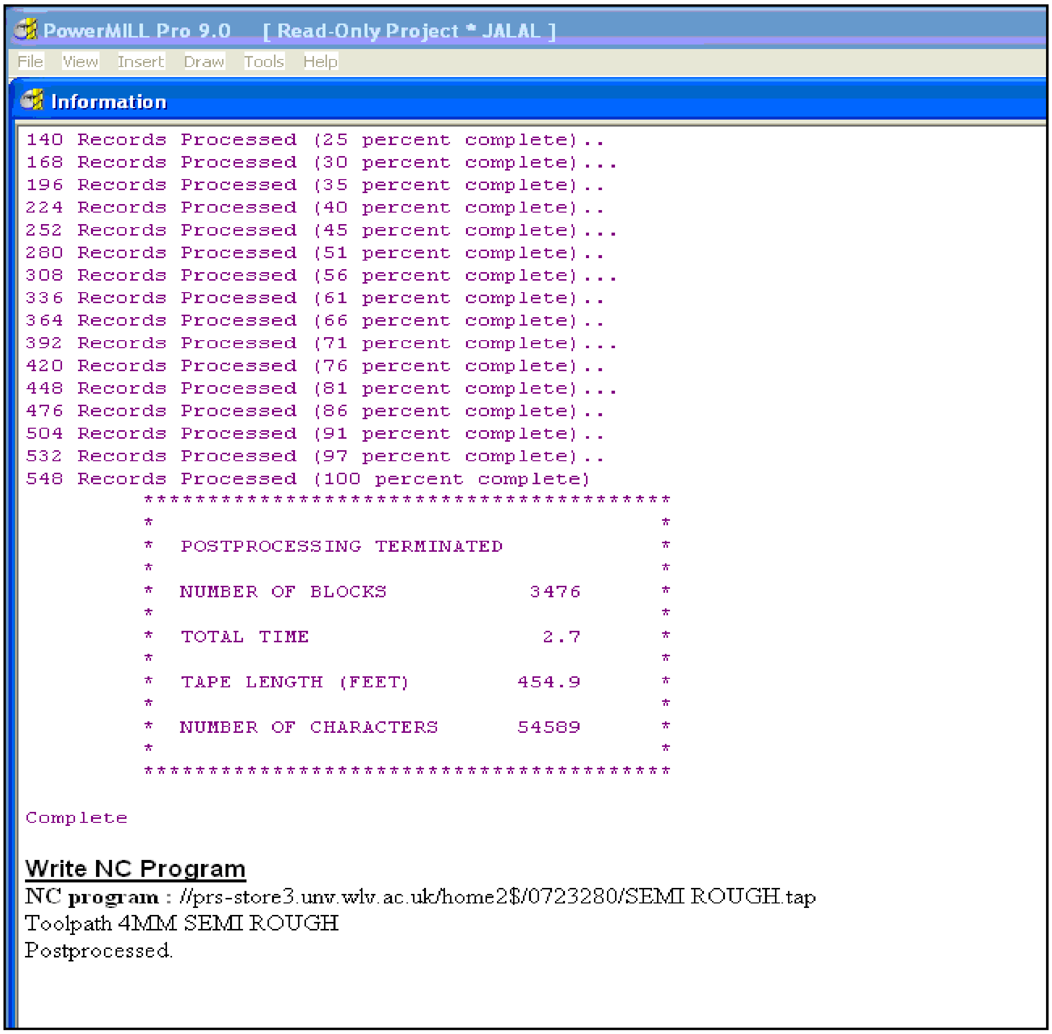

Figure (3-A): shows NC Program, the time cycle for the Semi- Rough Tool. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (4): illustrated the part within half block, as this is the one side operation process, with the Finishing tool which is tool number (1) that has (4mm Diameter, Ball Nose Slot Drill) and it used with the same speed and feed as shown in table (1). Usually, the area clearance operation followed by finishing strategy, however finishing process surrounded by vigorous values to control the accuracy required and amount of excess material to be left on the component by tool path. The control complete within two parameters which are thickness and tolerance, since tolerant control the accuracy to which the cutter path follows the shape of the workpiece (part) with finishing a (Fine) tolerance must be used.

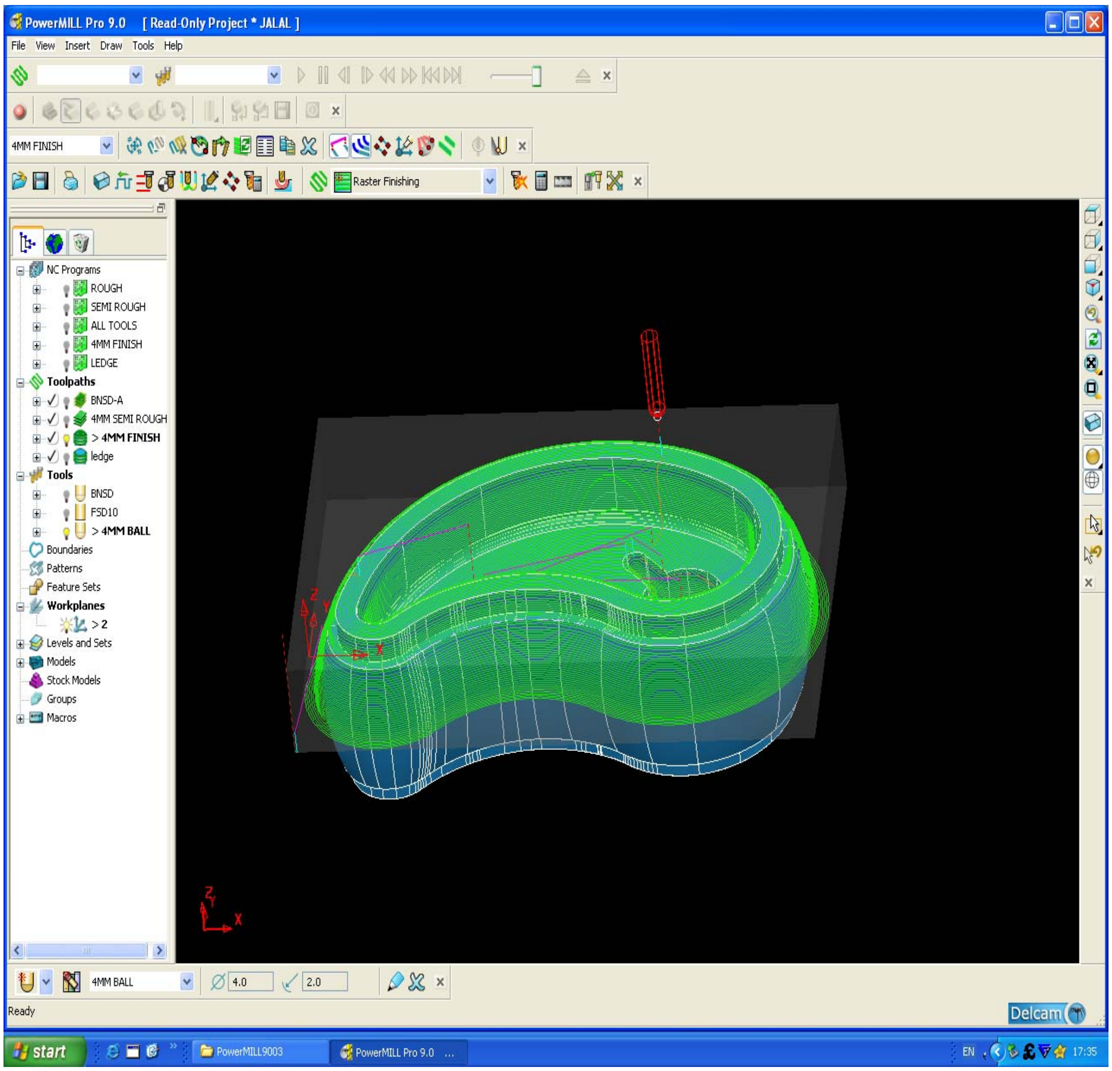

Figure (4): Illustrates the project part within the block with Tool (No.1) which is used to Finishing cut at the first side of the part. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (4-A): shows the NC program which includes the G-codes and the time required to Finishing Tool which is (8 minutes). This is the actual time required for the second tool to finishing the part; it is useful to calculating the manufacturing required time for product the part and can be used in plane management for the product. It remains the same for next parts.

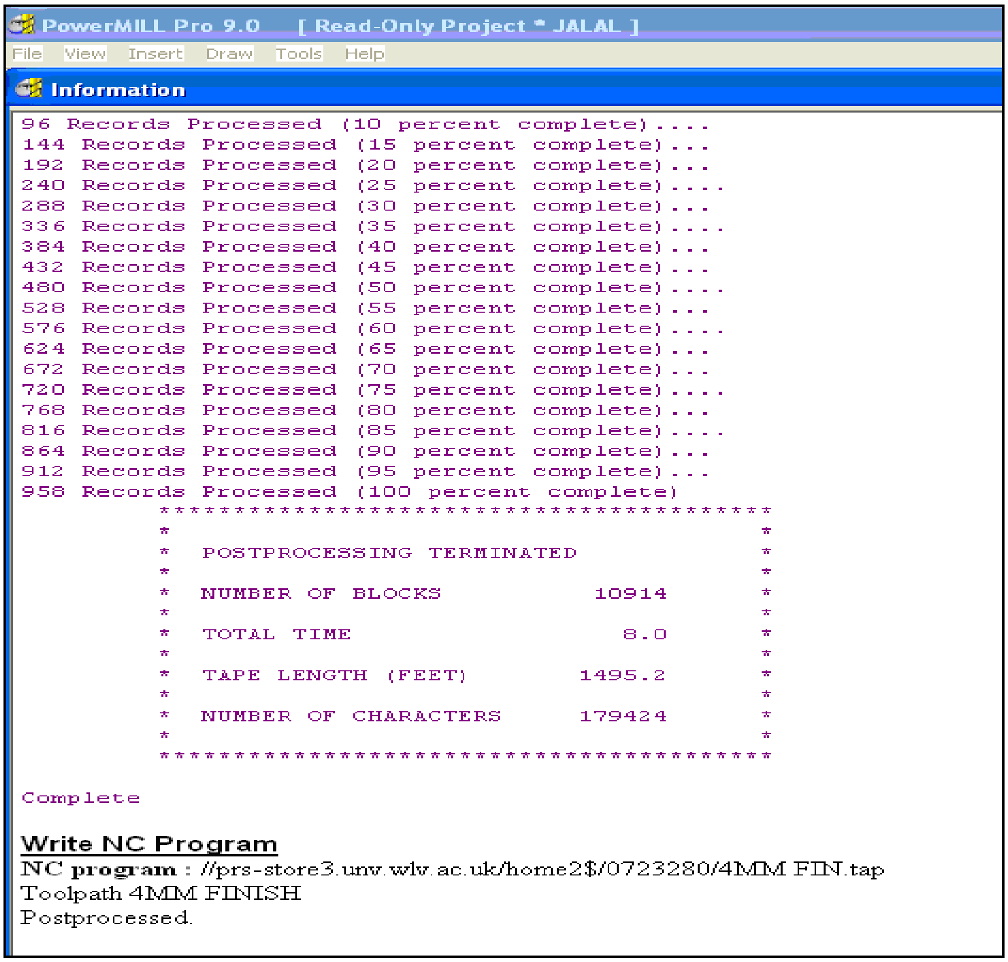

Figure (4-A): shows NC Program, the time cycle for the Finishing Tool. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (5): Illustrating the part within the block with the Tool number (3) which named (10mm Diameter, Flat Slot Drill), this tool used to make the sharp corners (Corner Finishing) for the Edges of the model, as the large tool in previous paths could not remove the material in the corners, so that, this step must taken along the Edges of the part from both sides. This figure shows that the certain area has been selected by creating a block around it with tool number (3) which is a flat blade tool is the only tool can finishing the corners.

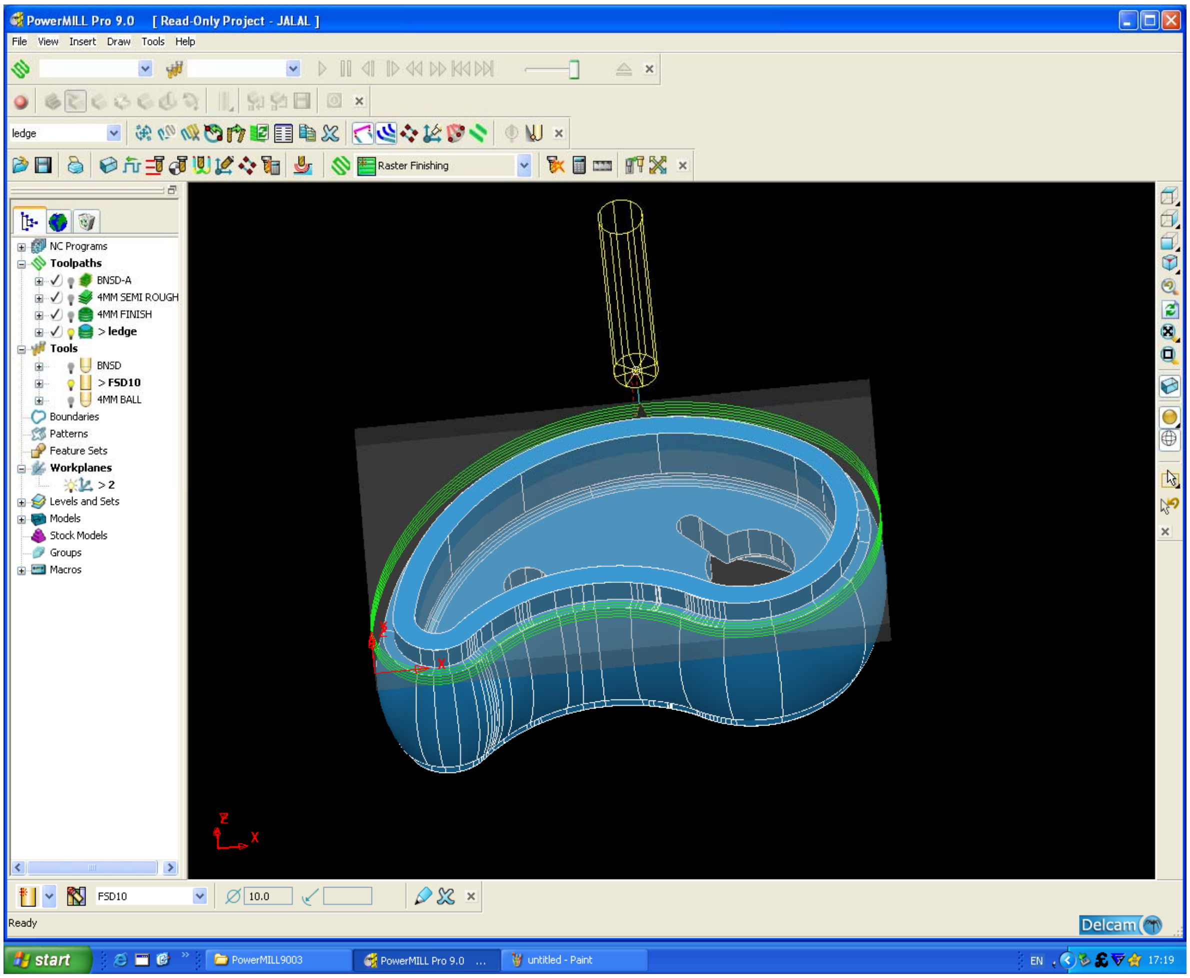

Figure (5): Illustrates the part project within the block with Tool number (3) which is used for Edges. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (5-A): shows the NC program which includes G-codes and the time required to finishing the sharp corners around the edges of the part with tool number (3), it takes (0.5 minute). This is the actual time required for the third tool to finishing the edges of the part; it is useful to calculating the manufacturing required time for product the part and can be used in plane management of the product. It remains the same for next parts.

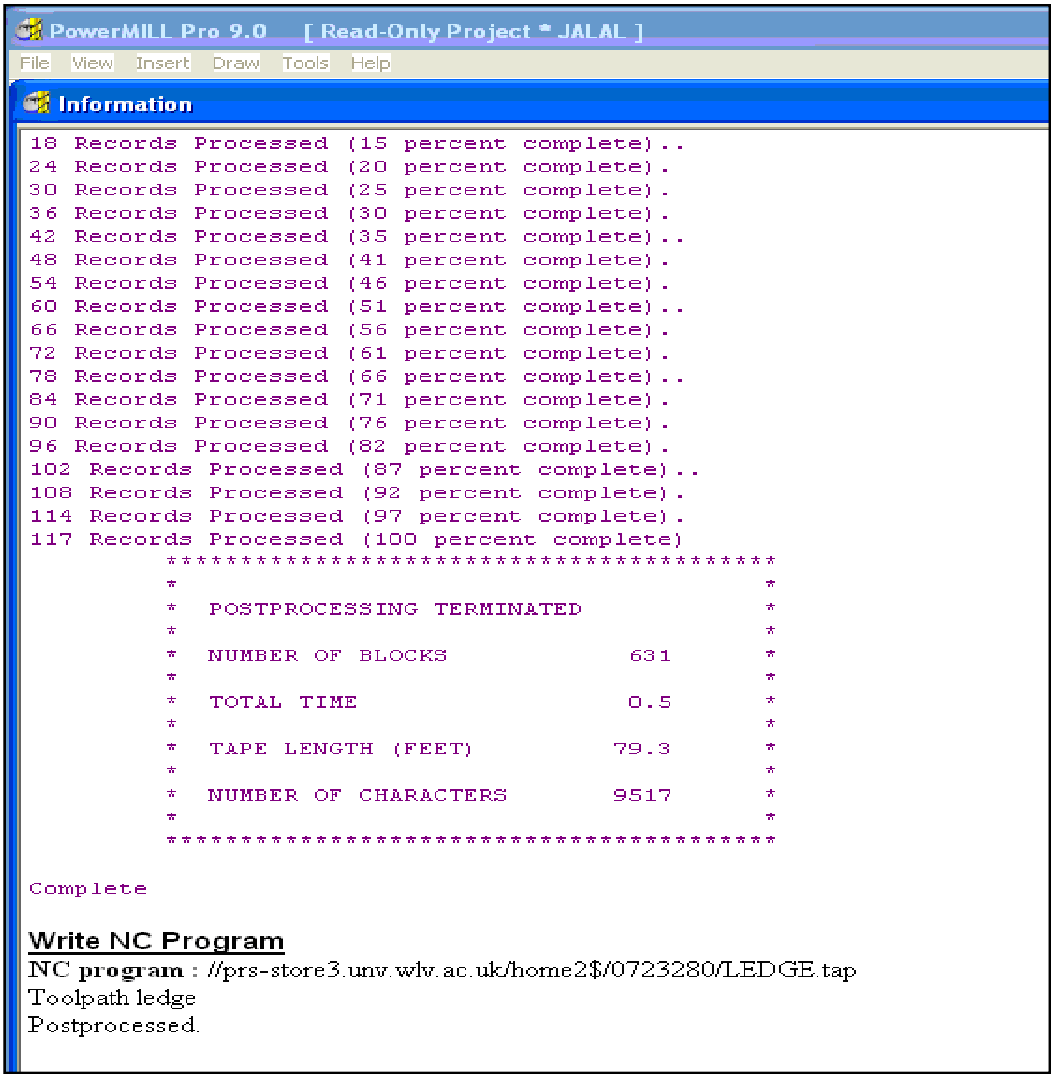

Figure (5-A): shows NC Program, the time cycle for the Edge Tool. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (6): Illustrating the second half (other side) of the part with the best work plane which referring tool positioning according to the holding the workpiece in the machine, this is to finding the best position to start cutting to give easier cut process and give long life for the tool. This side of the part needs to pass through the same processes as the first side passes through with the same tools actions. But the part turned over, now needs other work plane to give better dimensions for the tools to work on it, so that, the work plane is placed inside the part as shown in the picture.

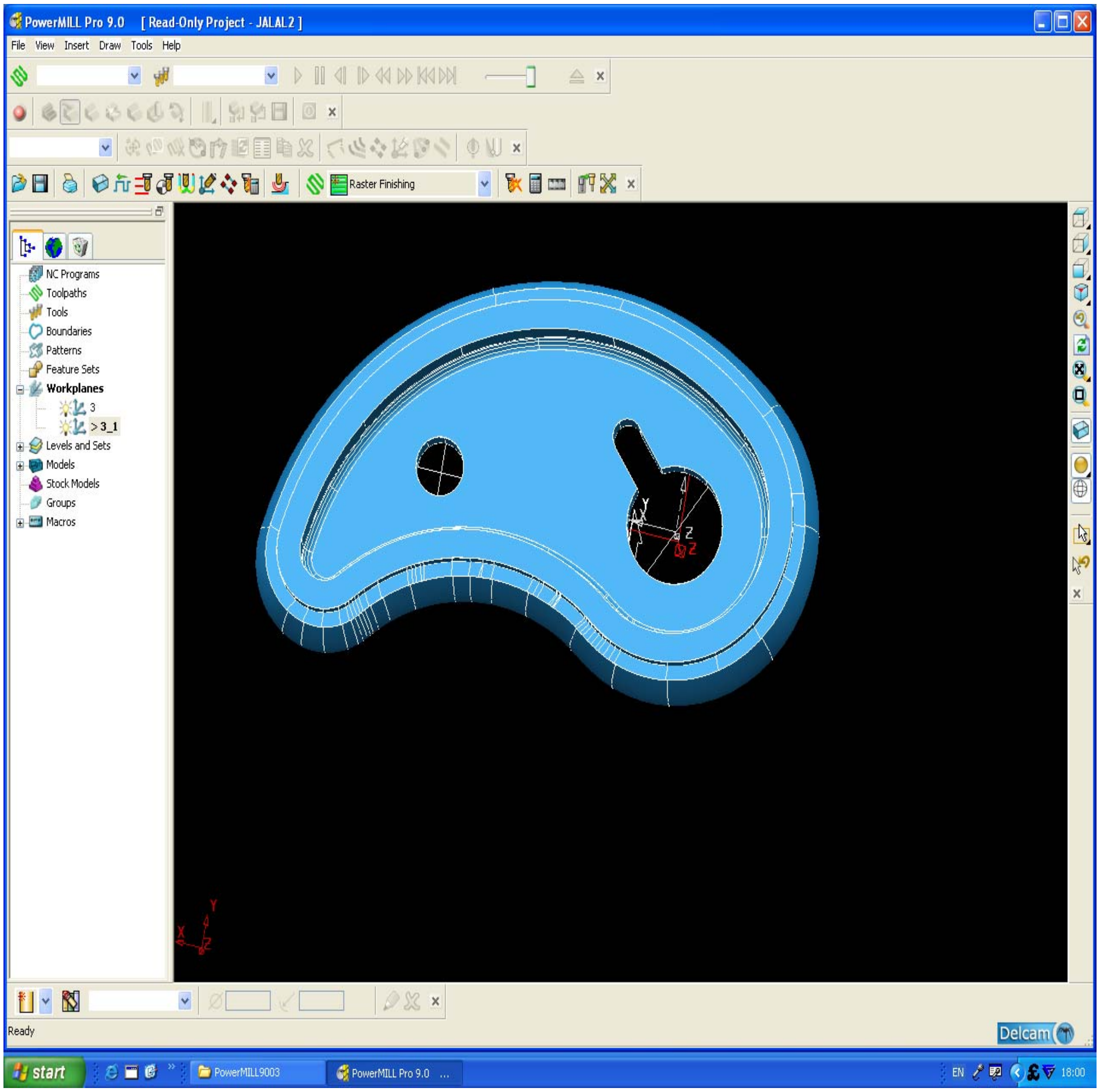

Figure (6): Illustrates the part project within the block, the second side of the part with the new work plane. (Figure obtained from practical programming the part project by PowerMILL software).

Figure (7) shows the NC program which includes the G-codes and the whole time required to the entire four tools, equal (15.6 minutes). This is the actual time required for cutting processes from starting point to completing the work. It is very important to know the total time to produce any part with CNC machine; this data has priority to calculate the manufacturing required time to product in companies, this helps plan management of production. This time required will remind the same for next parts within the same process and the same tool.

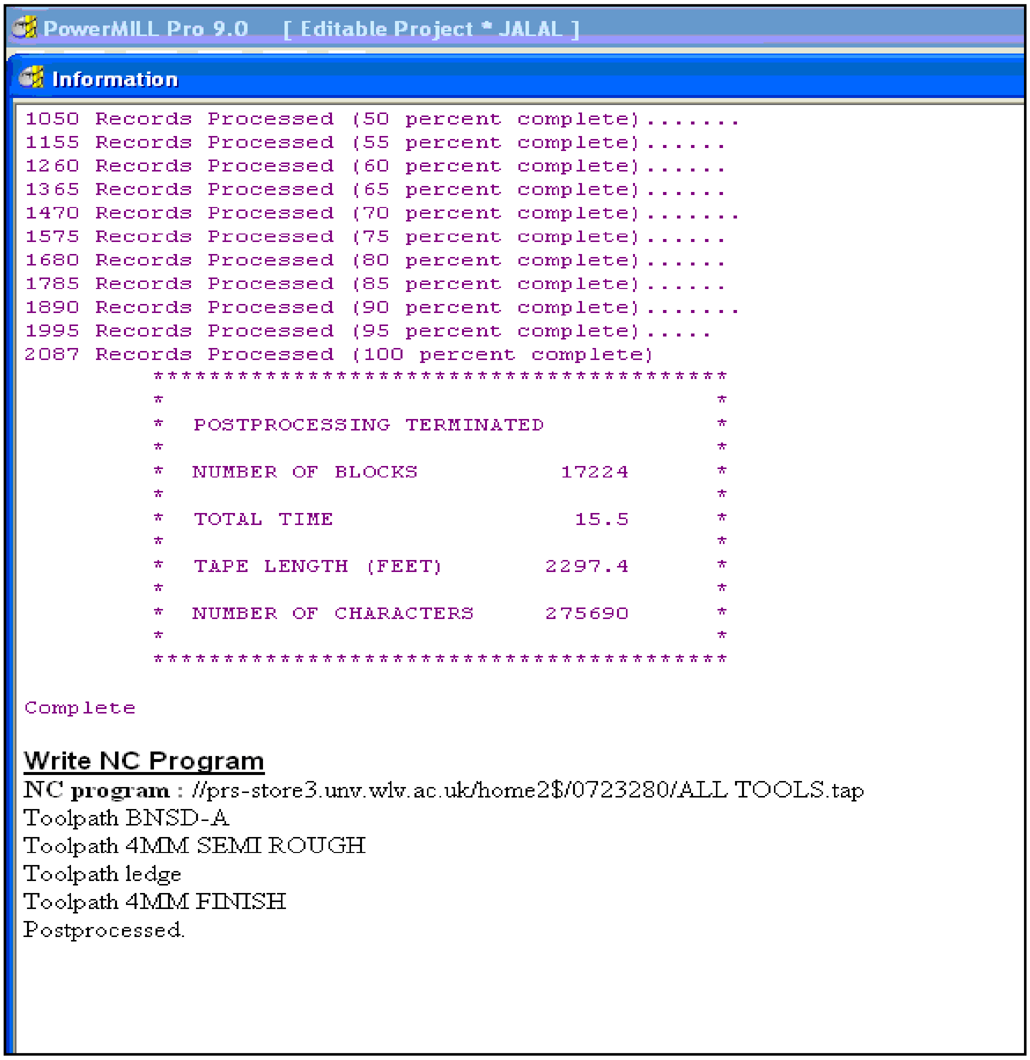

Figure (7): shows NC Program, the time cycle for all the tools (the four tools).
(Figure obtained from practical programming the part project by PowerMILL software).

3.2Productivity Management

The manufacturing process plan is to propose the routing of a previously designed part and results in a sequence of operations, to determine the feasibility of processes and operations together with the necessary parameters, assure that the finished manufactured part is obtained without any problems, with great concerns and requires to detailed information about the process. The purpose of production planning is optimising the flow of material and the use of the machines involved in manufacturing, taking into account various management and aims such as reducing the work in progress, minimising lead times, improving responsiveness to changes in demand and improving delivery time which enhance manufacturing orders at any given time regarding .

3.2.1 First phase of implementation:

The first phase is initial phase and the volume required is 500 parts per weeks;

Theoretical calculation:

The time cycle is 15.5 min/unit

As the required parts are 500 parts per week

500 per week = 100 part per day that is for 5 working days in the week.

The CN programme time required for the first side of the part is (15.5 minutes, Figure 7); hence total time for machining both side takes (31 minute) within one CNC machine.

Practically, there is a time to change over the parts on the machines, estimated time to open the door and fix the workpiece in the fixture at correct way and clamp the block manually takes some times per side. But due to long time machining the part, the time the machine operating fist side, the changeover can be done on other machine for next part, so that, this calculation can be done without indicating time for change over the parts.

There are different suggestions to calculation, as there is no limit for number of machines or operation time, the best managing can found through the probabilities:

a) First suggestion: Let the company use enough number of machines;

To produce 100 parts per day,

31 × 100 = 3100 minutes (time required per day)

3100 ÷ (24 × 60) = 2.15 (number of needed machines)

This figure roughly shows the estimated machines must be more than 2, so let the machines to be 3 machines for instance;

Hence:

3100 ÷ 3 = 1034 minutes (The time required for each machine per day)

1034 ÷ 60 = 17.22 hours

That time more than 2 shafts in day (as the normal shift is 8 hours)

So that, the number of machines must increased to reduce the running time

3100 ÷ 4 = 775 minute ÷ 60 = 12.91 hours per day

Diagram (1) shows a created Cell which consists (4 machines) and one operator per shift. These machines must work in tow series lines such as machine A and B are working serially to each other, whenever a part put in machine A for the first side machining and completed, then the part transfer to machine B to complete the other side in it. The machines C and D are working with the same manner in other series line, both lines are parallel to each other in the same cell which is run by one operator.

The machines must run 13 hours cautiously to produce the required parts. But in real practice, there are always lost times for the operator's break which intimately takes 30 mints per shift and some lost times between the shifts changeover also time to clean the machines at the end of each working day and there should be some spear times for changing the tools or any other contingency work down. So that, there must be two shifts work which will be 16 hours per day.

This calculation is done with 4 machines in the cell as shown in diagram (1) and they must run upto16 hours in a day, the results are:
$60 \div 15.5 = 3.87$ part per hour from one series line
$3.87 \times 2 = 7.742$ part per hour from both series line in the cell
$7.742 \times 13 = 100.6$ (this reaches the target required.)
This calculation proves that the machine must produce parts for13 hours cautiously. The rest of the time goes to downtime for the machines which is estimated by 10% of actual time, and lost time for operator's lunch which estimated by (0.5 hours per shift), hence, that 16 hour running the cell is close to real time on ground.

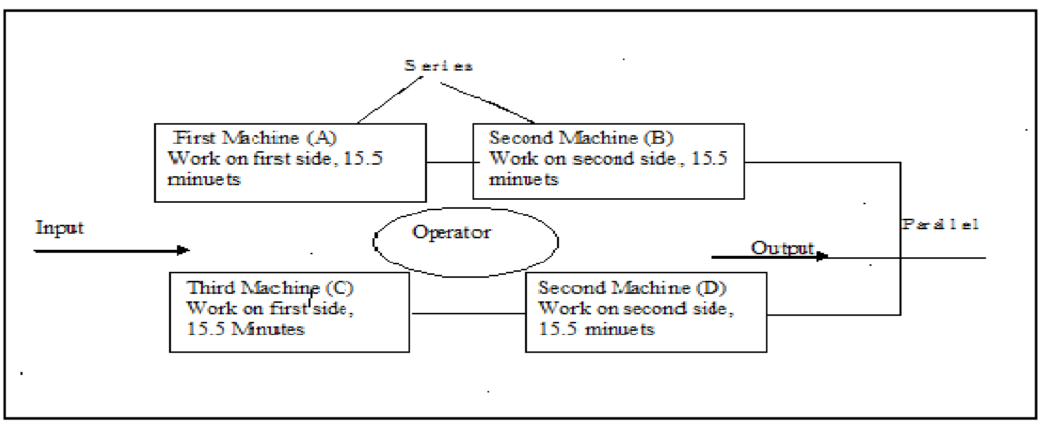

Diagram (1): Illustrates the series and parallel machines which setup in the cell.

b) Second Suggestion: longer running to reduce the number of machines

There is a possibility to change the strategy of work in the cell through the new planning process for machines to setup a machine to work with different tools and send the work to next machine with next tool to be finished.
Therefore, the change must start within PowerMILL program, to setup one machine does (First Roughing, Semi-roughing and edge) and send the workpiece (part) to the second machine to finish the work. This new planning process works with 2 machines which are work serially.
The first machine to do First Roughing which takes (4.3 mints each side) and the Semi-Rough which takes (2.7 minutes each side) also can do Edges which takes (0.5

minutes each side), these cycle times all equal (7.5 minutes each side), as shown in figure (8), and then the workpiece can sent to second machine to Finishing Process with takes (8.0) minutes each side, Figure 4-A).
There are enough time to fix the part in one machine while the other running, so that there is no need to accounting time for fixing workpiece or even for turn it over also the whole process can run by one operator.
Hence:
Throughout this process, the (2 machines) can produce one part in every 16mints; the diagram (2) illustrates the framework of plan process.
Hence:
60 ÷ 16 minutes = 3.75 part per hour
24 hour × 3.75 part = 92.88 part day
500 ÷ 3.75 = 133.33 ≈134 hours per week (running time required per week)
5 days × 24 hours = 120
120 + 16 = 136 hours per week
The machines can run for three shifts up to five day and only two shifts on the last day, the 2 hour spare time can used to serving machines. But this is an ideal time, it shows that the machines must not stop at all for 136 hours per week, even the operator must be covered by other operator in break times, and this cost more money for labouring calculations.
This calculation done in very simple way, there were no time for serving machines or breaking down, however, usually estimated general down time is 10% for machinery operations.

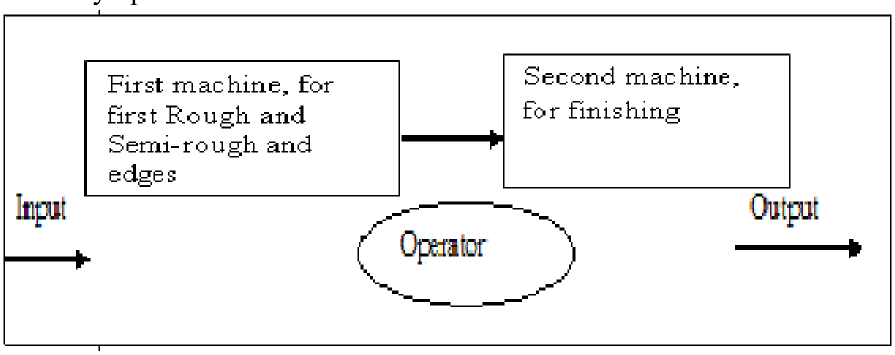

Diagram (2): illustrating the series setting for CNC machines in one cell

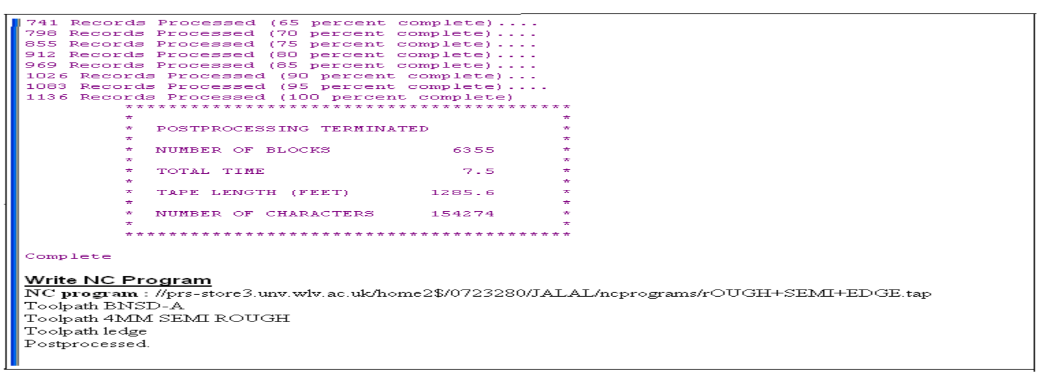

Figure (8): Illustrate the time cycle for (First Roughing, Semi-roughing and edge).
(Figure obtained from practical programming part project to PowerMILL software)

3.2.2 Second phase of implementation:

In this phase the productivity volume required is 2500 parts per weeks; the phase requires advanced management of manufacturing which characterized by the ability to allow that rapid response and other continuous changes of customer requirements. Manufacturing planning is a key issue in the integration of product design to produce through CNC machines, makes a significant contribution to the production cycle.
All the information may be accessed from any location for managing productivity, to ease and control production performance. Other information about the ability of machines, tool performance, the machine downtime, utilization, and tool utilization are required before start the productivity setup planning. However, there are other varieties and standards with the tools as the information shown in table (1) such as the spindle rotations, feeds, step over, step down, which are indicate the tool operation cycle times to product a part, must being appreciated.

As the number of machines unlimited for this project also the running time open, that give the manager to makes different suggestions to managing the process.

a) First suggestion; High number of machines, less running time:

The daily target production must be 500 parts to reach the weekly target. This needs more machines and operators than the first phase, as the cycle time for one part is 31minutes, if the company needs to run 5 cells such as the cell shown in diagram (1) or the Diagram (2), will reach the target easily but in the first plan the cost of buying and running that many machines very high, the second plan is difficult to run and its very fragile. This includes making several cells inside the company to run may CNC machines to reach the daily target

b) Second Suggestion; Minimum number of machines running for longer:

The new strategy plan tries to reduce the cycle times for the par through the reducing the cycle time for each tool. As Finishing cycle time is the highest cycle time in the process, it must reduce to the minimum possible time. The speed and feed used is standard, cannot increased especially for mild steel. So the only change can be done in tool setting is change in the step over, with permission from the company.

In tool setting for tool number (1), the step over increased from (0.5 to 0.8 mm), this reduced finishing operating cycle time from [(8 minute, Figure 4-A), to (6 minutes, figure 9)] for each side. The new cycle time for cutting one side is (13.5 minute, figure 10); the cycle time to complete one part will be (27 minute).

The new manage plan to production is making a cell which consists of three different stages which are in series to each other; each stage consists of different number of machine as shown in Diagram (3). As there are much different times between the cycle times for each tool, there should be relationship between the time cycle and the number of machines in each stage. The tool which has longer cycle time needs more machines in its stage, to give continuity for all stages to finish the work equally and avoid from any accumulation of part at the end of any stage.

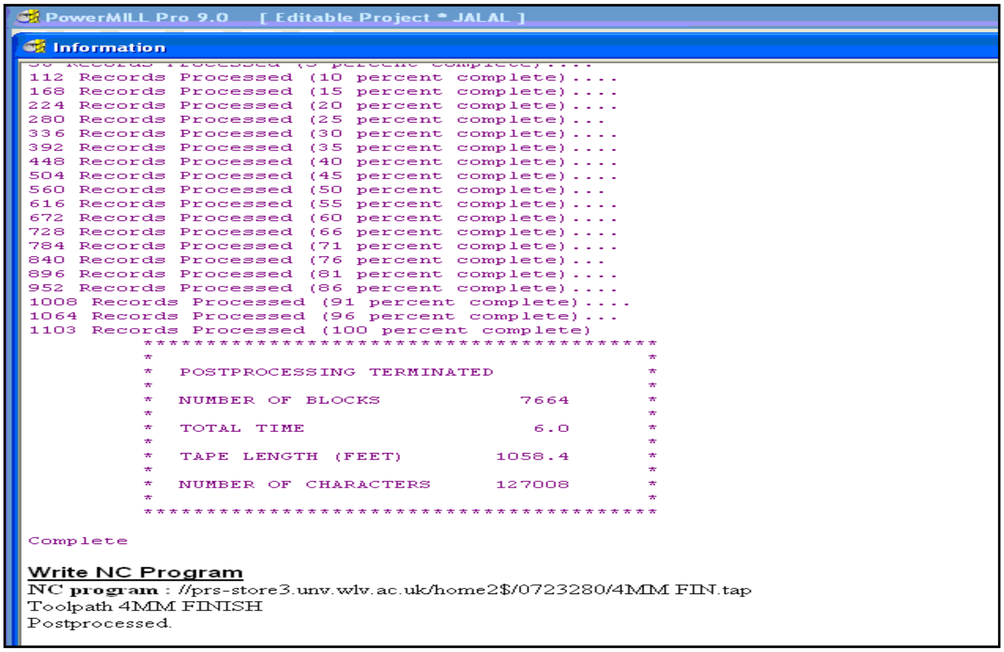

Figure (9): shows NC Program, the time cycle for the Finishing Tool with new setting (Figure obtained from practical programming part project to PowerMILL software)

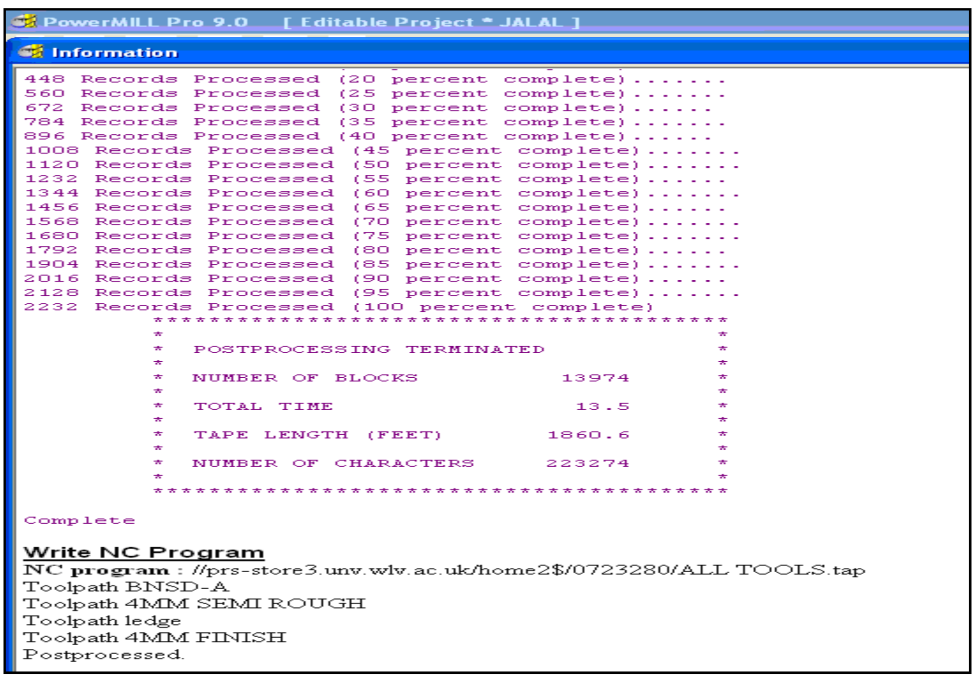

Figure (10): shows NC Program, the time cycle for all the tools (the four tools) within the new setting. (Figure obtained from practical programming part project to PowerMILL software)

Calculation:

Theoretical calculation:

2500 × 27 = 67500 minutes (absolute time work required per week)

67500 ÷ 5 day = 13500 minutes (absolute work required per day)

13 500 ÷ (24 × 60) = 9.375 ≈ 10 number of machines for 24 hour full work.
In practice there are many parameters affect the product lines directly or indirectly, however all of that factors must appreciated, so the theoretical figures cannot accepted to implement the project practically in real ground.

In review to the cycle time for the tools, due to Finishing cycle time, theoretically a product line need (12 minutes) to produce one part, this gives average (5 parts) per hour for each machine.
2500 ÷ 5day = 500 part per day
500 ÷ (5prat × 24 hour) = 4.16 minimum number of machines in the last stage.

4.16 > 4, so the finale stage must have 5 machines;
This show that the final stage which the machines do finishing work on parts, must consists of 5 machines to produce 25 parts per hour, other ways cannot reach the target. But the stage before this must be able to input 25 parts per hour into this stage.

Due to short cycle time for Semi-Rough and Edges, the machines in this stage can setup to do both work (Semi-Rough and Edges) cutting on the workpiece, the CN program show the cycle time for this merged in figure (11). The machines in this stage need (3.2 minutes) for each side which is (6.4 minutes) per part, but required parts only 25 per hour
60 ÷ 6.4 = 9.375 part per hour from each machine
25 ÷ 9.375 = 2.666 ≈3 machines
3 × 9.375 = 28.12 part per hour

So, only 3 parallel machines can do the work in this stage with some extra parts every hour.
To avoid accumulate at the end of this stage, machines slowed or stop these machines earlier time the others in next stage.

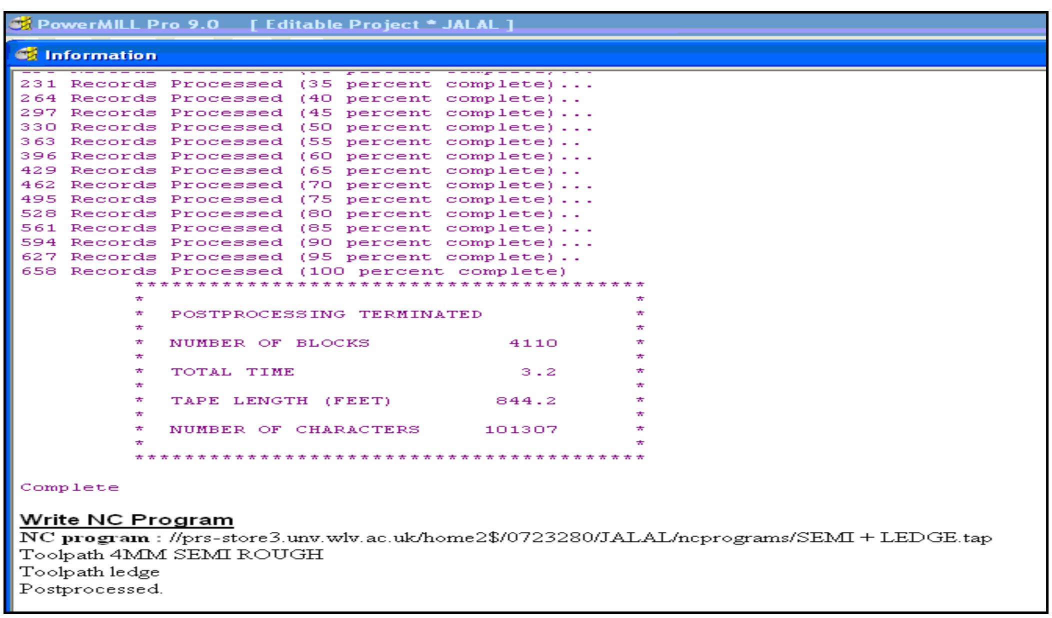

Figure (11): shows NC Program, the new time cycle for the (Semi-Roughing and edges) Tools, together. (Figure obtained from practical programming part project to PowerMILL software).

The stage before second stage must be able to input 25 parts to this stage too. Due to the time cycle for First Roughing is (4.3 minutes, figure 2-A) for each side, the whole Roughing time (8.6 minutes) for each part.
60 ÷ 8.6 = 6.9 part per hour from each machine
25 ÷ 6.9 = 3.623 ≈4 number of required machine
6.9 × 4 = 27.6 part per hour

The stage gives some extra parts every hour, same as the second stage. This stage needs a solution to avoid accumulation of parts at the end of the stage. The machines must slowed or stop these machines earlier time than the last stag.

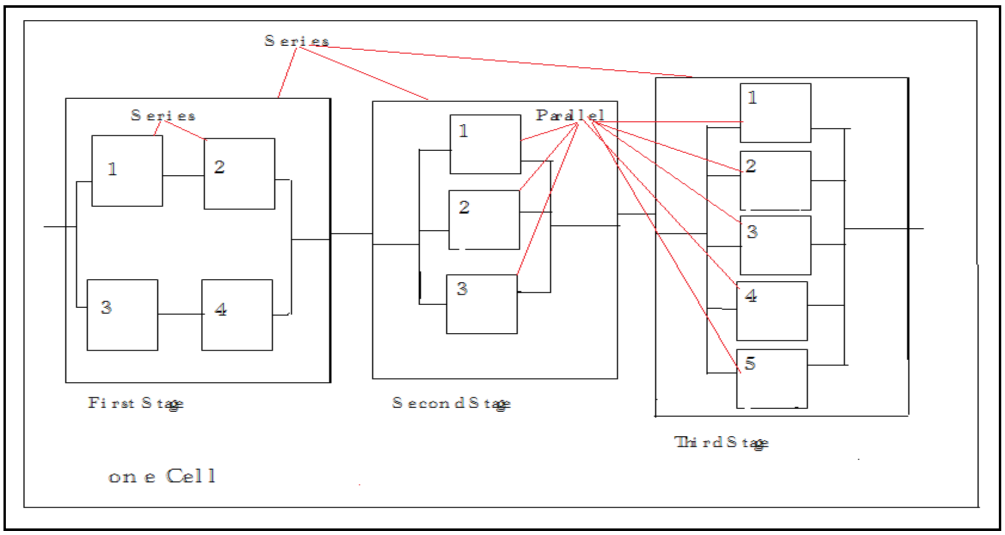

Diagram (3): Illustrates the cell consists of three series stages with the number of required machines in each stage.

First stage consists of four machines which are setup with the tool (No.5) to do the First Roughing in the parts, this takes (4.3 minute) per each side figure (2-A). The machines in second stage are setup to do (Semi-Rough and Edges) together which takes (3.2 minute, figure 11) per each side. But the third stage machines setup to do only Finishing on parts which takes (6 minute, figure 9).

Hence:
Third stage produces 5 parts per hour from each machine;
5 part ×5machine = 25 part per hour
500 ÷ 25 = 20 hours daily required time to run the machines

Through the 20 hour continues run for the machines, the target can reached. But the production preparation schedule usually comes with plan for break down time for the machines which in most cases estimated by 10% of actual time of machining. Also the time for operator's lunch breaks which at least estimated (30 minute per shift). There are some other lost times between the shift changeovers, can estimate by (30 minute) par day.
20 × 10% = 2 hour per day (machines down time)
3 × 0.5 hour = 1.5 hour (operator's lunch time)
2 + 1.5 + 0.5 = 4 hour total down time per day

The calculation above proves that the company at least needs to make a cell within 12 machines and run 3 shifts per day to reach the daily target. If there any unexpected machine down which cause delay in delivery, or any late delivery the blocks, can covered during weekends as overtime work. This is the minimum machines number and running time to deliver the request parts at the time to customer.

c) Third Suggestion: Reducing the tools cycle time to minimum;

In an attempt to reduce the First Roughing cycle time tool (No.5, table-1) changed to the tool (No. 3, 10mm Diameter Flat Slot Drill, table-1).The first Roughing cycle time increased to (4.8 minutes, Figure12-Appendix), that is because these two tools have the same standard for speeds and feeds, but the diameter of tool (No.5) is (12mm) while diameter of tool (No.3) is (10 mm) which cuts less, so the cycle time increased with this change. Also the Semi-Roughing cycle time increased incredibly from (2.7 minute, Figure 3-A) to (11.5 minute, Figure 13- Appendix) that caused by the value of material left from the First Roughing with the tool (No.3).

NC Program for the cycle time for all the tools (the four tools together) within the new setting with tool (No.3) show (24.8 minute, Figure14-Appendix) comparing by the cycle time for all the tools with tool (No.5, for First Roughing) which is show (13.5 minute, Figure 10), the cycle time raised an acceptable. So that, changing like this new setting cannot be used due to a big different cycle time for the part. This can also prove that the tool (No.5, 12mm diameter) is the best tool for the First Roughing in this process.

The fact of this project part implementation can be demonstrated in the various steps of the sequential system being followed by the company's ability of equipments and machines to specify the productivity process. To indicate the best plan to implement the production processes is necessary to have data concerning the machines, the fixtures, the tools or the specific parameters to integrate them into the planning system. For example, in the analysed suggestions, and taking into account only the part referring to process planning, but the production plan must consider many important parameters to determine the best consequences which lead to some important goals such as total cost, time delivery and capacity, which are main aims of product.

4. Conclusion:

This investigation presented an activity model to summarise all the steps needed to plan a product from the order stage to the product the order to be ready to deliver for client. This is an analysis encompassing two general independent decision processes, planning productivity processes and planning production. Developing the example has clearly demonstrated how each activity requires a set of information, or input, which it then converts into output according to the available resources used.
The implementation of the project part has been developed to integrate into planning productivity processes and the production planning of its processes. This demonstrates how the different processes effect the time, capacity of output of the systems, not only what currently equipments and machines availed but essential how they being used in the processes. The suggestions have established the framework, the relationships between the cycle time of tools and the productivity per limited time or limited number of machines.
This investigation not integrated the processes with all the parameters like machine tools and fixtures, shop floor machine's capacity, which have to be recorded, these production parameters such as the information related to distances between workshops, breakdowns, capacity must also be saved to perform the correct work and catch the delivery in limited time and cost.

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Appendix

```
155 Records Processed (25 percent complete)...
186 Records Processed (30 percent complete)..
217 Records Processed (35 percent complete)...
248 Records Processed (41 percent complete)...
279 Records Processed (46 percent complete)..
310 Records Processed (51 percent complete)...
341 Records Processed (56 percent complete)..
372 Records Processed (61 percent complete)...
403 Records Processed (66 percent complete)..
434 Records Processed (71 percent complete)...
465 Records Processed (77 percent complete)..
496 Records Processed (82 percent complete)...
527 Records Processed (87 percent complete)...
558 Records Processed (92 percent complete)..
589 Records Processed (97 percent complete)..
603 Records Processed (100 percent complete)
          ******************************************
          *                                        *
          *  POSTPROCESSING TERMINATED             *
          *                                        *
          *  NUMBER OF BLOCKS           2681       *
          *                                        *
          *  TOTAL TIME                  4.8       *
          *                                        *
          *  TAPE LENGTH (FEET)        328.6       *
          *                                        *
          *  NUMBER OF CHARACTERS      39427       *
          *                                        *
          ******************************************

Complete

Write NC Program
NC program : //prs-store3.unv.wlv.ac.uk/home2$/0723280/JALAL/ncprograms/FSD10-A.tap
Toolpath FSD10-A
Postprocessed.
```

Figure (12): shows NC Program, the new time cycle for the (First Roughing) with tool number (3). (Figure obtained from practical programming part project to PowerMILL software).

```
1375 Records Processed (55 percent complete)........
1500 Records Processed (60 percent complete).......
1625 Records Processed (65 percent complete).......
1750 Records Processed (70 percent complete).......
1875 Records Processed (75 percent complete)........
2000 Records Processed (80 percent complete).......
2125 Records Processed (85 percent complete).......
2250 Records Processed (90 percent complete).......
2375 Records Processed (95 percent complete).......
2484 Records Processed (100 percent complete)
         ******************************************
         *                                        *
         *  POSTPROCESSING TERMINATED             *
         *                                        *
         *  NUMBER OF BLOCKS          19096       *
         *                                        *
         *  TOTAL TIME                 11.5       *
         *                                        *
         *  TAPE LENGTH (FEET)       2501.1       *
         *                                        *
         *  NUMBER OF CHARACTERS     300132       *
         *                                        *
         ******************************************

Complete

Write NC Program
NC program : //prs-store3.unv.wlv.ac.uk/home2$/0723280/SEMI ROUGH.tap
Toolpath 4MM SEMI ROUGH
Postprocessed.
```

Figure (13): shows NC Program, the new time cycle for the new (Semi- Roughing) with tool number (1), which does the rest of tool No.3. (Figure obtained from practical programming part project to PowerMILL software).

```
2070 Records Processed (50 percent complete)..........
2277 Records Processed (55 percent complete)...........
2484 Records Processed (60 percent complete)..........
2691 Records Processed (65 percent complete)..........
2898 Records Processed (70 percent complete)...........
3105 Records Processed (75 percent complete)..........
3312 Records Processed (80 percent complete)..........
3519 Records Processed (85 percent complete)...........
3726 Records Processed (90 percent complete)..........
3933 Records Processed (95 percent complete)..........
4139 Records Processed (100 percent complete)
         ****************************************
         *                                      *
         *  POSTPROCESSING TERMINATED           *
         *                                      *
         *  NUMBER OF BLOCKS          33262     *
         *                                      *
         *  TOTAL TIME                 24.8     *
         *                                      *
         *  TAPE LENGTH (FEET)       4398.7     *
         *                                      *
         *  NUMBER OF CHARACTERS     527843     *
         *                                      *
         ****************************************

Complete
```

Write NC Program

NC program : //prs-store3.unv.wlv.ac.uk/home2$/0723280/ALL TOOLS.tap
Toolpath FSD10-A
Toolpath 4MM SEMI ROUGH
Toolpath 4MM FINISH
Toolpath ledge
Postprocessed.

Figure (14): shows NC Program, the new time cycle for all the tools (the four tools) with the new setting for tool (No.3). (Figure obtained from practical programming part project to PowerMILL software)

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