# Process Optimization of High Speed Cnc Milling Machine

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***Abstract-*** *In any manufacturing industries the major problem is to reduce the machining time of each operation so as to keep the cost low and high profit rate without sacrificing quality of the component. Due to high capital cost and machining costs of CNC machines, there is an economic need to operate CNC machines as efficiently in order to obtain the required pay back. Since the cost of machining on CNC machines is sensitive to the machining parameters, optimal values have to be determined before a part is put into production.*

*In this project the simulation model has been developed which develops the required machining time for each operation by specifying the exact tool and machining parameters. This project focuses on the minimization of manufacturing time. Genetic Algorithm is proposed for the optimization of machining parameters such as speed and feed with respect to the constraints (maximum machine power and cutting force) for milling operation in CNC milling machine and MASTER CAM is used as simulation software.*

***Keywords***- Simulation, optimization, Genetic Algorithm.

## I. INTRODUCTION

### 1(a)HISTORY OF NC TECHNOLOGY

We all know and heard the word automation. These machine works with primitive mechanical control system. The operating systems controlled by mechanical devices had their own advantages. As the industrial growth immersed the research and development of each company all over the world there engrossed with new ideas to bring out better machines which can deliver quality product in less time and with very little human effort. Scientists in Massachusetts institute of technology in the year 1948 started working on U.S. Air force concept projects to develop a computer packed controlling system for machine tools. The first ever numerically controlled (NC) machine, a hydraulic vertical spindle machine was built by Cincinnati Company in the year 1948. Then onwards a rapid technological advancement in the area of NC technology began.

In the year 1960, the NC machines built by Germans were displayed at the Hanover international trade fair. In the year 1965 the first batch of NC machines with automatic tool changer had appeared in the world market. In the year 1969, NC machines with pallet changing system was marketed. In the year 1972 the first batch of CNC incorporated system came in the world market.

In the year 1978 onwards the fast growth of CNC techniques was noticed. The features like graphic assisted path movements, interactive program inputs, scaling factors, mirror imaging etc. were incorporated in the machine memory system and side by side the computer integrated manufacturing developed and introduced.

### 1(b) APPLICATIONS OF CNC MACHINES

CNC can be applied to all types of machines ranging from simple sawing machine to complex contour grinding machines. Major application areas as follows:

1. Metal cutting machines: CNC milling, CNC turning, CNC drilling/jig boring, gear cutting CNC grinding etc.
2. Metal forming machines: Press tools, Injection/ Blow Moldings / Die casting machines tube bending etc.
3. Non – Conventional machining processes such as,
   - EDM Die- sinking and EDM wire cut machines,
   - Plasma Arc cutting machines.
   - Electron beam machining,
   - Laser beam machining,
   - Ion beam machining,
   - Ultrasonic Machining, etc.
4. Welding machines: TIG, MIG, Submerged Arc welding, etc.
5. Inspection and quality control systems: CMM, LMM
6. Assembly, Testing and Des-patch equipment and
7. Tool and work handling systems.

The rapid evolution of CNC technology transformed the complete manufacturing technology and leads to modern concepts of CIM- Computer integrated Manufacturing and Engineering.

### 1(c) ADVANTAGES AND DISADVANTAGES OF CNC MACHINE

**ADVANTAGES:**

**i).REDUCED NON PRODUCTIVE TIME:**

It accomplishes this by means of fewer set ups, less time in setting up, reduce work piece handling time, automatic tool changes on some machines etc.

**ii).CONSISTENT CUTTING TIME (Cutting time):**

CNC machining is under the control of a computer. The main benefit of a consistent cutting time is for repetitive jobs where the production scheduling and work allocation to individual machine tools can be done very accurately.

**iii).GREAT MANUFACTURING FLEXIBILITY:**

Can easy to modify engineering changes, alterations of production schedule etc.

**iv).IMPROVED QUALITY CONTROL:**

CNC produces part greater accuracy, reduced scrap and inspection frequencies.

**v).REDUCED INVENTORY:**

Due to fewer setups and more operation using same tool, the amount of inventory carried by the company is reduced.

**vi).REDUCE FLOOR SPACE REQUIREMENTS:**

Since one CNC machine can often accomplish the production of several conventional machines, reduce floor space .

## II. LITERATURE REVIEW

Process parameters such as cutting speed, feed rate and depth of cut are affecting on production cost and product quality. Thus it is important to use optimization technique to determine optimal levels of these parameters so as to reduce the production cost and to achieve the desired product quality simultaneously. Therefore, if an increase in productivity is desired then an increase in these three cutting parameters is required. But, there are limits to these cutting parameters since they also have an effect on the tool life, tool wear, surface quality, surface integrity, cutting force, and heat generation. Keeping this in view, many researchers have investigated effect of these parameters pertaining to the high speed machining. The following sections present the findings of some of the research studies involving these parameters with reference to high speed machining.

2.1 Studies on cutting force

The force acting on the tool is important aspect of machining. Knowledge of the cutting forces are needed for the estimation of power requirements, the adequately design of machine tool elements, tool-holders and fixtures for vibration free operations. Many force measurement devices like dynamometers have been capable of measuring tool forces with increasing accuracy. By measuring the cutting forces, one is able to understand the cutting mechanism such as the effects of cutting force, the machinability of the workpiece, the process of chip formation, and tool wear. The cutting force in even unsteady state conditions is affected by many parameters. The variation of cutting force with time has a typical characteristic. Cutting forces can be resolved into three components i.e. thrust force, feed force, and cutting force.
Pawade and Joshi [5] analysed multi-objective optimization of cutting force and surface roughness in the high speed turning of Inconel 718. A commercially available low cubic boride nitride (CBN) content inserts were used as cutting tool.Results showed that depth of cut had statistical significance on overall turning performance. They concluded that an increase in the value of predicted weighted GRG from 0.1160 to 0.2071 confirms the improvements in the performance of high speed turning process using optimal values of process parameters.
Aouici et al. [6] experimentally studied the effects of hard turning process parameters such as cutting speed, feed rate, workpiece hardness, depth of cut on surface roughness and cutting force. AISI H11 steel had a hardness of 40, 45, 50 HRC, machined using a CBN tool. Results showed that the cutting force components are influenced principally by the depth of cut and workpiece hardness.

Ozel et al. [7] carried out experimental investigation on the effects of cutting edge preparation geometry, workpiecehardness and cutting conditions on the surface roughness and cutting forces in the finish hard turning of AISI H13 steel. The results indicated that cutting force is influenced not only by cutting condition but also cutting edge geometry and workpiece surface hardness.

Lalwani et al. [8] carried out experimental investigation of process parameters influence of cutting forces and surface roughness in finish hard turning of MDN 250 steel. Results showed that cutting speed hasno significant effect on cutting force and surface roughness. Cutting force model: the depth of cut is most significant factor with 89.05% contribution in the total variability of model whereas feed rate has a secondary contribution of 6.61% in the model.

Fang and Wu Q [9] investigated a comparative experimental study of high speed machining of two materials- titanium alloy Ti-6Al-4V and Inconel 718. The results show that of both materials: while cutting speed increases then cutting force, thrust force and feed force are increases.

Ekanayake and Mathew [10] carried out experimental investigation of high speed end milling. The experimental results are cutting force increases with increasing feed and depth of cut does not show a specific trend with increasing cutting speed. This could be complex effect of temperature and strain rate on the flow stress of the material. From the observations, the chamfer insert is used high speed machining, because they are generated lower cutting force.

Kurt et al. [11] investigated the effects of chamfer angle on the cutting forces and stresses by PCBN cutting tools in finish hard turning of AISI 52100 bearing steel. They found that the chamfer angles (20° and 30°) have a great influence on the cutting forces and Von Mises tool stresses distribution.

2.2 Studies on surface integrity

The surface integrity of machined part after high speed machining gives further information about the physical properties of machined surface. Surface integrity includes the existence of micro-cracks, surface finish, untempered and over tempered mertensite, phase transformation, residual stresses imposed by the machining process, the pull-out of carbide from the grainboundary,plastic deformation and change in microhardness. Residual stress on the machined surface and subsurface is known to influence the service quality of a component, such as fatigue life, tribological properties, and distortion. The findings of some of the research studies pertaining to the effect of cutting parameters on surface integrity are presented below.

Peng et al. [12] studied the effect of machining on microstructural and residual stresses respectively. High speed turning of Inconel samples under different cutting conditions. It was concluded that mechanical force and heat generation are most significant process parameters affecting on microstructural and residual stresses.

## III. METHODOLOGY

### 3(a) Introduction

This concludes with creating of a 2D model, selection of material, selection of cutting tool , speed ,feed, properties of material and tool path generation .

High Speed Machining (HSM) of hardened die steels should not be feared but embraced. Many people feel that hard metal machining is a black art, but with a few basic principles it is not only profitable but also a straight forward machining process. There are several components of the process, which include: the effective utilization of the machine tool, cutting tools, tool holders, and programming. If these areas are addressed correctly, hard metal machining loses its mystery and mystique and becomes a predictable process where established formulae and guidelines can be used. In this article, the focus is on the cutting tool but other areas will be addressed as well.

### 3(b) Choosing the Process

There are three major machining methods: soft machining, hard machining, and EDM. The configuration and hardness of the die or mold material determine which method or combination of methods will work best. Soft machining – machining the part prior to heat treatment – should be considered when machining large parts of parts that require deep cuts. Semi – finishing and finishing can then be done in the hardened state. If the part is not very large, or calls for shallow machining, the entire part can be milled in the hardened state. If the part geometry requires thin features and deep cuts, EDM may be the only option.

In high speed milling there are two disadvantage

1) Temperature control between cutting tool and work job.
2) Cost control

Due to high temperature some time cutting tool will be melted. This problem can be solve by selecting suitable cutting tool material ,spindle speed , feed rate and coolant.

### 3(c) Selection of spindle speed and feed rate

Function F and S code

These are given according to the tools to be used and the material of the work piece to be cut.

| | |
|---|---|
| F01 | 1mm/min |
| F10 | 10 mm/min |

| | |
|---|---|
| F1000 | 1000 mm/min |
| S10 | 10revolution per min (rpm) |
| S1500 | 1500 revolution per min |
| S4000 | 4000 revolution per min |

**3(d) CUTTING SPEED, RPM & FEED FORMULA**

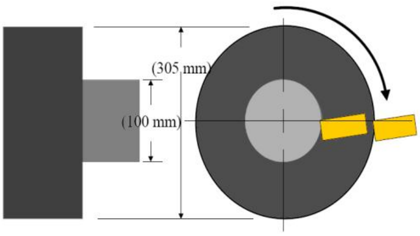
$$\text{Cutting Speed} = \frac{3.14 \times D \times RPM}{1000}$$

$$RPM = \frac{\text{Cutting Speed} \times 1000}{3.14 \times D}$$

End Mill Feed = Speed x No of tooth x Feed per tooth
Drill Feed = Speed x Feed per revolution
Tap Feed = Speed x Pitch

CUTTING SPEED (Vc) Vs RPM

Vc – dependant on material of work piece / tool & cutting conditions
RPM – dependant on diameter




Figure(1) Effective

| To Find | Given | Formula |
|---|---|---|
| Vc | D, rpm | $Vc = \frac{3.14 \times D \times RPM}{1000}$ |
| RPM | D, Vc | $RPM = \frac{Vc \times 1000}{3.14 \times D}$ |
| f | F | f = F / RPM |
| F | fz, Z, RPM | F = fz x Z x RPM |
| fz | F, Z, RPM | $fz = \frac{F}{Z \times RPM}$ |
| fz | Z, f | Fz = F / Z |

| Legend | |
|---|---|
| Vc | Cutting Speed |
| f | Feed per revolution |
| F | Feed per minute |
| fz | Feed per tooth |
| Z | No. of effective tooth or inserts in cutter |
| 3.14 | 3.1416 |

**3(e) Calculation Speed & Feed by using below data**

- Cutting speed (V)=250 m/min
- Cutter Diameter (d)= ø 10 mm
- No of tooth (z) = 2
- Feed per tooth (ft ) = 0.1

Calculating RPM:

$$n = \frac{250 \times 1000}{3.14 \times 10} = 7960\text{rpm}$$

Calculating Feed :

F = 7960 x 2 x 0.1
(n x z x f)
F = 1592mm/min

**3(f) Calculation Cutting Speed & Feed Per Tooth by using below data**

- Rpm = 15000 rev/min
- Feed = 3000 mm/min
- No of tooth = 2
- Cutter Diameter = 6 mm

Cutting speed :

$$V = \frac{3.14 \times 6 \times 15000}{1000} = 283\text{m/min.}$$

Feed per tooth :

$$= \frac{3000}{2 \times 15000} = 0.1\text{mm/min.}$$

**3(g) Selection of cutting tools and tool raw materials.**

Selection of tools is depended up on the operation. In this project I am going to select two cutting tools one is bull noise and another is ball noise. Bull noise is used for pockets where fillet is required for between bottom face and side face. That mean bull noise tool have fillet or radius at is edge and it is used for both roughing and finishing . Ball noise it is used only finishing where we required smooth surface at inclined places and it is mostly used in 3axis machines. The corner radius tool does not have as large of a radius as the ball, and therefore does not dissipate the heat and force as well as the ball end mill. The square corner radius tool has removed as much materials as possible from the part. The sharp corner of a square end tool acts as a focal point for all the heat and force and will have a tendency to chip. The only time a square end mill should be used is when a sharp corner is required at the transition of a floor and a wall.

Selection of tool material is depend on work tool material. Basically there are several materials are used . There are some important properties we need to remember in the process of selecting cutting tool raw material there are

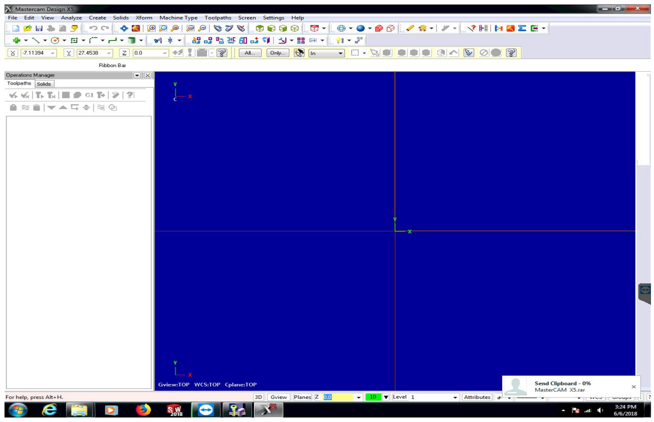
- The material must withstand excessive wear even though the relative hardness of the tool materials changes.
- Ability to retain hardness under severe working condition.
- Ability to withstand cutting forces.
- The frictional coefficient must remain low for minimum wear and reasonable surface finish.
- Cost and easiness of fabrication should have within reasonable limits.

By selecting the proper coating, higher temperatures can be reached without compromising the cutting tool. For example, the maximum working temperature for Titanium Carbonitride (TiCN) is 750 degree F (400 degree C) compared to Titanium Aluminium Nitride (TiAIN) with a maximum working temperature of 1470 degree F (800 degree C). Generally, TiAIN is the preferred coating for HSM of hardened die/mold materials because of its high heat resistance. The higher heat resistance of the TiAIN coating enables the use of faster RPMs without damaging the cutting tool.

### 3(h) Cost control

Cost control is the most important part and cost can be control in different types programming optimization most effect. By selecting proper cutting tools and feed also can reduce the cost. There is a another way to reduce the cost of machining by process optimization. Process optimization in this process we need to increase the machining time by reduce the ideal time or lead time. Ideal time mean where cutting is moving from one position to another position without touching any work job or cutting any raw material. Mastercam X5 is used for simulating the cutting process and to generate part program.

In this process of program optimization cam software are very helpful. In mastercam x5 2D drawing is required to create tool path. This drawing can be drawn in mastercam or autocad file can be open in mastercam. In our work drawing is drawn in mastercam by using 2D tool commends and xform commends. Creating programming optimization for cavity plate for single setup



Above figure 2 show how the Mastercam work bench look like and how it is divided in to work coordinates

**Step 1**

Pocket right click on the operation manager. select milling operation and select the pocket

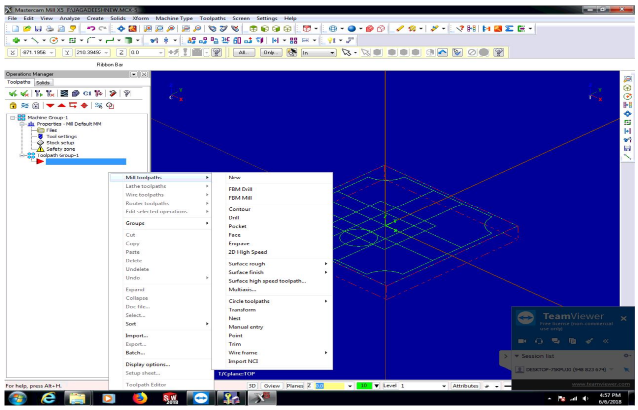
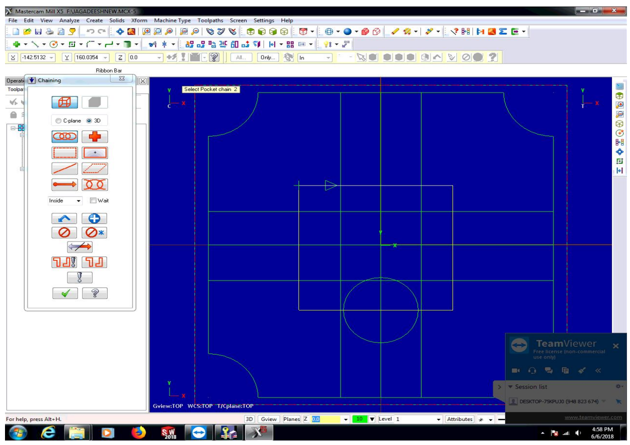
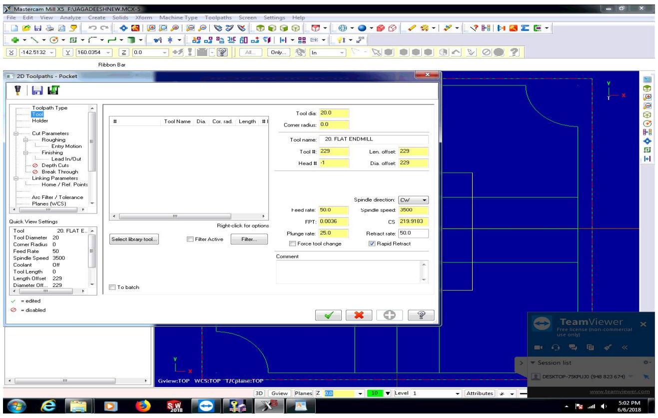


Figure (3) selection of operation

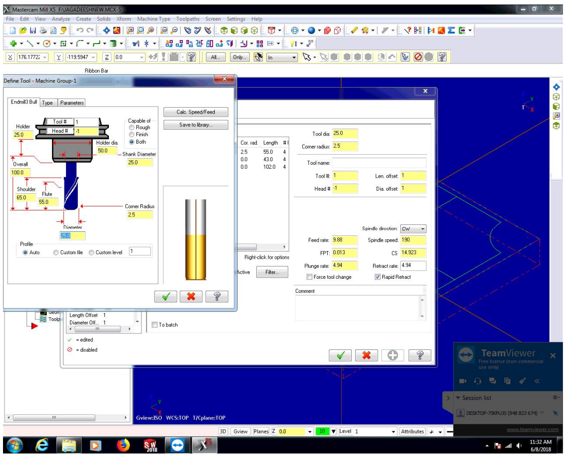


Figure(4) Select chain and select the pocket area. Click on the direction of cut



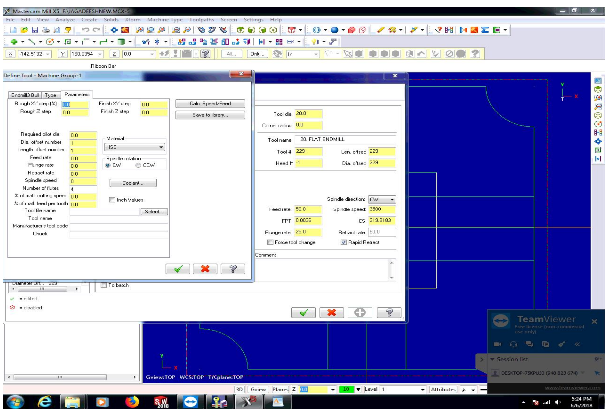
Figure(5)

2D tool path will be open as show above fig 5 and click on tool

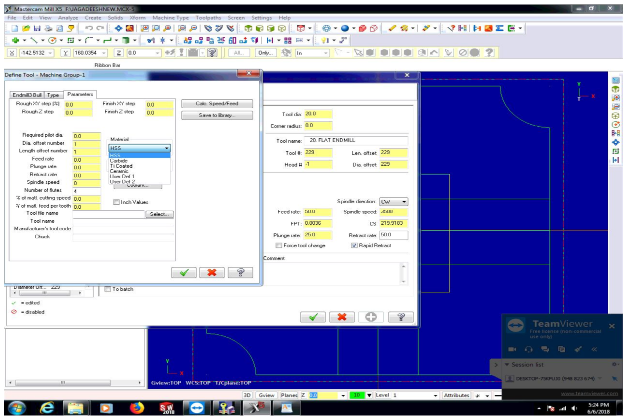


Figure(6) selection of tool

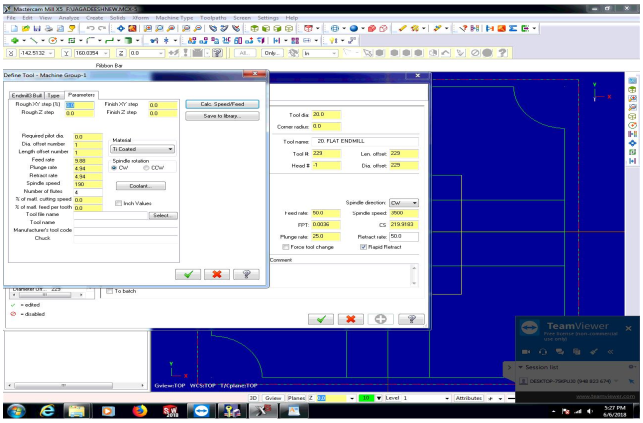
- Select tool from the library (or) right click and select the new tool.
- In this process select the bull noise 25 dia with radius 2.5.



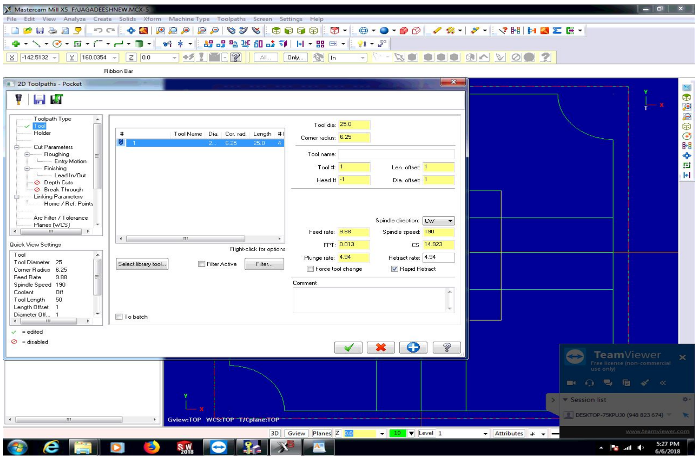
Figure(7) Speed and feed can be calculated automatically by clicking on the calc speed and speed or type manually as show above.



Figure(8) selection of Tool parameters like raw material and no of flutes.

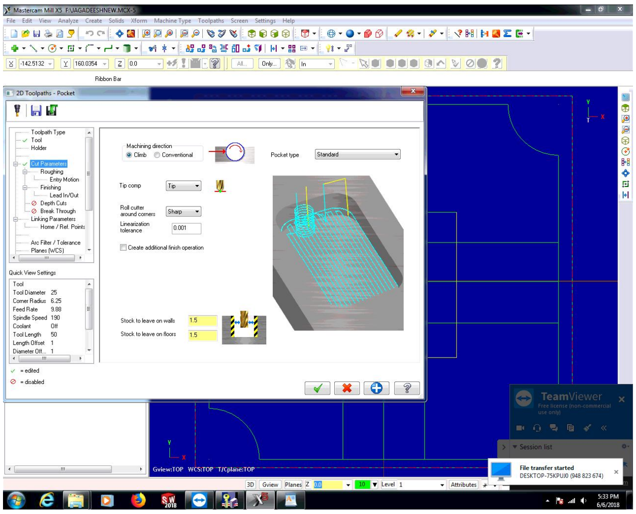


Figure(9)



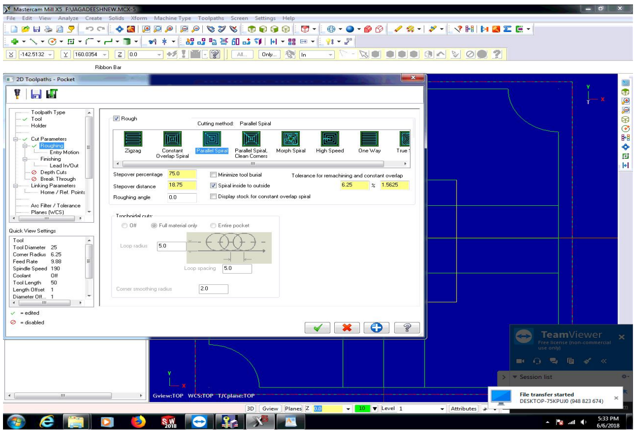
Figure(10)

- As seen in above figure 10 feed rate, spindle speed, FPT,CS and Plunge rate
- FPT means Feed per teeth.
- CS means Cutting speed.
- Any value can be change as per our requirement.



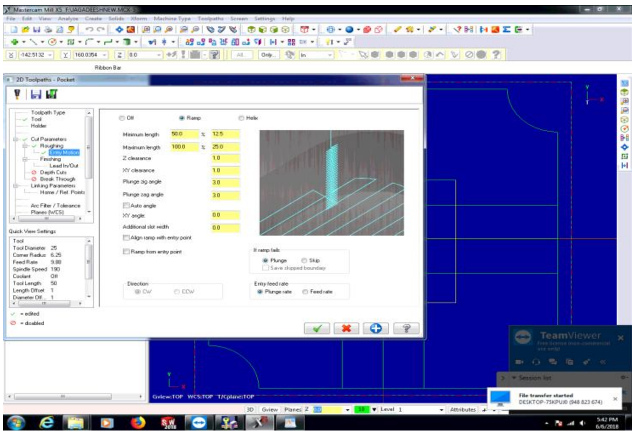
Figure(11) Select the cutting parameters

- click on the machining direction click either climb or conventional as show in the above figure 11



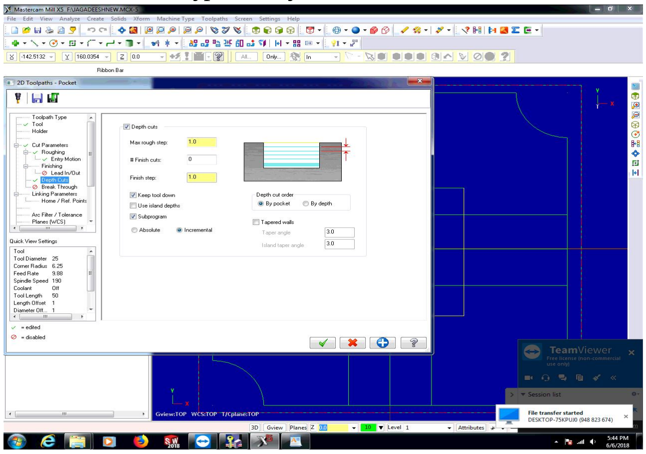
Figure(12) Select the roughing in cutting parameters

- There are different type of roughing types select the required suitable



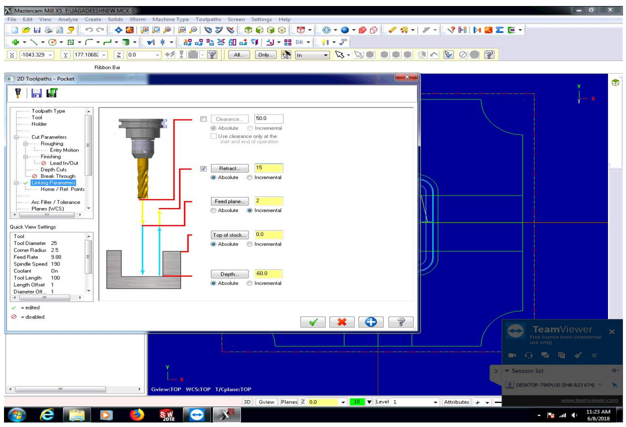
Figure(13) Select the Entry motion

- Select the Entry motion is very important there are different types entry motion



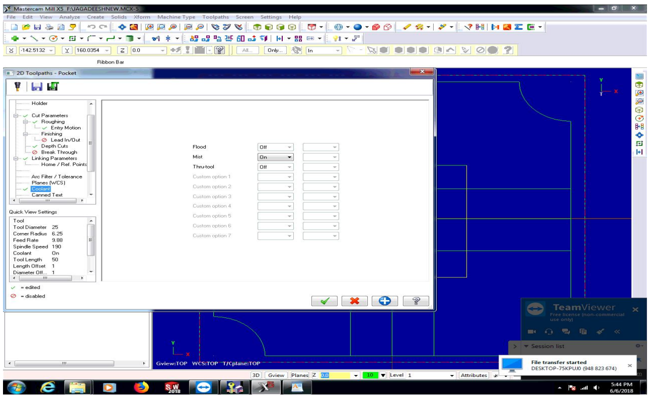
Figure(14) depth cuts

- Depth of the cut is very important in order to decrease load on cutting tool.
- Max rough step means depth of cut layer by layer my depth of cut is 1mm as show in fig 14
- Select the keep tool down is very important so cutting tool will no lift until the pocket is over so ideal time will be decrease.

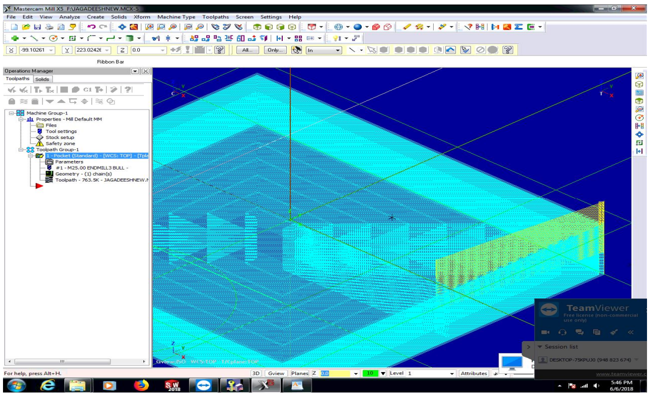


Figure(15) select linking parameters

- Select linking parameters in linking parameters tool retract, feed plane , top of stock and depth.
- Tool retract means tool lift after cutting the job.
- Feed plane means at which height load will be applied on the tool.
- Top of stock means where machining need to be start.
- Depth means total depth of the cut in raw material.



Figure(16) Selection of coolent.



Figure(17) This fig show tool path.

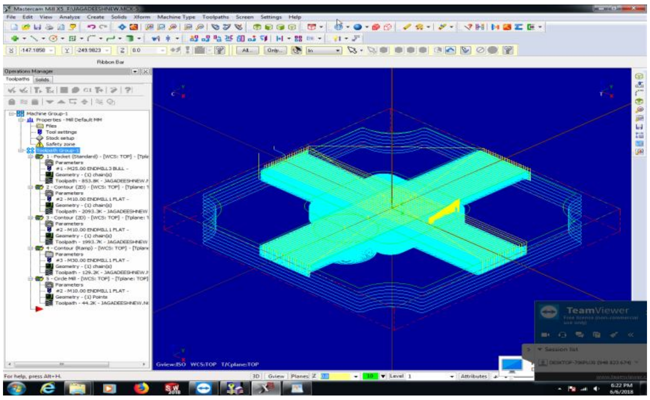


Figure (18) Tool Path generation

The above fig 18 show all the tool path .

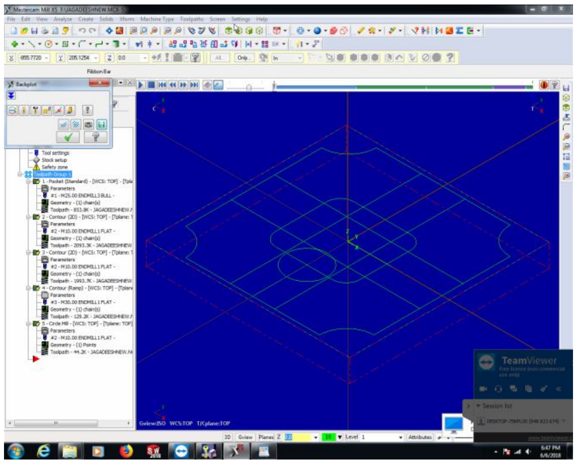
## IV. RESULTS AND DISCUSSION

Simulation of all the operations can be do either 2D tool verification or 3D tool verification

By modify any values or any tool in the above operations tool path must be regenerate before simulation to regenerate click on  regenerate tool path.

**4(a) 2D tool verification.**

By clicking on the 2D tool verification backplot will be open and select required things like tool show or tool path show in figure 19



Figure(19) selection 2D verify

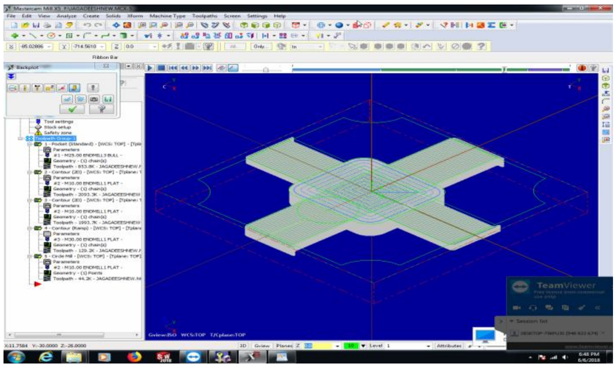
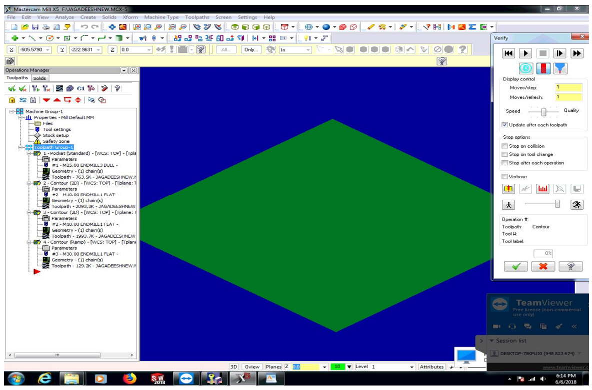


Figure (20) verifying tool path

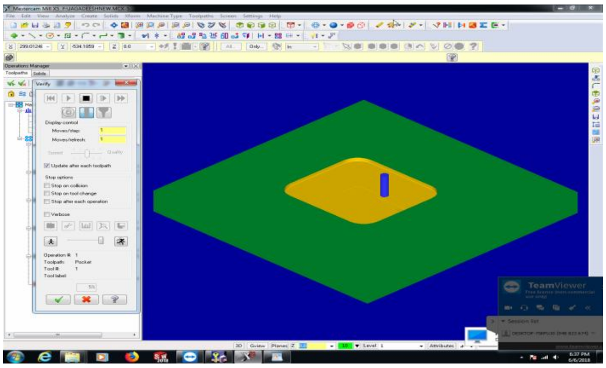
**3D tool path verification**

by clicking on the  verify.



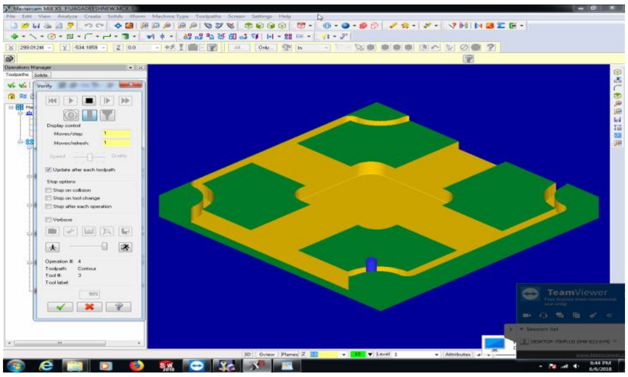
Figure(21) 3D verify

| Methods | Opereations | Spindle Speed (m/min) | Feed Rate (mm/ Tooth) | Machining time | Total machinng time |
|---|---|---|---|---|---|
| Without appling Ramoing and keep tool down | Pocket Milling.<br>Counter 1<br>Countur2<br>Counter3<br>Circular drilling. | 190<br>477<br>477<br>477<br>358 | 0.015<br>0.039<br>0.039<br>0.039<br>0.026 | 32.45<br>28.22<br>28.22<br>47.28<br>18.03 | 2hours .56.2mins |
| With Ramping and keep tool down | Pocket Milling.<br>Counter 1<br>Countur2<br>Counter3<br>Circular drilling | 190<br>477<br>477<br>477<br>358 | 0.015<br>0.039<br>0.039<br>0.039<br>0.026 | 36.95<br>29.752<br>29.752<br>56.838<br>18.73 | 2hours .38.2mins |



Figure(22) Cutting Pocket

- In the above figure 22 Pocket operation is done by using bull noise cutting tool



Figure(23) countur cuts

In the above figure 23 counter operation is doing by using end mill in ramping with 3 degree entry.

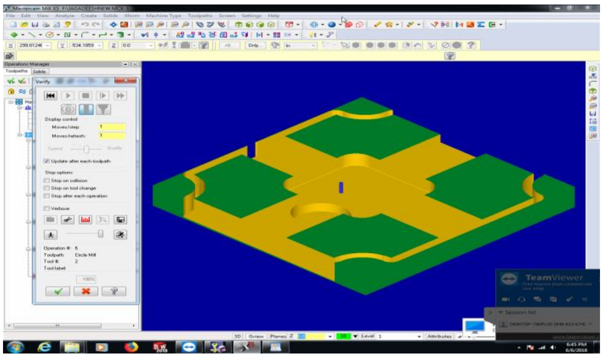


Figure (24) Final cut

While doing machining we can not cut material through all atleast leave the material up to 1 mm or 0.5 mm in order to aviode the damage to cnc bed

## V. CONCLUSION

- The simulation process is finding to minimize the ideal time in high speed machine is carry out for one of the model.
- Initially 2D model is generated which is undergone by five milling operations (Pocketing, three contour and circular drilling ) and required machining parameters(speed, feed and depth of cut) is given.
- While giving the tool path we found that two milling operation can be minimized pocketing and contour.
- In pocketing and contour feed plane high is 2mm in incremental and by selecting keep tool down so ideal time decrease that mean machining time is increase so 10.22% time is saved in this process .
- For outer profile or (3)counter 15mm tool diameter is chosen instead of 18mm since clamping is done on two corner sides for part to avoid the damage.

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