ADVANCED CAD/CAMSYSTEMS

Mould Design/Validation and CNC Machining

Author:

Mohammad Foroughi

Contents

1. **Introduction**

Computer aided design (CAD) is a computer technology which allows the users to create they desired models and visualise it in 3D environment. Today would not exist without the help of CAD. Virtually every building we visit, every product or price of equipment we use and every man made environment we explore is the result of CAD. Computer aided design (CAD) allows you to produce diverse consumer products efficiently and effectively (Adigitaldreamer 2010). The 3D model can be change from the dimensions to the materials very easily using the CAD, Also it can be reused and integrated with other software. Today CAD has many exchange transformation data files which allow the 3D model integrated with other CAD packages.

In the manufacturing world CAD can be linked to the manufacturing machines such as CNC. Computer aided manufacturing (CAM) refers to the software that is used to generate instruction codes for the CNC machine which allows the machine to cut out the created shape from CAD physically. Sometimes the CAM software is integrated with CAD systems, but not always. Every bits of CAM software should solve the data exchange problem of CAD. Whilst in CAD system which produces the data, it often stores in its own proprietary format which is similar with world processes. Usually it is necessary to change the CAD operator to export the data in one of the common data formats such as, IGES or STL.

2. Moulding Process

The injection moulding process first was design around 1930s and originally was based on metal die casting design. Injection moulding offers many advantages to different manufacturing methods, including minimum losses from scrap (since scrap pieces can be melted and recycle) also minimum finishing requirements. Injection moulding differs from metal die casting in that molten metals can simply be poured with injecting the plastic resins by force.

The process uses large injection molding machines, which advance the resins through six major processes to produce everything from computer parts to plastic Halloween spiders. Although an injection moulding machine is a complex piece of equipment, it consists of two basic elements, the injection unit and the clamping unit.

The process starts with a mold, which is clamped under pressure to accommodate the injection and cooling process. Then, pelletized resins are fed into the machine, followed by the appropriate colorants. The resins then fall into an injection barrel, where they are heated to a melting point, and then injected into the mold through the runners.

Then comes the dwelling phase, in which the molten plastics are contained within the mold, and hydraulic or mechanical pressure is applied to make sure all of the cavities within the mold are filled. The plastics are then allowed to cool within the mold, which is then opened by separating the two halves of the mold. In the final stage, the plastic part is ejected from the mold with ejecting pins. The completed part may contain unrelated bits called runners, which are trimmed off and recycled. The whole entire process is cyclical, with cycle times ranging from between ten and 100 seconds, depending on the required cooling time.

The whole injection moulding process requires some complex calculation. Every different type of resin has a shrinkage value which most be factored in, If this value is not correctly determined, the final product will be incorrectly sized or may contain flaws. Injection molding can be used with a variety of plastic resins, the most popular resins for this type of molding include: polypropylene (PP), polyethylene (PE), and ABS. Each resin has its own set of advantages and disadvantages and are chosen based on the desired characteristics of the final part.

Injection molds themselves can be surprisingly expensive, however, is great enough, the mold cost becomes relatively insignificant, and the resulting plastic parts are very reasonably priced. Some molds are made with more than one cavity; these multi cavity molds cost more than their single cavity counterparts, but due to increased production efficiency, the cost per part is minimized. (Wise Geek, 2010)

2.1 Advantages of Injection Molding

- High production rates
- High tolerances are repeatable
- Wide range of materials can be used
- Low labor costs
- Minimal scrap losses
- Little need to finish parts after molding

2.2 Disadvantages of Injection Molding

- Expensive equipment investment
- Running costs may be high (Injection molding, 2010)

3. Mould Design Validation

A mould mainly consists of two parts they are namely:

- Inner surface known as core
- Outer surface known as cavity

After the mould is been created by using the solid model the next step is to design the runners, injection point, gates, vents and etc.
To manufacture the part, the core and cavity are joined together and melted material will inject in to the system and then solidified generate the part.

The below process was fallowed to create the core and cavity for the break disc

1. Mould design (core and cavity)
2. Gates design
3. Runner design
4. Injection point
5. Vent and cooling system

1. Mould Design (Core and Cavity)

After creating break disc using solidworks 2010 software the model was import it to NX6 software for mould design and manufacturing process.

To start the mould process the model was Initializing first in order to select the material (ABS), shrinkage (1.006) and units (Millimeter).

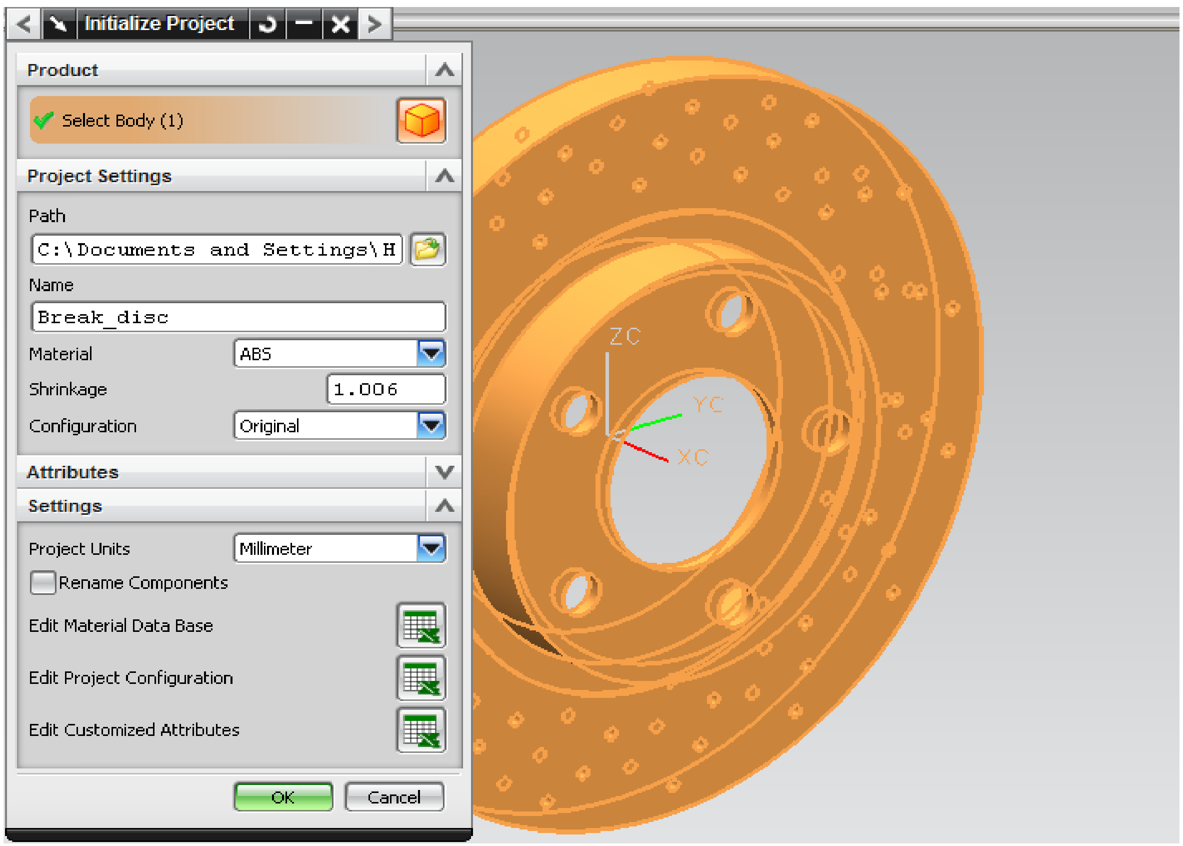


Figure 1

After Initializing the project next step is to set the origin of the mold assembly.

- The origin of the mold assembly is at the center of the mold base
- The XC-YC-plane of the mold CSYS is where the fixed and moving plates meet (the principal parting plane)
- The positive ZC-axis points in the direction in which the molded part is ejected from the mold

By using the **Mold CSYS** command to orient and position the product subassembly in The mold base so that the ejection direction of the product part matches the mold WCS Z+ direction, and so that the parting plane of the product part lies on the XY-plane of the mold

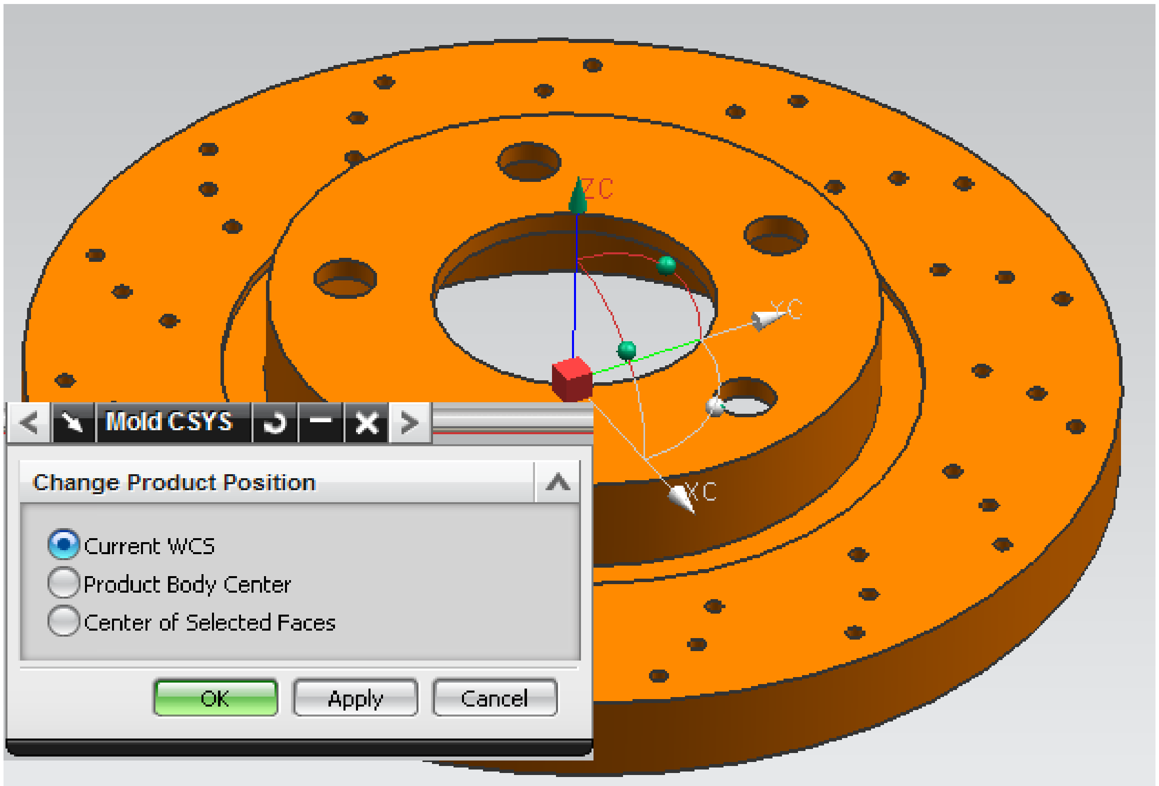


Figure 2

The next step after setting the origin in the right direction is to set up the workpice to match the available standard plate thickness in the mold base which will be use. Simply by activating workpice the type and size of workpice can be defined.

Definition type:

Size	Minus	Plus	Total
X	24.25	24.25	300
Y	24.25	24.25	300
Z	40	56	96

Table 1

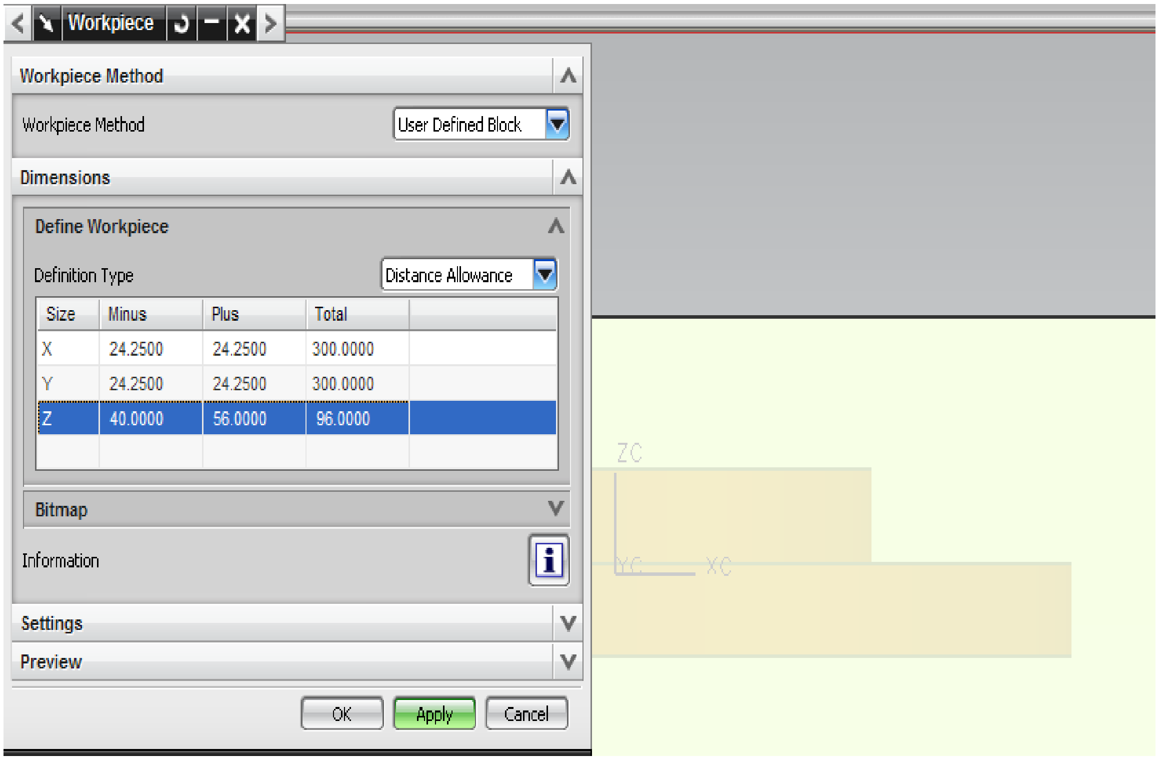


Figure 3

The next step is to define the cavity layout for the total number of the mould cavities and their position in mould.

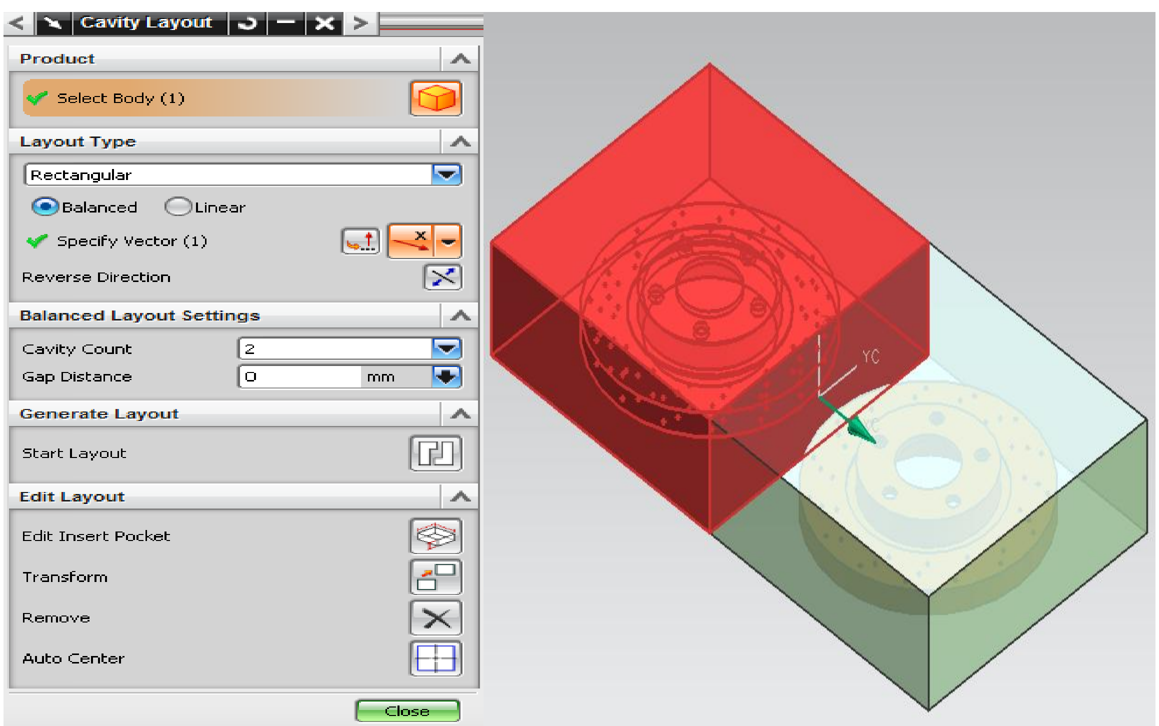


Figure 4

Figures 5 and 6 show that the dimension and type of the pockets which been selected.

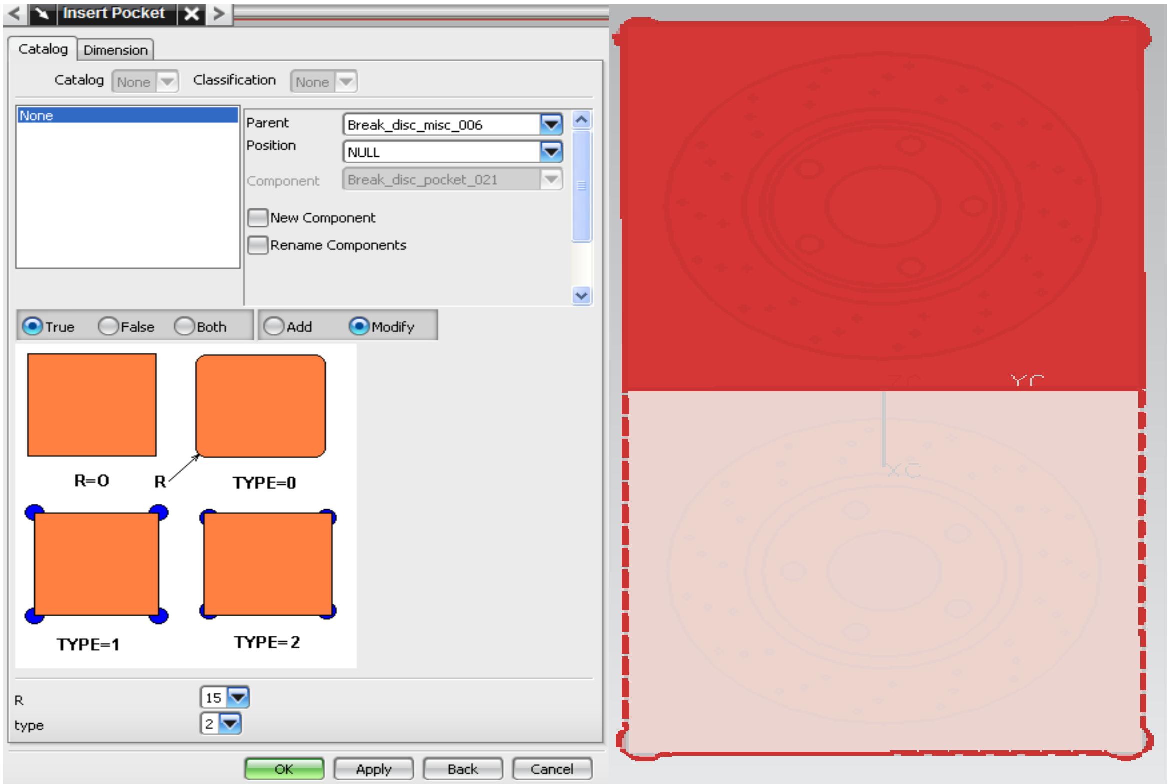


Figure 5

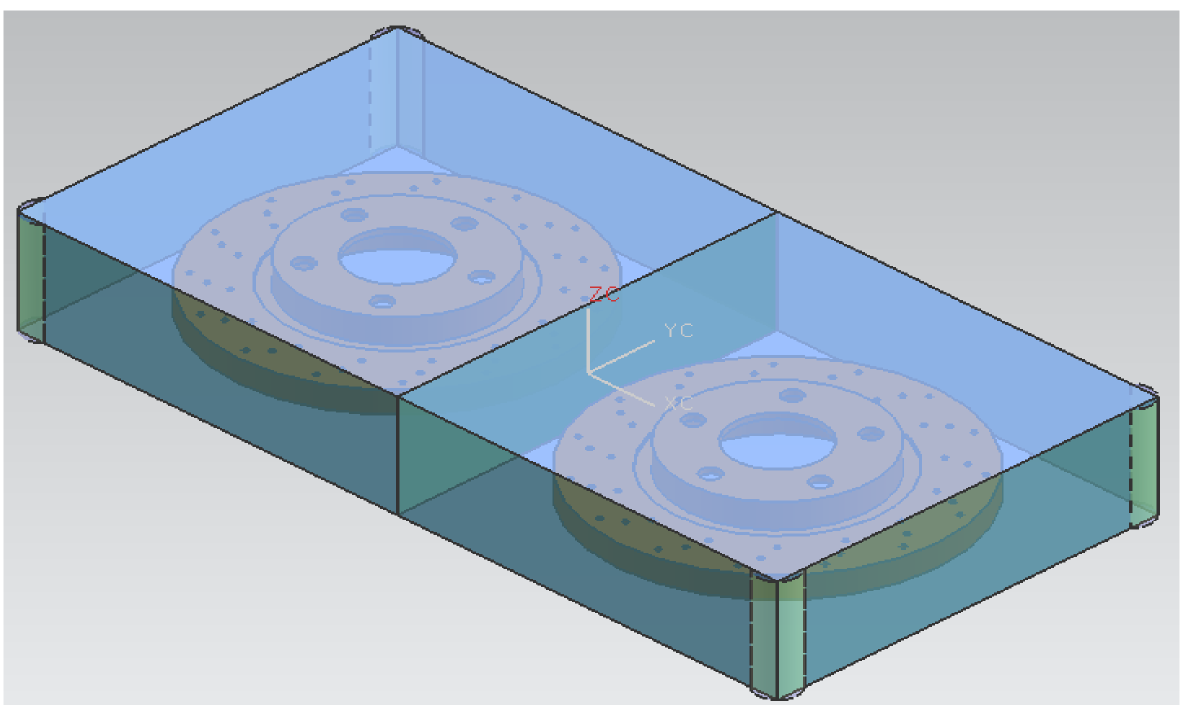


Figure 6

Next stag is to defining a parting which consists of several steps, parting steps which been use for this process are include

1. Design Regions
2. Extract Regions and Parting Lines
3. Create/Delete Patch Surfaces
4. Create/Edit Parting Surfaces
5. Create Cavity and Core

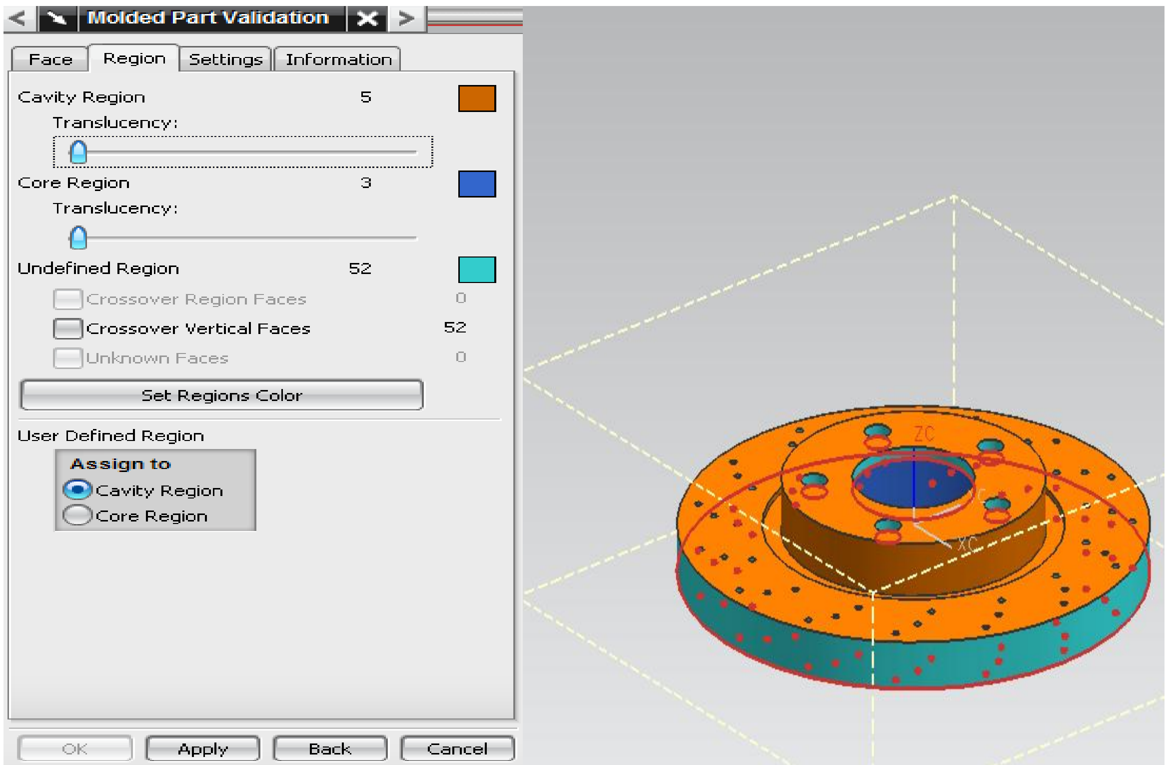


Figure 7

In order to set the design regain for the part first moulded part needs to be validated by set the regions colour as shown in above figure, also it can be notice that 52 crossover vertical faces are undefined region which can be selected for core and cavity in next step.

Figure 8 and 9 shows that 11 region been selected for the cavity and 49 region for the core part.

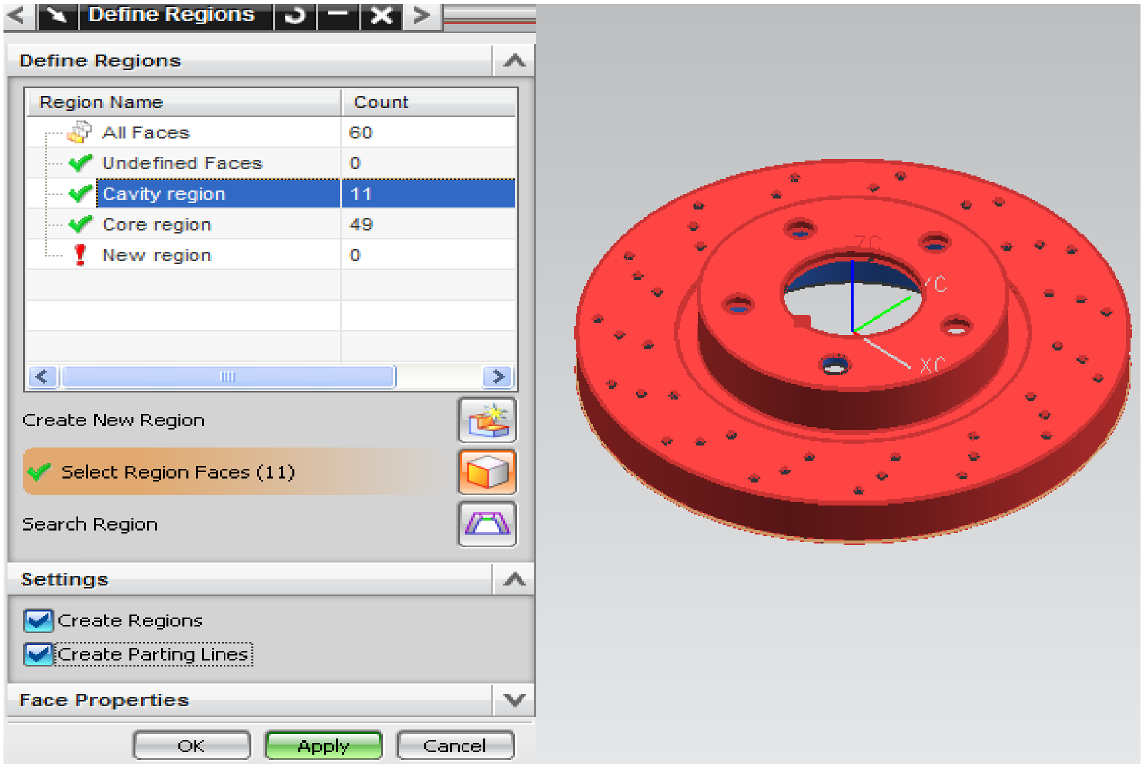


Figure 8

Also the above and below figures shows the region and parting lines been created for the model.

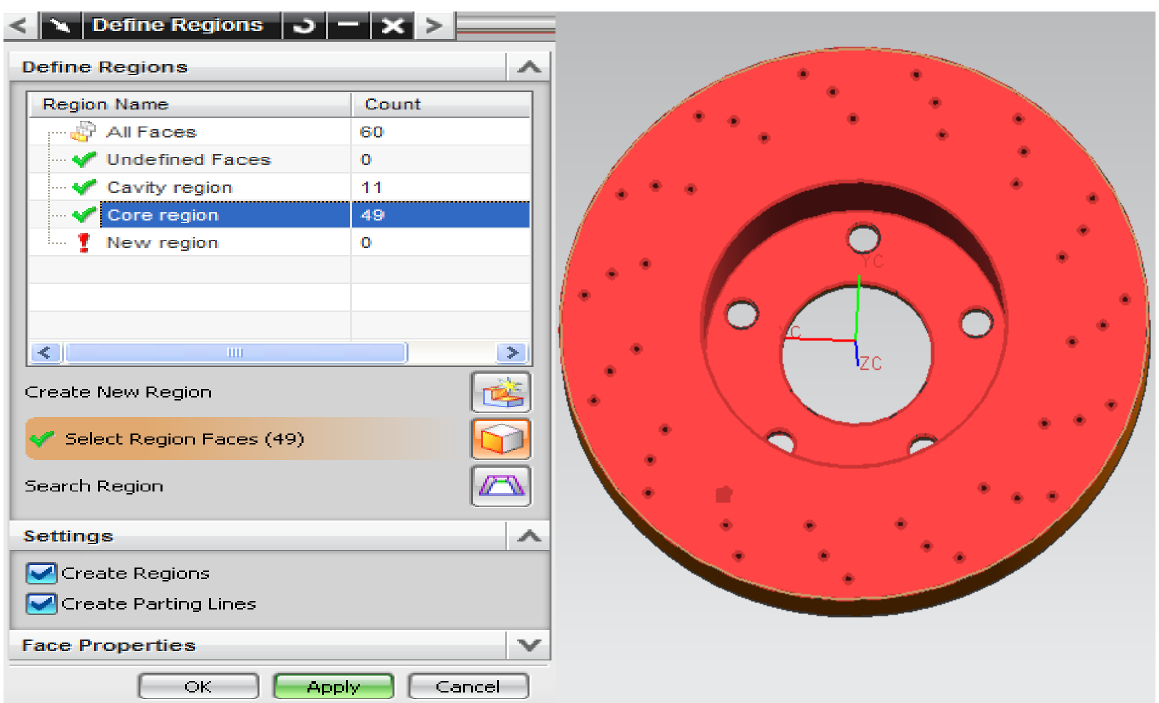


Figure 9

Each of the two internal openings must have a shut-off or patch-up sheet to define the Contacting cavity steel and core steel surfaces in the opening, there for the next step is to Create Patch Surfaces.

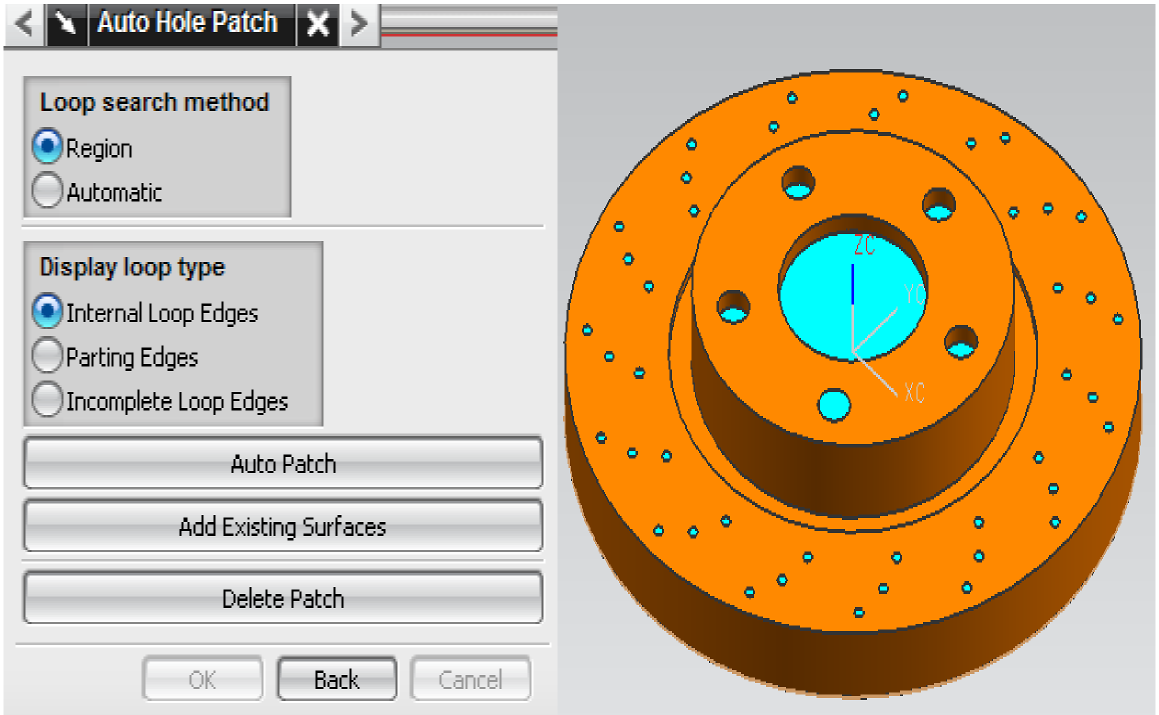


Figure 10

Figure 10 shows the loop search method been set to region and display loop type set to internal loop edges, by using the auto patch option all the holes in the core and cavity region will be patch.

The next step after patching is to create parting surface. The parting sheet will be automatically sewn together with the region features and patch sheets to trim the cavity and core inserts.

Figures 11 and 12 show that how the parting surface was created for the core and cavity.

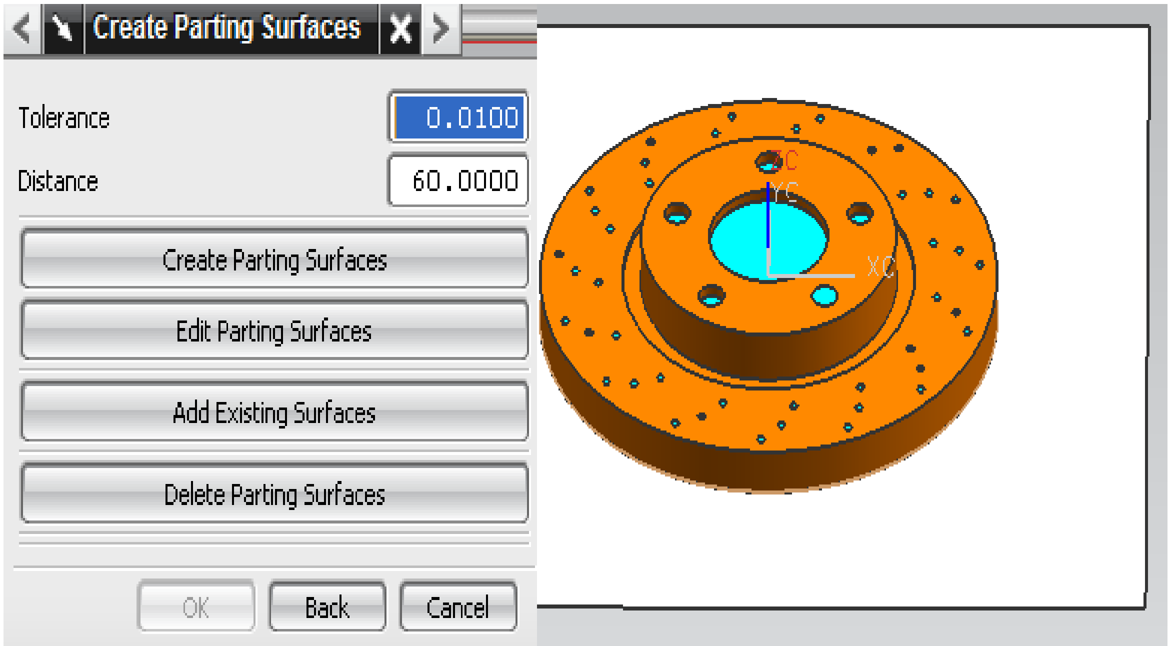


Figure 11

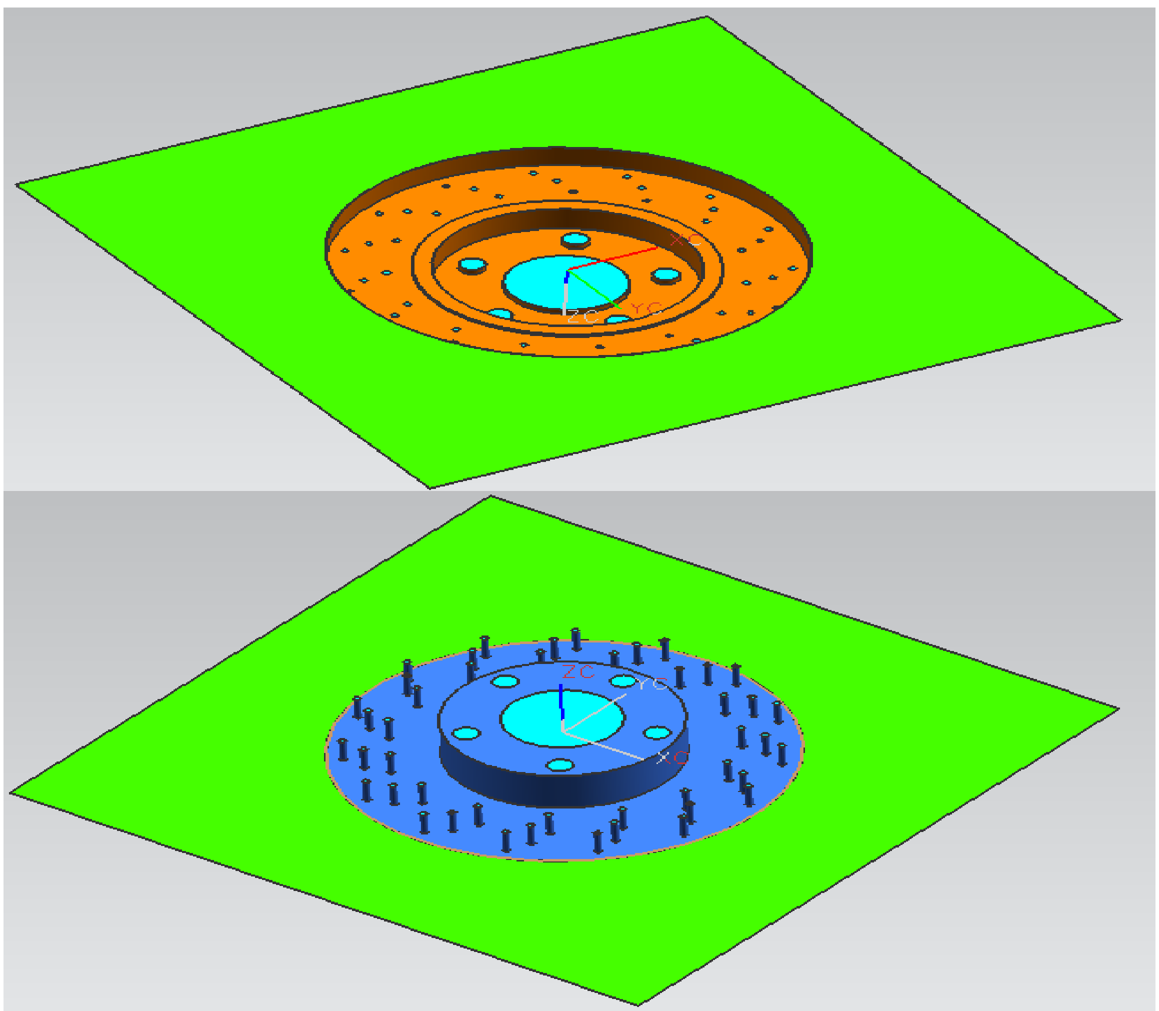


Figure 12

After creating parting surface the next and final step for the parting section is to create core and cavity. By creating the core and cavity copies of the parting surface, the two patch sheets, and the extracted region sheets are sewn together and used to trim-existing WAVE linked insert blocks.

Figure 13 and 14 show the core and cavity block at this final stage of parting.

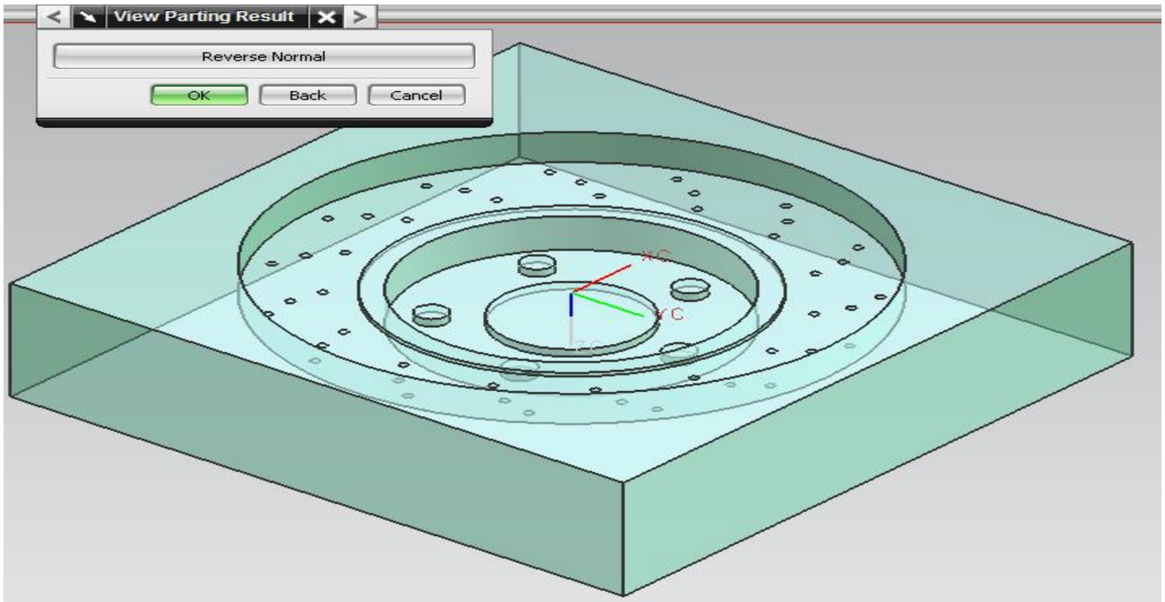


Figure 13

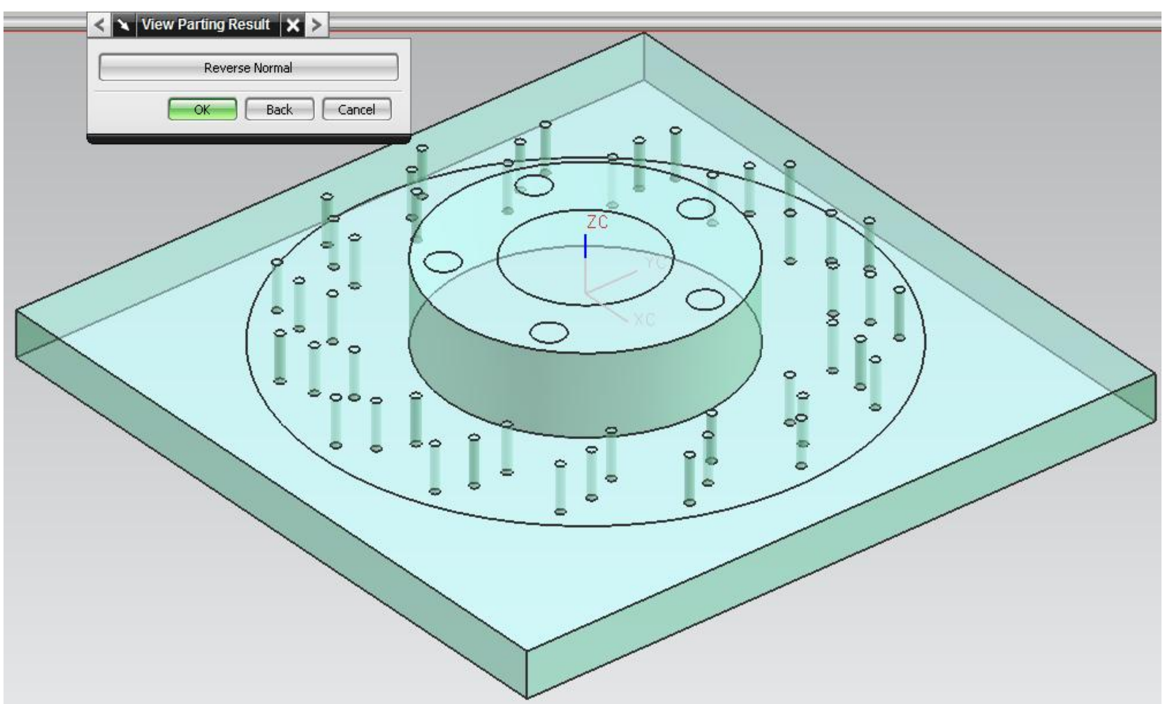


Figure 14

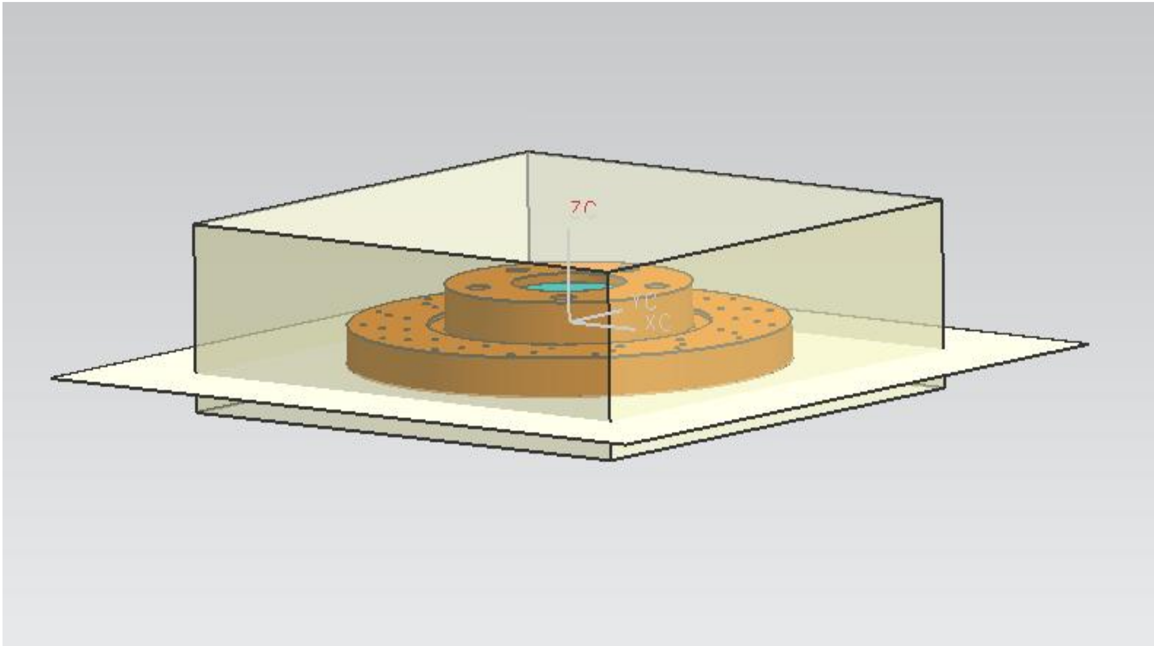


Figure 15

Starting the Mould Process

As explained before there are six major steps in the injection moulding process which can be named as:

1. **Clamping**
2. **Injection**
3. **Dwelling**
4. **Cooling**
5. **Mold Opening**
6. **Ejection**

The below figure indicate the name of the component of mould base which will be select for the next stage of the moulding process.

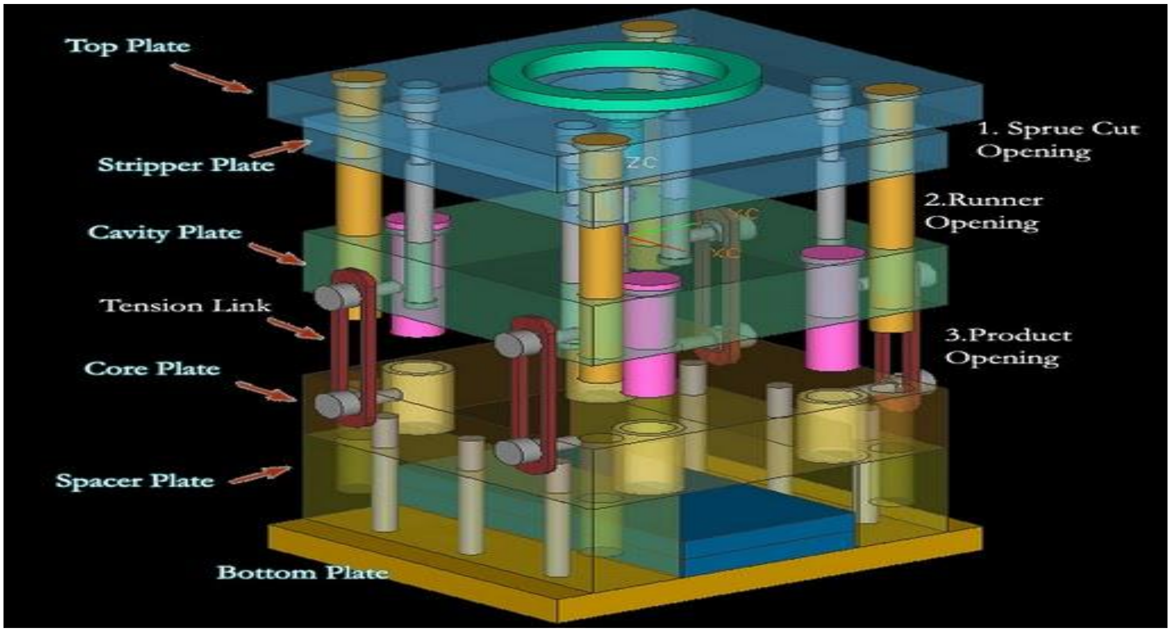


Figure 16

The next stage of the process is to create mould base in order to continuo the design of the runner, injection points, gate, vent and cooling system. Figure 17 shows the mould base with the following specifications to suit core and cavity of the break disc component

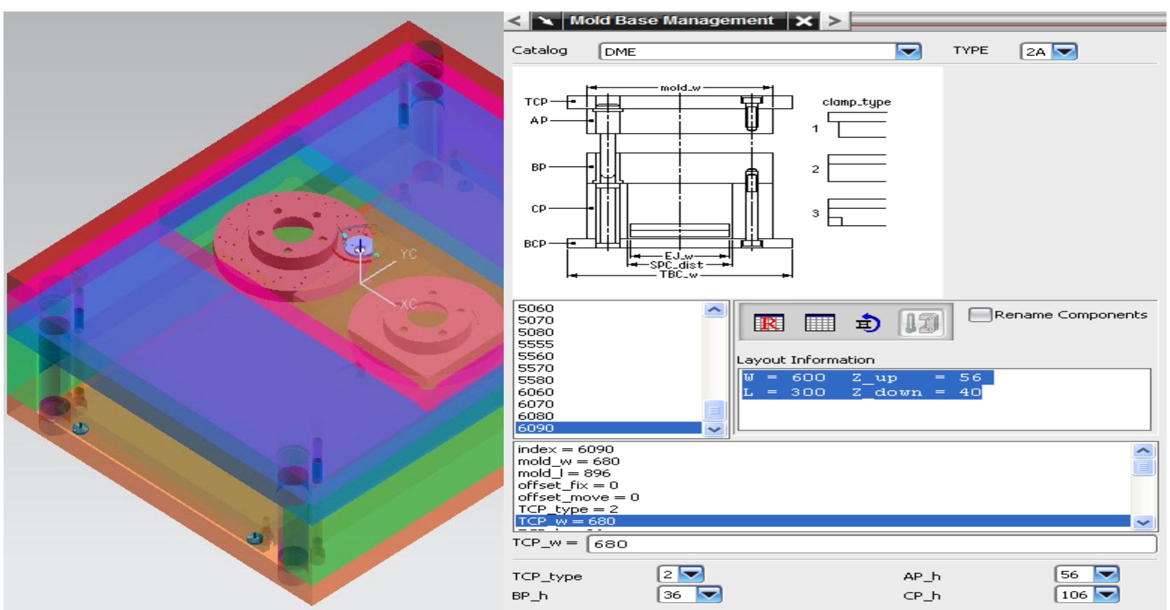


Figure 17

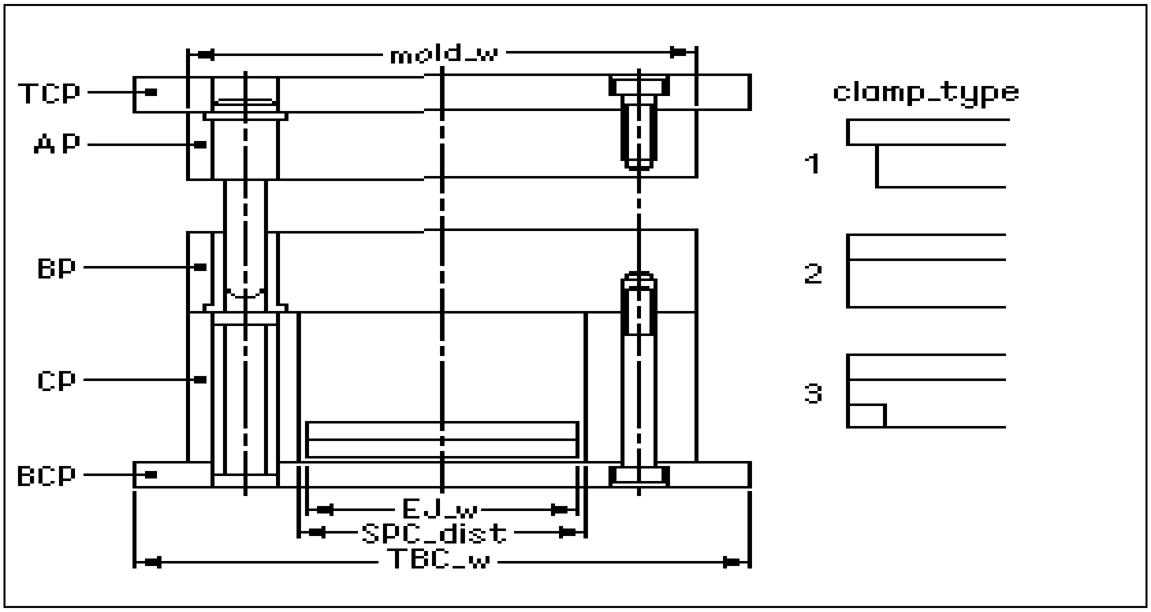


Figure 18

Index	**6090**	**BCP-h**	**36**	**EJ-w**	**464**
Mould-w	**685**	**AP-h**	**56**	**Stp-D**	**26**
Mould-l	**896**	**BP-h**	**36**	**Gp-d**	**50**
Offset-fix	**0**	**CP-h**	**106**	**Scr-d**	**16**
TCP-type	**2**	**CP-w**	**64**	**Ej-scr-d**	**12**
TCP-w	**685**	**EJA-h**	**20**	**D1**	**42**
TCP-h	**36**	**EJB-h**	**26**	**DB**	**41**

Table 2

During the injection phase, the material, usually in the form of pellets, are loaded into a hopper on top of the injection unit. The pellets feed into the cylinder where they are heated until they reach molten form. Within the heating cylinder there is a motorized screw that mixes the molten pellets and forces them to end of the cylinder. Once enough material has accumulated in front of the screw, the injection process begins. The molten plastic is inserted into the mold through a sprue, while the pressure and speed are controlled by the screw.

By completing the mould base with required dimensions the next stage is to selecting the location ring with screws and Sprue_Bushing. The length of sprue_bushing was set to 80mm which will go trough the cavity and core region.

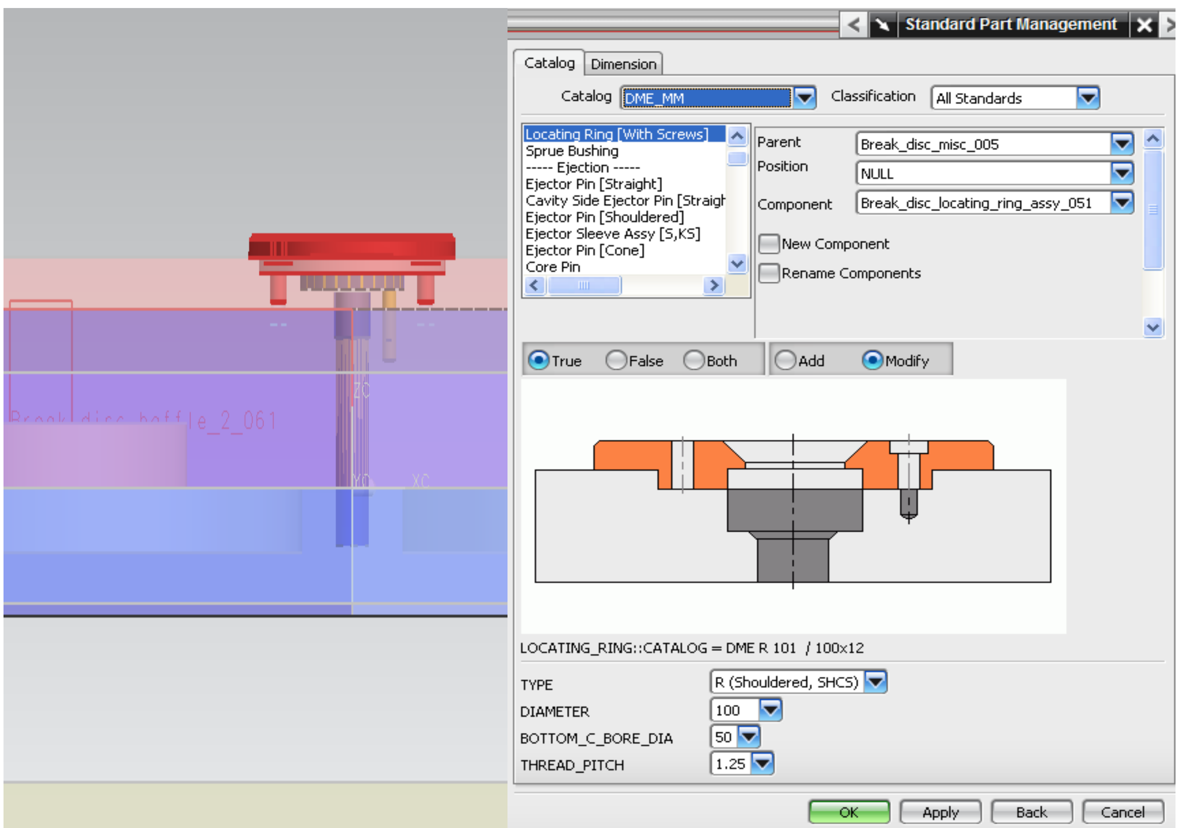


Figure 19

The figure 20 shows the dimensions of the sprue_bushing

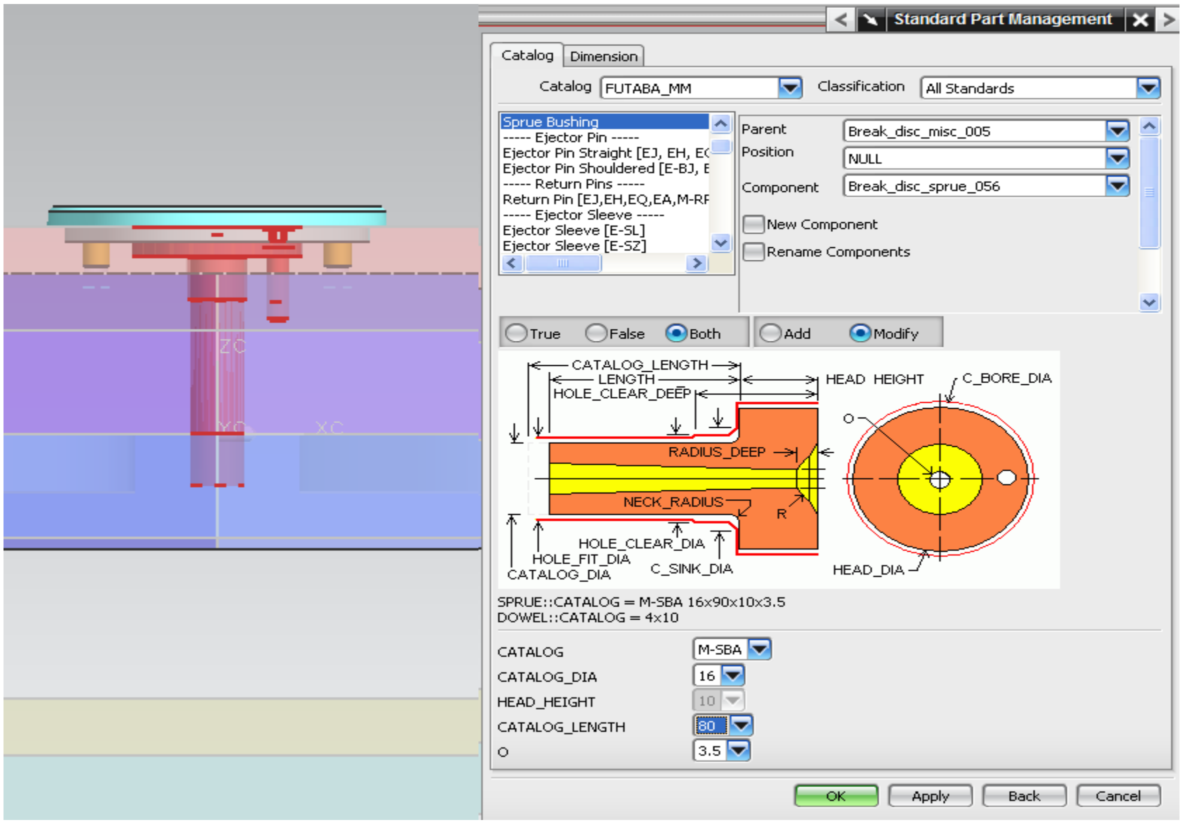


Figure 20

Catalog	M-SBA
Catalog-Dia	16
Head-Height	10
Catalog-length	80

Table 3

The following stage after selecting sprue_bushing is to trim the sprue_bushing to suite the mould process specification. The figure 21 shows the trim method which been select for this purpose and the sprue_bushing been trim down up cavity region.

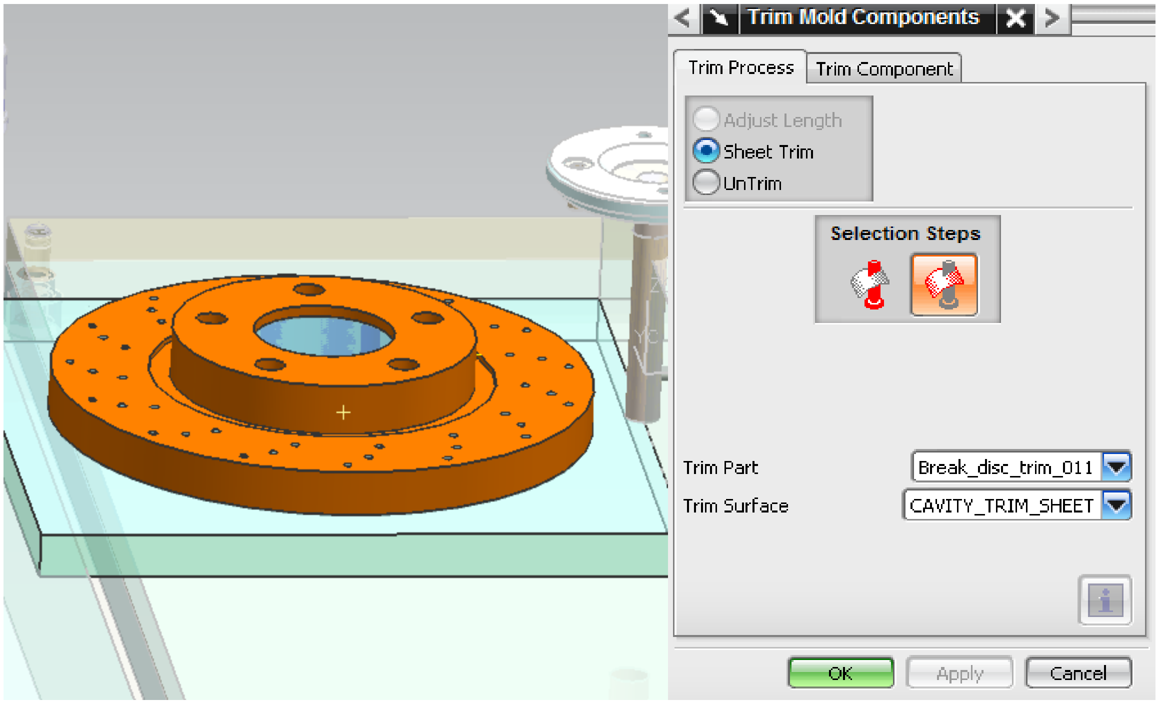


Figure 21

The next step is to designing the ejection pin in order to eject the finish component or part from the mould device at the end of process. Due to geometry and size of the component, five injection pins been design for this purpose. Table 4 shows the specification of the ejection pins which been selected at this stage

Material	**Nitrided**
Catalog-Dia	**8**
Catalog-length	**200**
Head_Type	**1**
Fit_Distance	**5**

Table 4

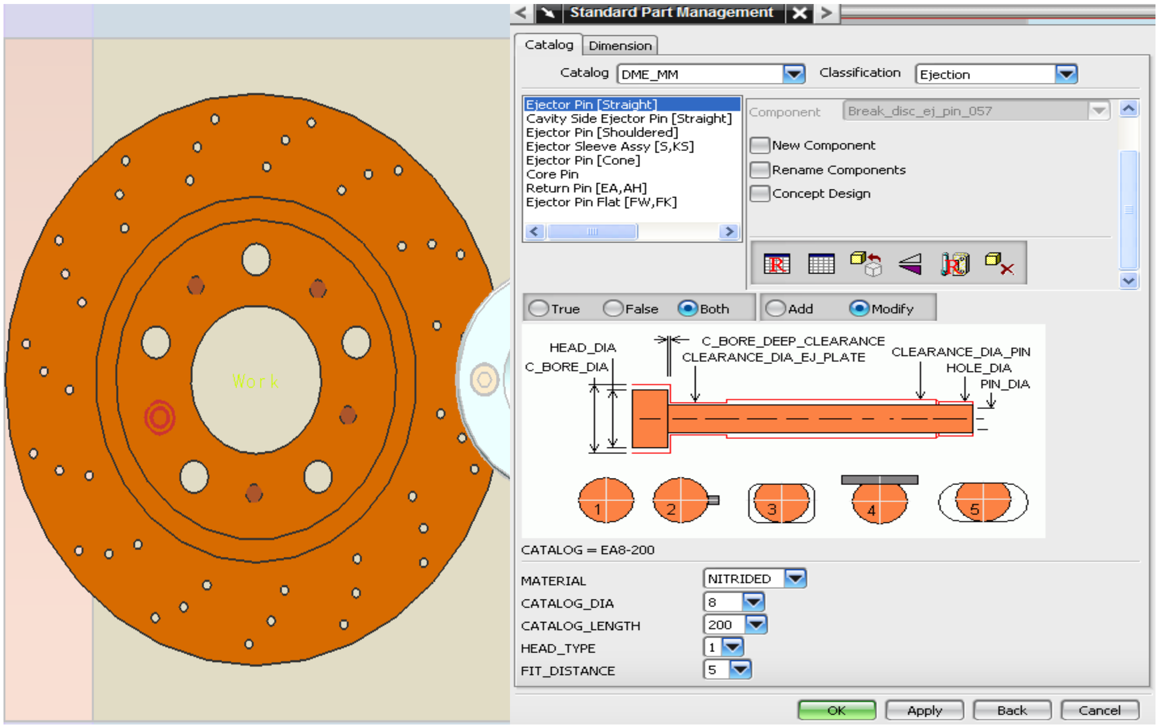


Figure 22

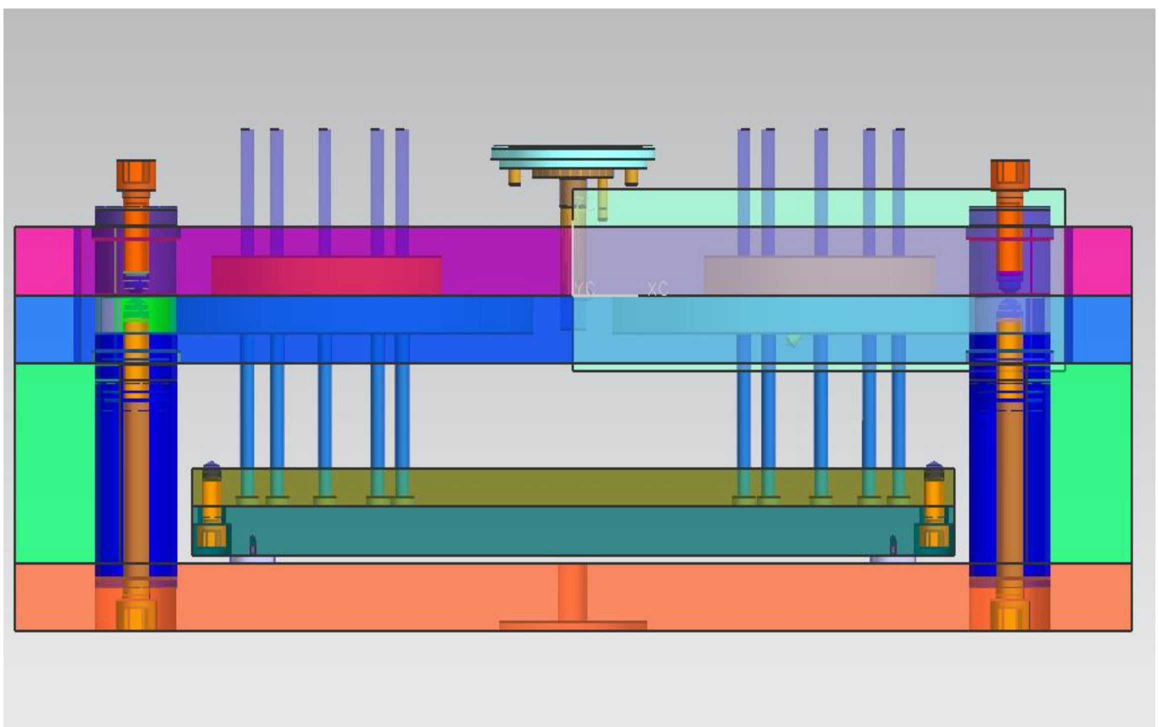


Figure 23

Figure 24 shows the method of trimming the ejection pin which been completed after repositioning the each ejection pin

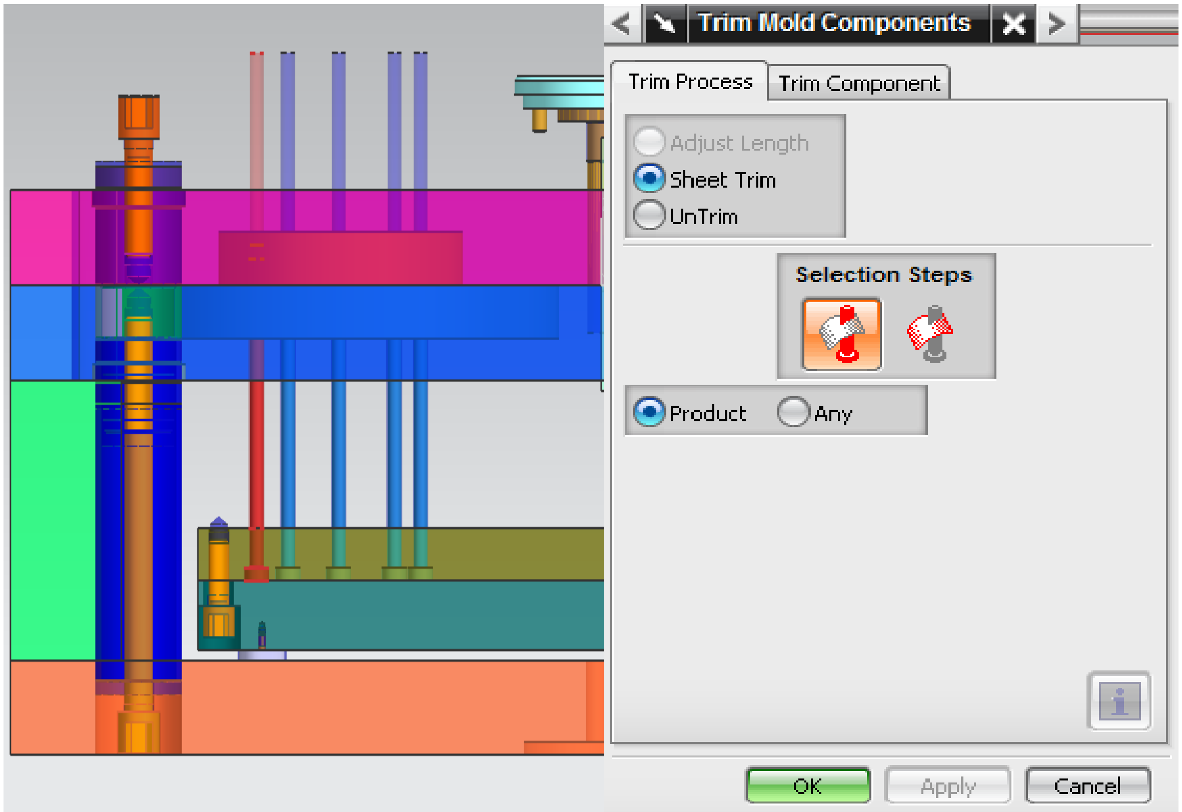


Figure 24

2. Gate Design

Before designing the gate and runner in the order to receive location ring, screw, ejection pin and mould inserts the top plat, stripper plat, core and cavity plates needs to be cut, there for the pocket needs to be define for this purpose, the below figure shows the method which been select at this stage.

- In the target section, Body of 3 plates been selected
- In the tool section, the locating ring, the sprue bushing, and the red-line been selected
- In the reference set section, false been selected
- In the settings section, Show Target and Tool Bodies been selected

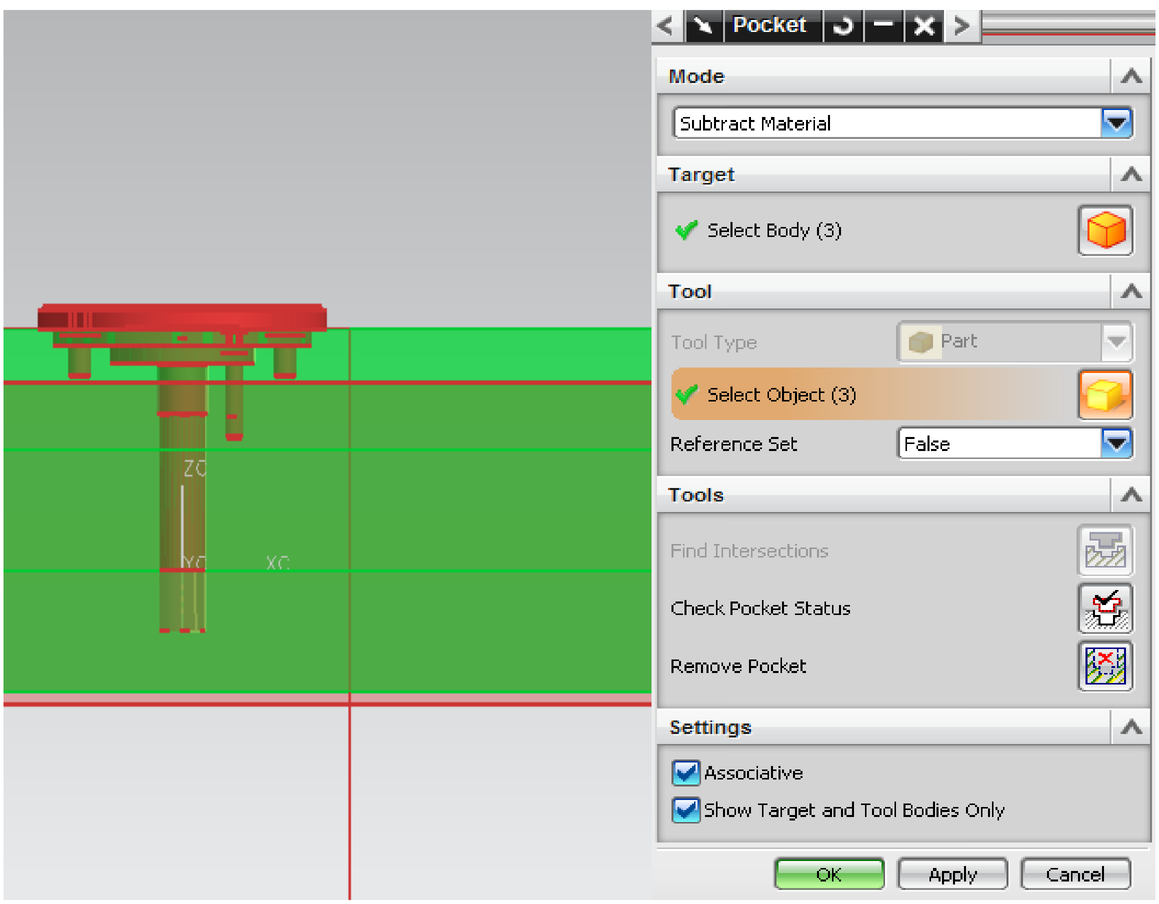


Figure 25

For the designing of the gate, cavity region was selected. By selecting the one of the vertical faces of the component (break disc) in cavity region can define the gate point for the gate position, once defining the gate point the next step is to selecting or designing the suitable gate with specific dimensions such as the height, length and angle of the gate to suit the moulding process. The type of the gate been chosen as submarine.

Figure and table below shows the method of the gate design with selected dimensions.

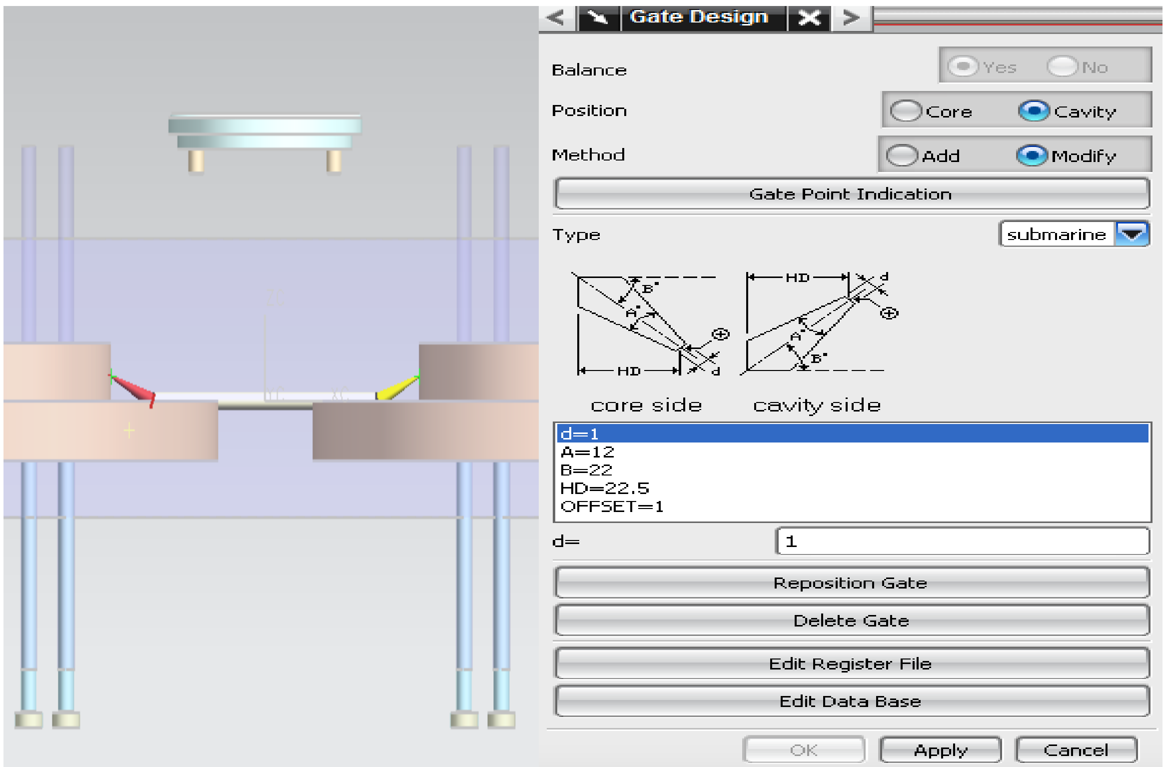


Figure 26

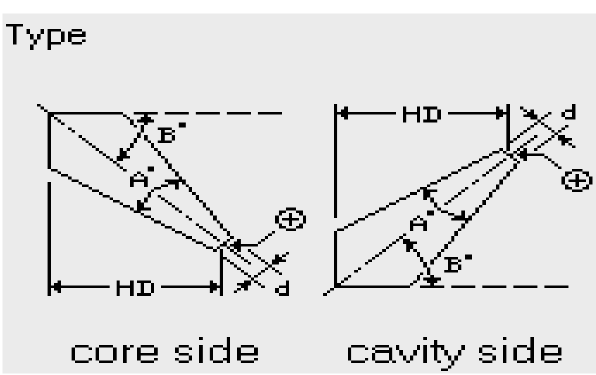


Figure 27

d	**1**
A	**12**
B	**22**
HD	**22.5**
Offset	**1**

Table 5

3. Runner Design

Designing the runner method it's been explain as below which is the next step after gate design.

- In the expression list, a was set to 115 so suit the gate
- From the Cross Section list the Circular option been chosen
- 5.5 been set for the A section which is the runner radius
- In the Cold Slug Position section the Both End been selected

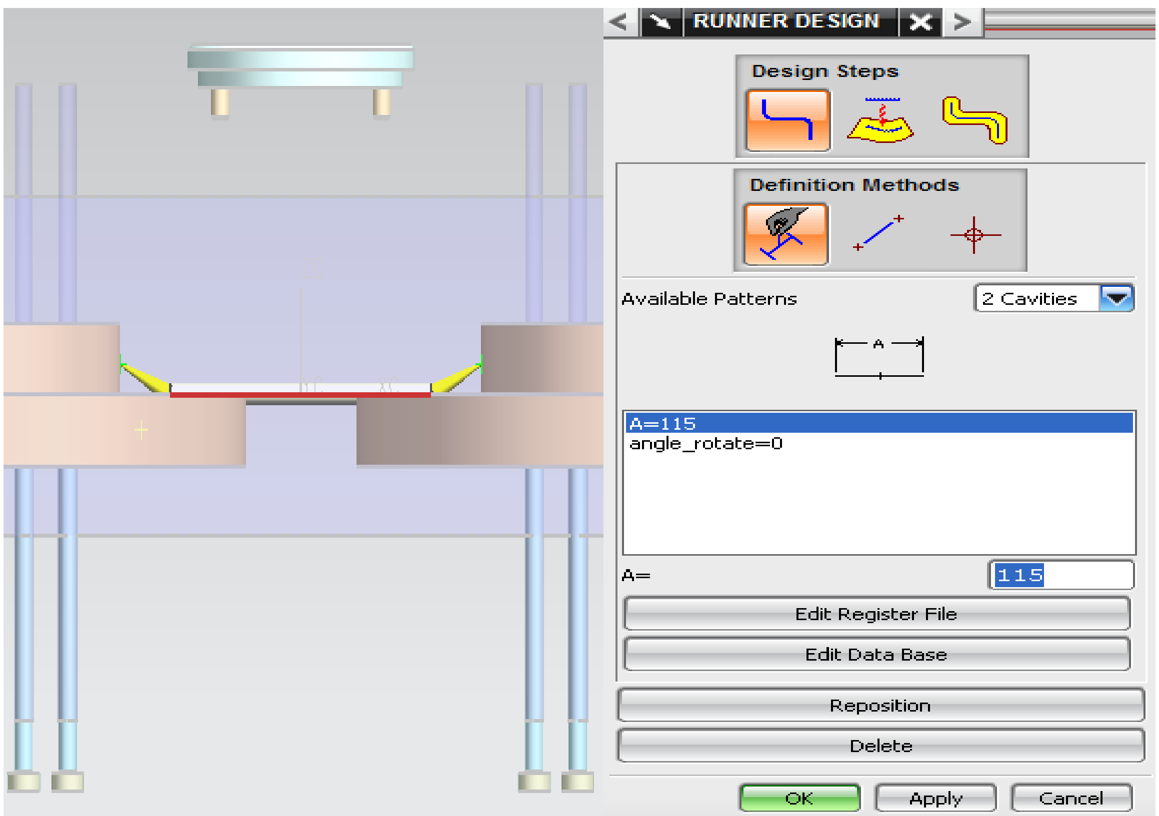


Figure 28

Figure 28 shows that the runner between the two gates in the horizontal line.

4. Injection Point

By designing the gate and runner the location of the injection point will be identify, the injection point is the place where the molten material will go through the runner and inject in to the core and cavity region.

Normally the injection point is made where there is a higher cross section in total part geometry. By looking at the pervious figure clearly can see the injection point of the mould process where the gate nozzle meat the vertical face of the break disc component.

After designing the gates, runners and identifying the injection points the next step is to Create pockets for the gates and runners in the mould insert. The below description and figure 29 shows the method of designing the pockets at this stage.

- In the Mode section Subtract Material is selected
- In the Target section Body of core and cavity been selected
- In the Tool section the gates and runners been selected as the objects
- The Show Target and Tool Bodies Only been selected

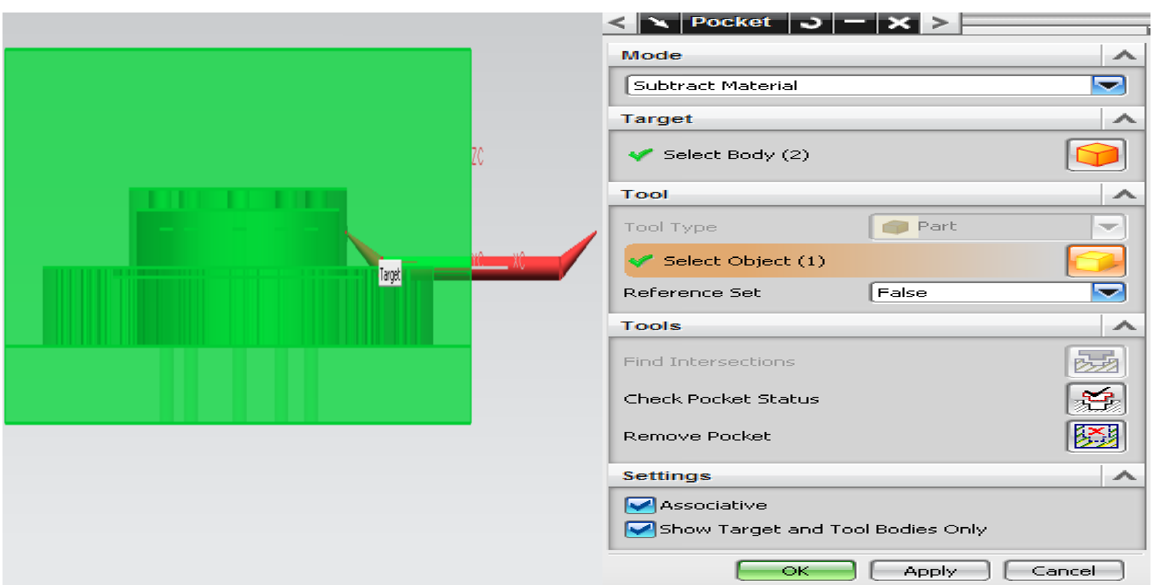


Figure 29

The following method been use to create pockets for the ejection pins by selecting the core region only as the target body.

5. Vent and Cooling System

Once all the above stages had been completed the next stage for the moulding process is to design the vent and cooling system which allow the material to cool to its solid form within mould before ejection.

The following shows the method of designing the first part of the cooling system which is cooling holes

- ➢ In the Cooling Component Design section COOLING HOLE been selected
- ➢ From the COMPONENT_TYPE section, CONNECTOR_PLUG been selected
- ➢ From the PIPE_THREAD section, 1/4 been selected
- ➢ In the D2 section, 17mm been selected

Table 6 and figure 30, 31 shows the exact dimension parameters which been set for the cooling holes components

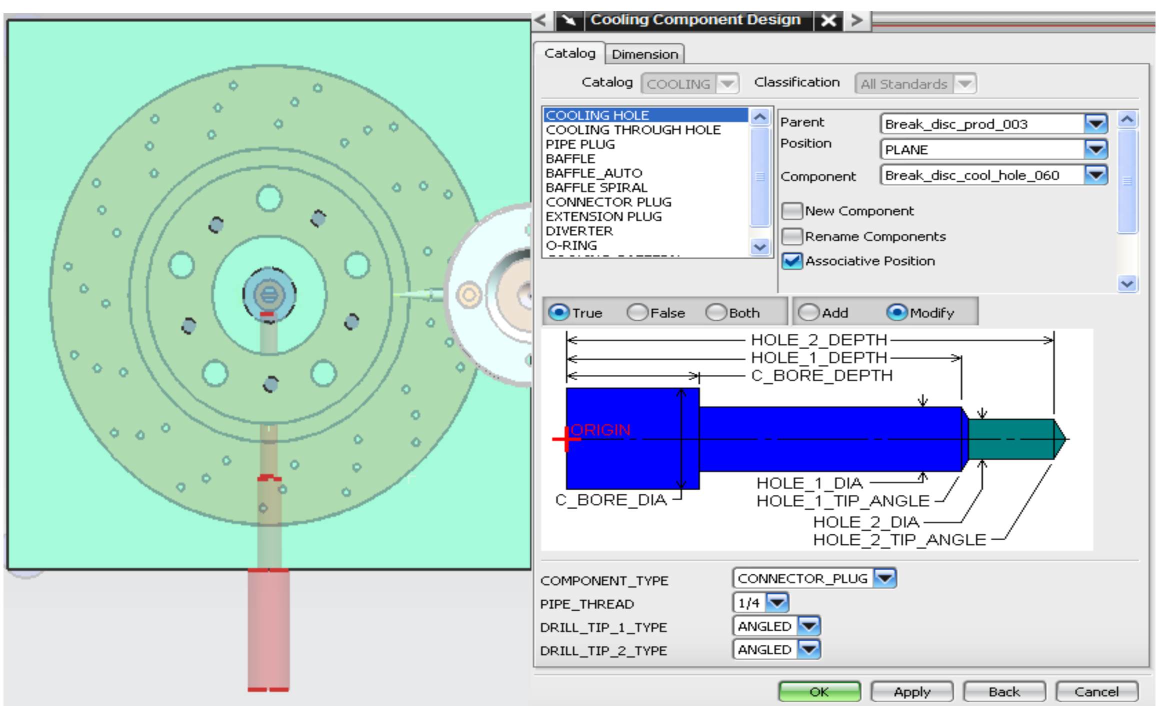


Figure 30

HOLE_1_DIA	14
C_BORE_DIA	0
EXTENSION_HOLE_DIA	24
EXTENSION_ON_OFF	1
EXTENSION_DISTANCE	65.5
HOLE_1_DEPTH	50
HOLE_2_DEPTH	130

Table 6

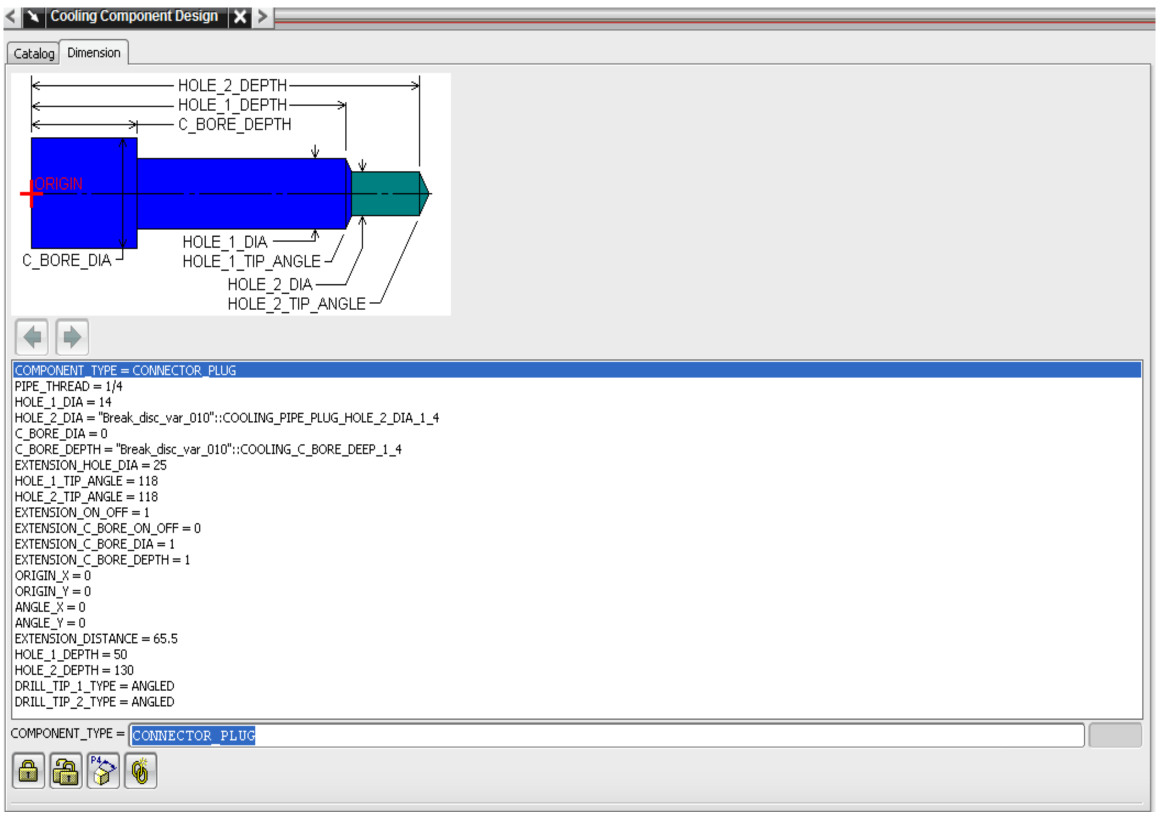


Figure 31

The location of the cooling holes is on the both side of the core and cavity region.

The next step is to design the Baffle Auto which been located on top of the cavity region. The following shows the method of the baffle auto design follow by the require specification which can be seen from table 7.

- From the part section, BAFFLE_AUTO been selected
- From the SUPPLIER section, DME been selected
- From the PIPE_THREAD section, 3/8mm been selected
- From the DRILL_TIP_2_TYPE section, ROUND been selected

BAFFLE_END_CLEAR	**3**
HOLE_1_DEPTH	**12**
HOLE_1_DIA	**25**

Table 7

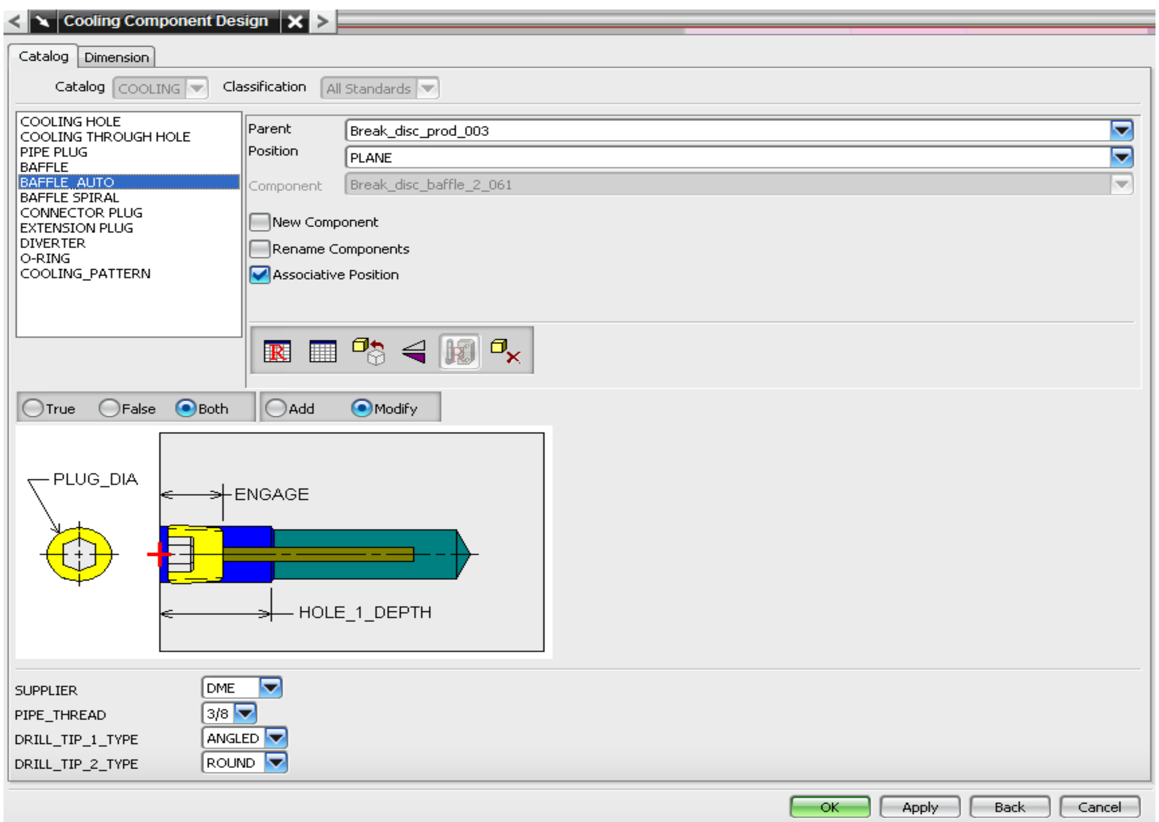


Figure 32

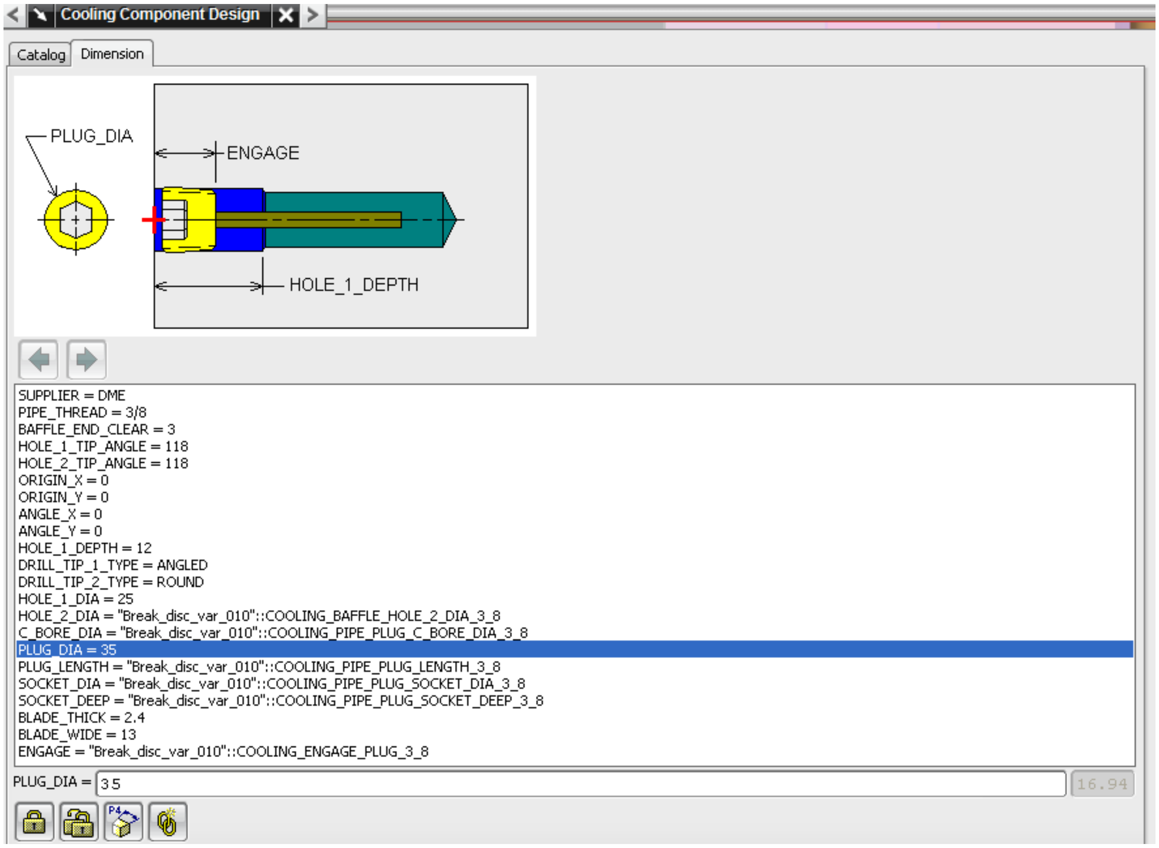


Figure 33

The figure 32 and 33 explain the design method of the baffle auto which been create for the mould process at this stage.

- For the Baffle Length Adjust, in the Axial Clearance section, 6mm been selected
- For the Radial Clearance section, type 6 been selected
- For the Parting Surface Side section, Cavity Side been selected

The final stage of the mould process is to create the EXTENSION PLUG to finalize the cooling system of the mould process.

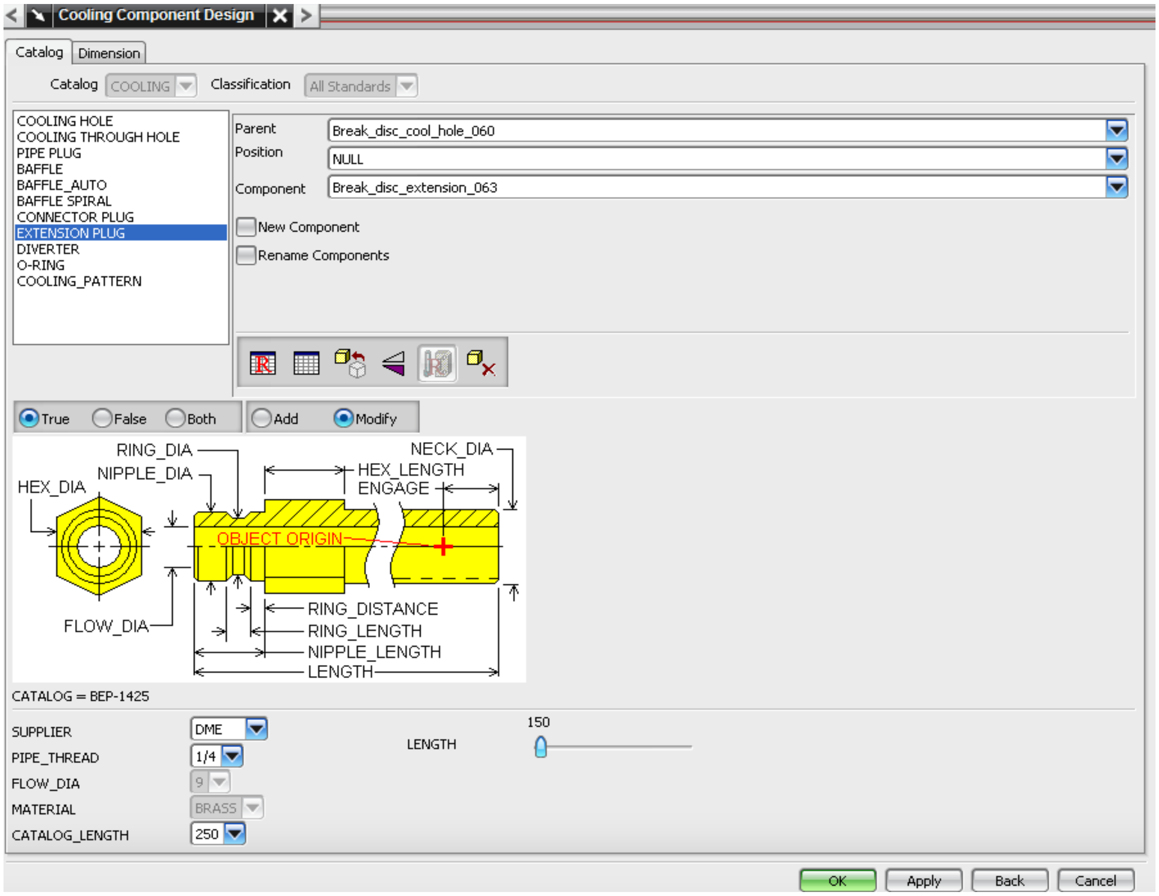


Figure 34

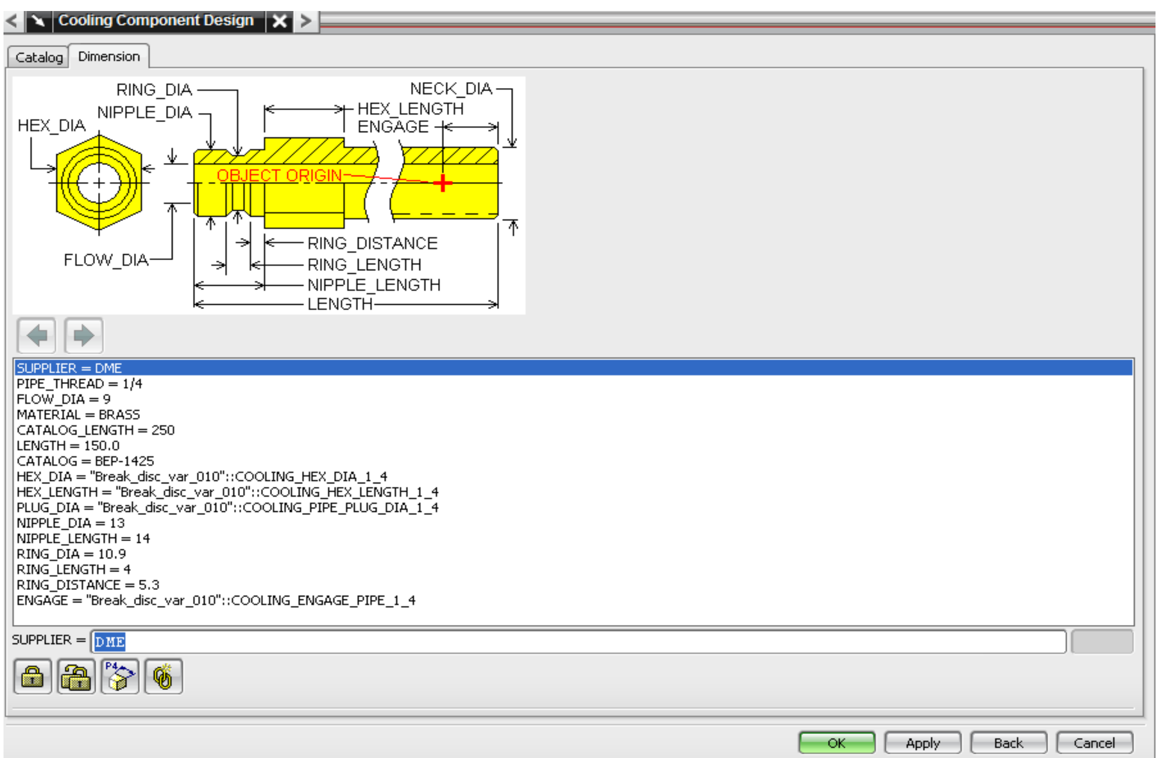


Figure 35

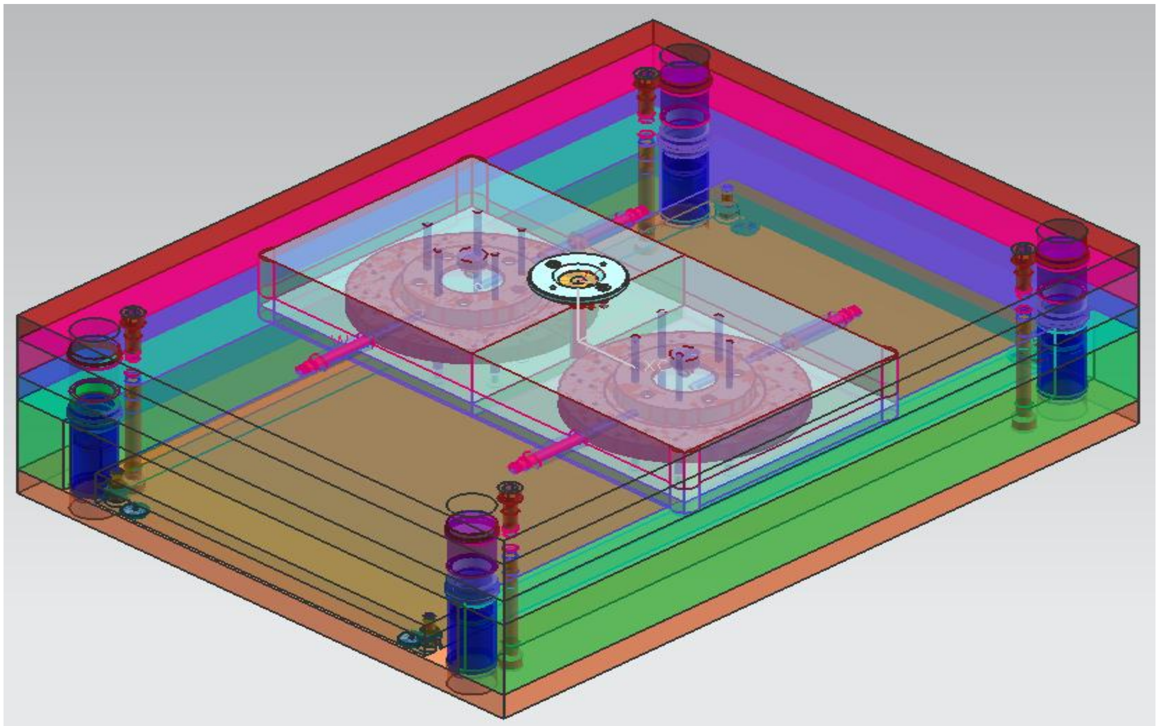
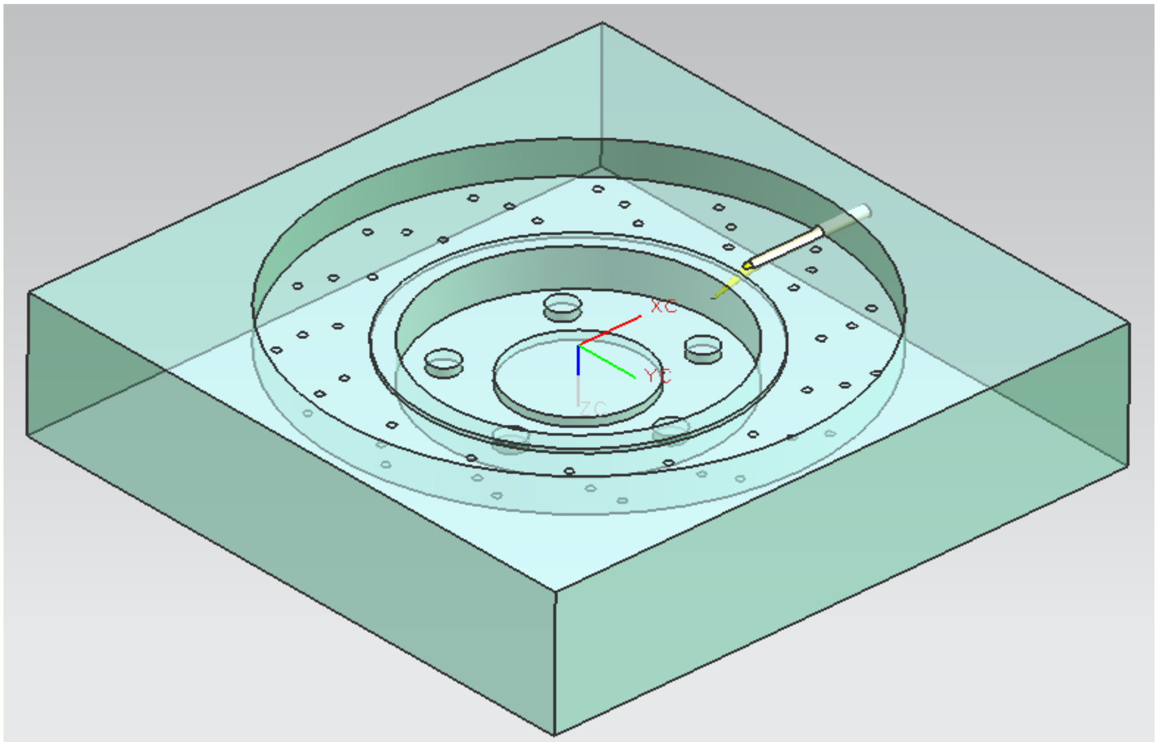
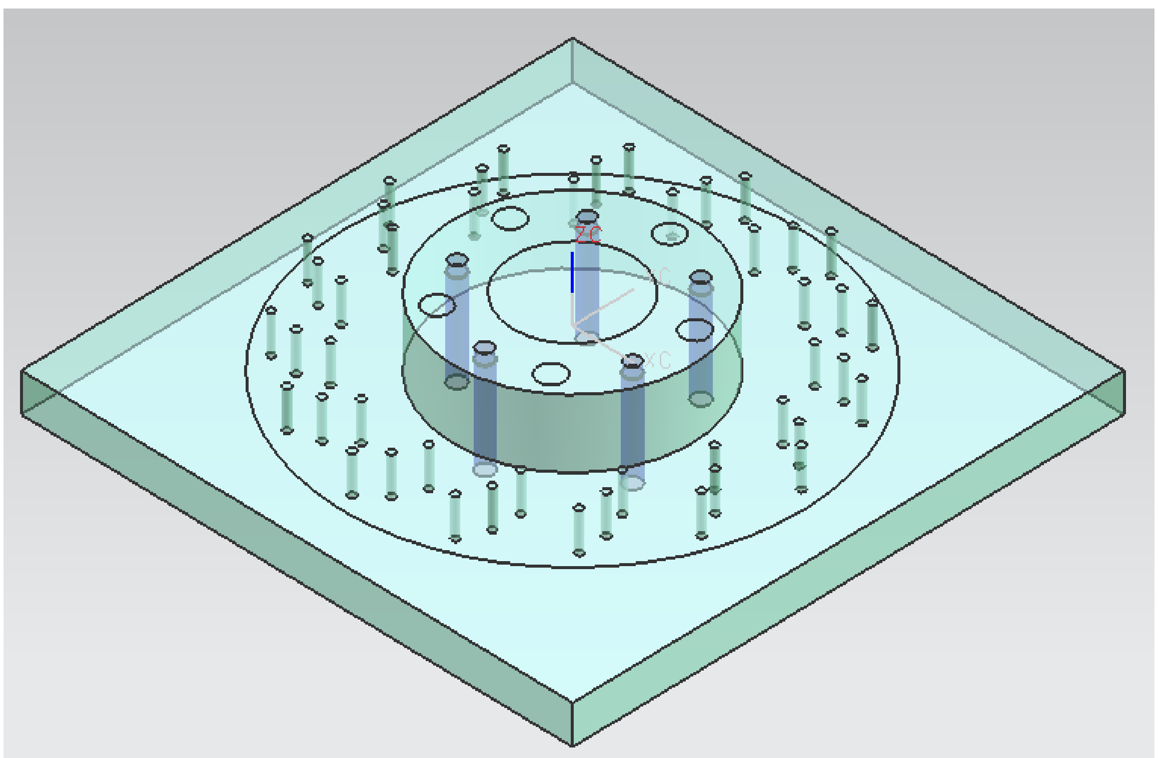


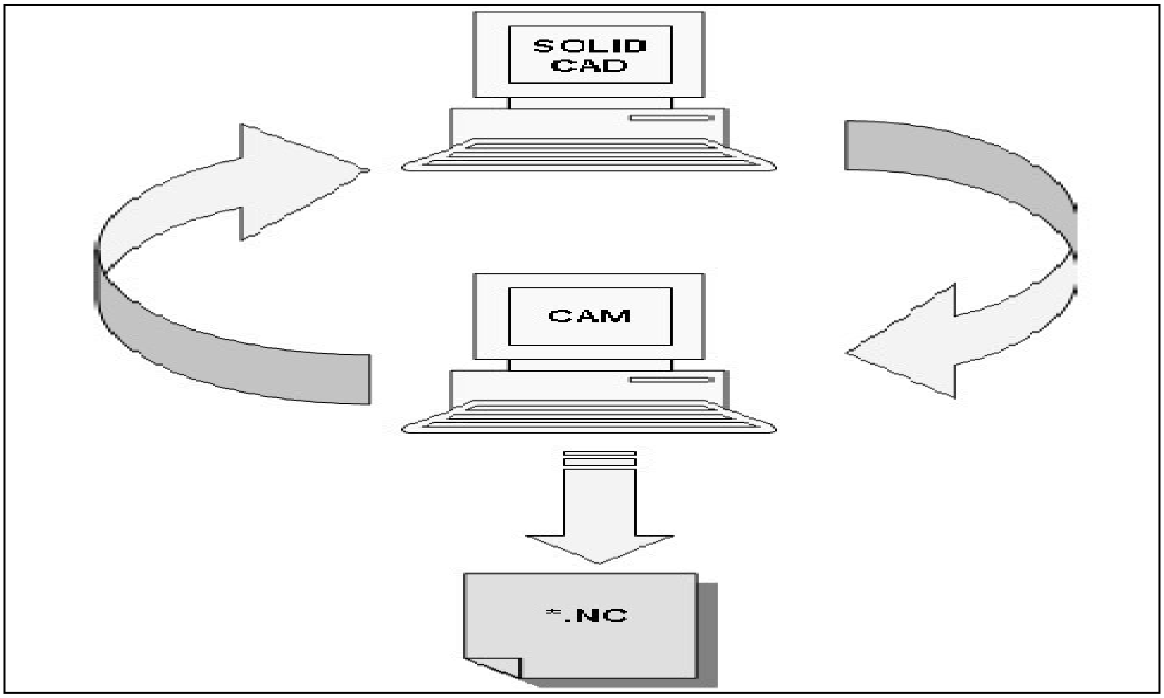
Figure 36





Figures 38 and 39

10. CNC Machining



The Computer Numerical Control (CNC) fabrication process offers flexible manufacturing runs without high capital expenditure dies and stamping presses. High volumes are not required to justify the use of this equipment.

Tooling is mounted on a turret which can be as little as 10 sets to as much as 100 sets. This turret is mounted on the upper part of the press, which can range in capacity from 10 tons to 100 tons in capacity.

The turret travels on lead screws, which travel in the X and Y direction and are computer controlled. Alternatively, the workpiece can travel on the lead screws, and move relative to the fixed turret. The tooling is located over the sheet metal, the punch is activated, and performs the operation, and the turret is indexed to the next location of the workpiece. After the first stage of tooling is deployed over the entire workpiece, the second stage is rotated into place and the whole process is repeated. This entire process is repeated until all the tooling positions of the turret are deployed (efunda 2010).

11. Cavity Machining

The below steps show the process of machining a prismatic model using 3-axis planar surface programming techniques, The workflow consists of three parts:

1. Machining Setup
2. Machining Operation Program
3. Machining Code Output

The setup defines conditions and parameters that are used commonly throughout the program. The setup tasks for this workflow are:

- Open a Solid Model part
- Choose the setup
- Define geometry
- Create tools

11.1. Setup

1. Creating an assembly with the part as a component, this allows the NC Data to be stored separately from the geometric data.
2. Creating a program named Cavity Machining
3. Created a carrier (tool carousel, tool chain) with 10 pockets for holding cutting tools
4. Creating some geometry
5. Creating some machining methods (Rough, Semi-Finish, Finish)

11.2. Defining Geometry which is the next step for this operation

1. Verify and edit the machine coordinate system
2. Define the clearance plane
3. Specify part geometry
4. Specify blank geometry

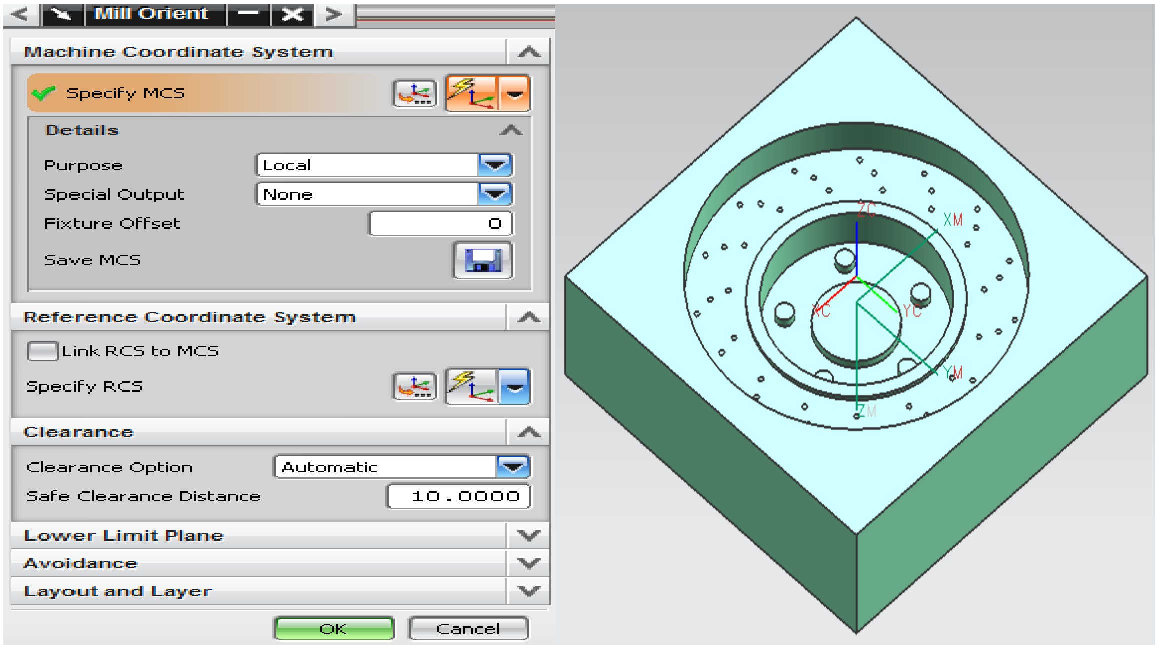


Figure 39

The figure 39 shows the reference coordinate system which been set for the operation. This is down mainly because the coordinate system used for giving various parameters will be based from that reference point which been created rather than using the absolute coordinate system. This method makes it easier for this operation to give the necessary coordinates with respect to the reference point which been created at start. Also in the clearance section the clearance distance been set to 10mm.

The next step is to specify part geometry by selecting the workpiece. The figure 40 shows the method which been specified for the part and blank. The blank part has identical dimension in X and Y direction which been level with the part, but in the Z direction the top face of blank part is 10mm higher then the part face (Height). This method adds a 10 mm stock to the top of the block. The tool will clear the blank geometry by 10 mm during non-cutting moves as specified by the safe clearance distance you defined earlier.

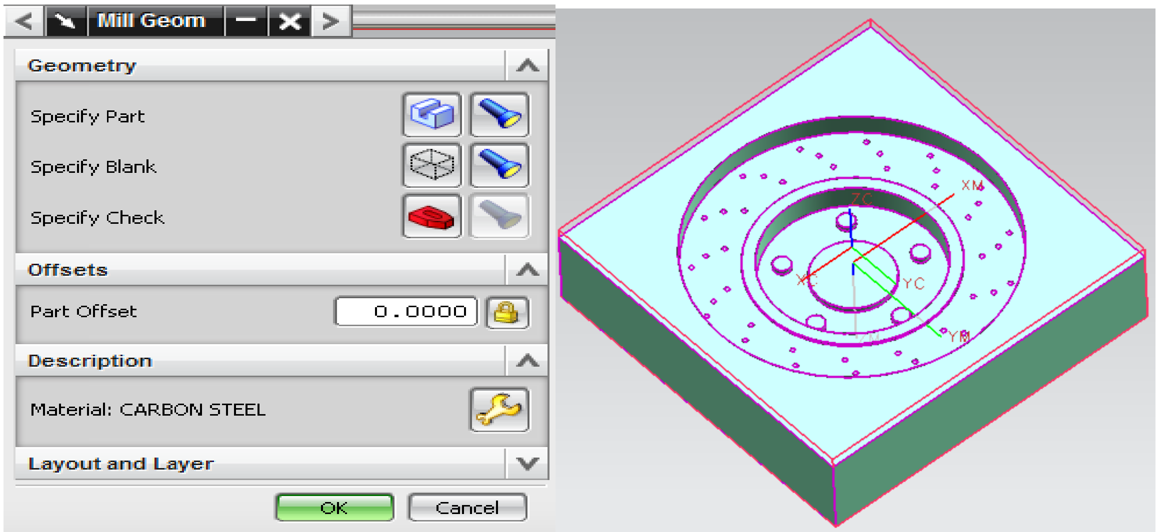


Figure 40

11.3. Create Tools

There are five different tools which been created for this operation, table 8 shows the number off tools with the deferent dimension for each operation, also figure 41 shows the method of creating the tools. Martial of all 5 tools been selected as high speed steel (HSS).

The location of cutting for all tools been set to center point of the part geometry as can be seen from figure 41.

FACE_MILL_50D
CAVITY_MILL_30D
CAVITY_MILL_20D
CAVITY_MILL_10D
FLOOR_MILL_5D

Table 8

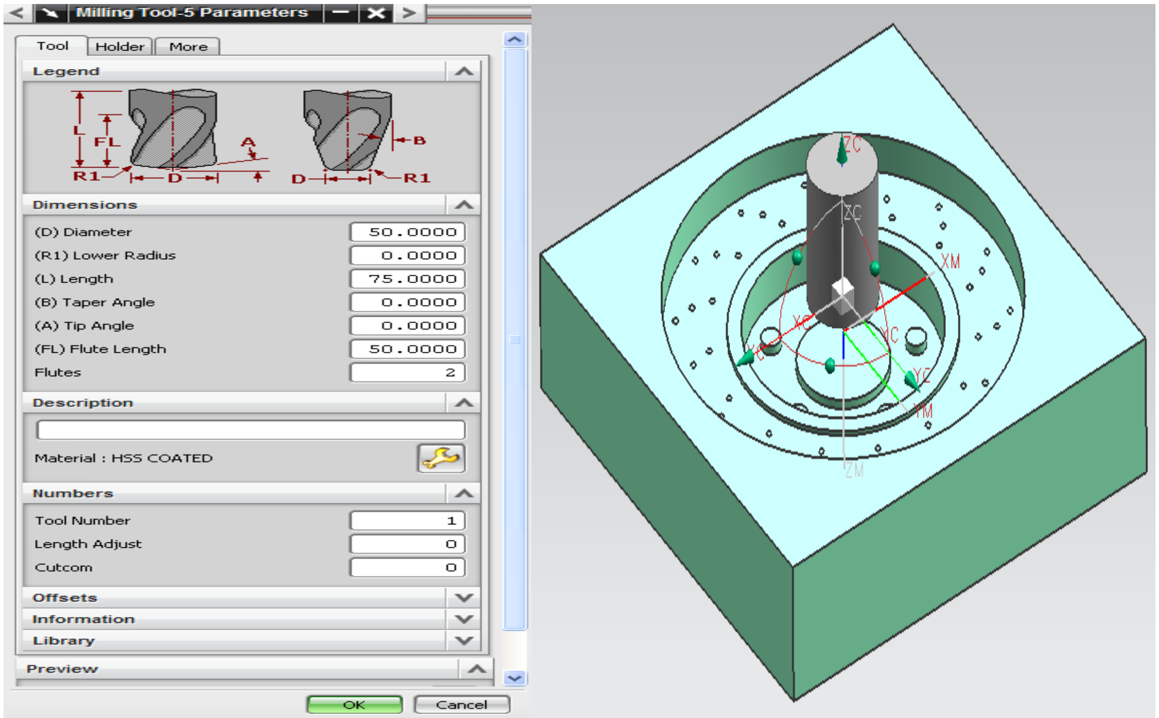


Figure 41

After creating the tools for the operation the next step is to create operation and in this stage the type of the tools would varied depend to the machining methods. They are three methods been specified for machining:

- Roughing
- Semi-Finish
- Finish

11.4. Cavity Roughing

This method been used to remove the material as much as possible which been set to 8mm before going to the semi-finish stage. Also by using the roughing method as a first stage the operation become more accrete with minimum tolerances. The below figures show the roughing areas for each stag of this operation. For roughing, semi-finish and finish the operation been divided to five different area.

11.4.1 Face Mill Roughing Area 1

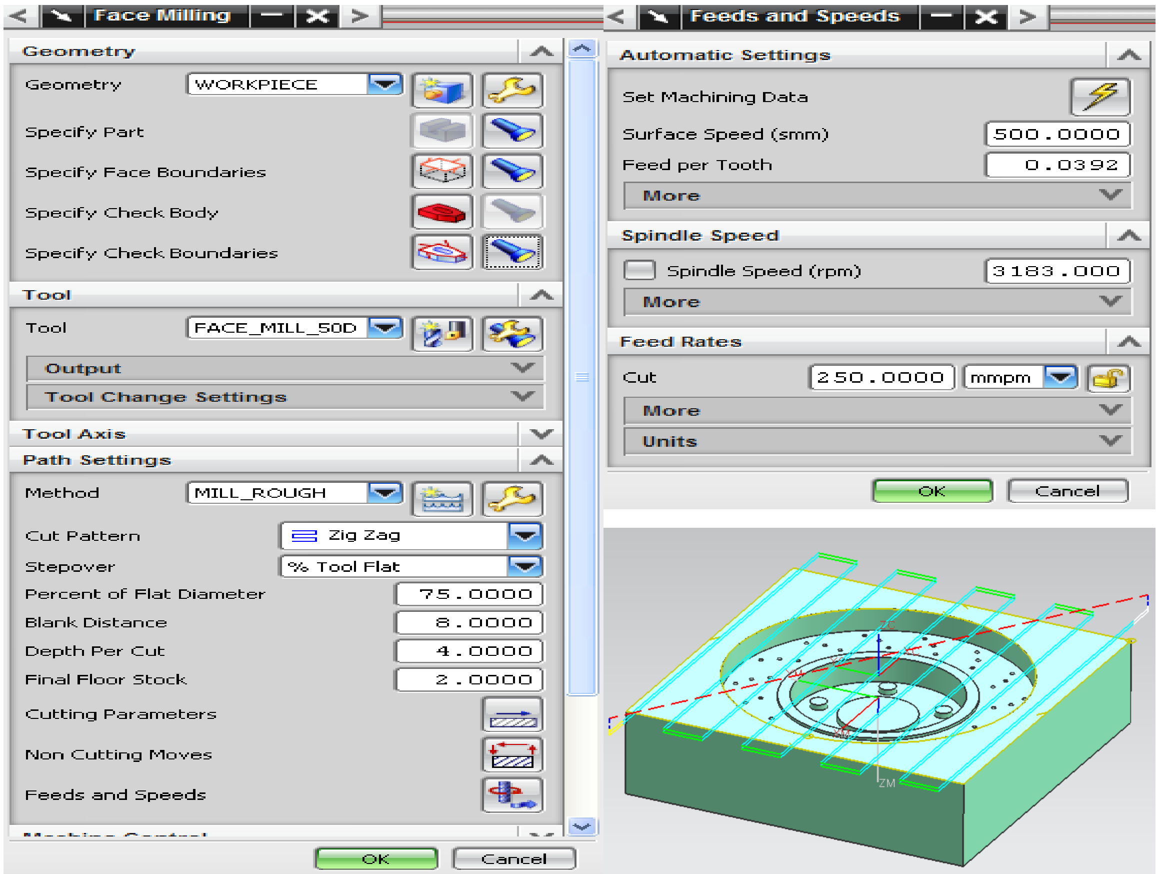


Figure 42

Tool	50 diameter
Cut pattern	Zig zag
Stepover	Tool flat
Percent of flat diameter	%75
Blank distance	8
Depth per cut	4
Final floor stock	2
Surface speed	500
Feed per tooth	0.0392
Spindle speed (rpm)	3183
Cut	250 mmpm

Table 9

11.4.2 Cavity Mill Roughing Area 2

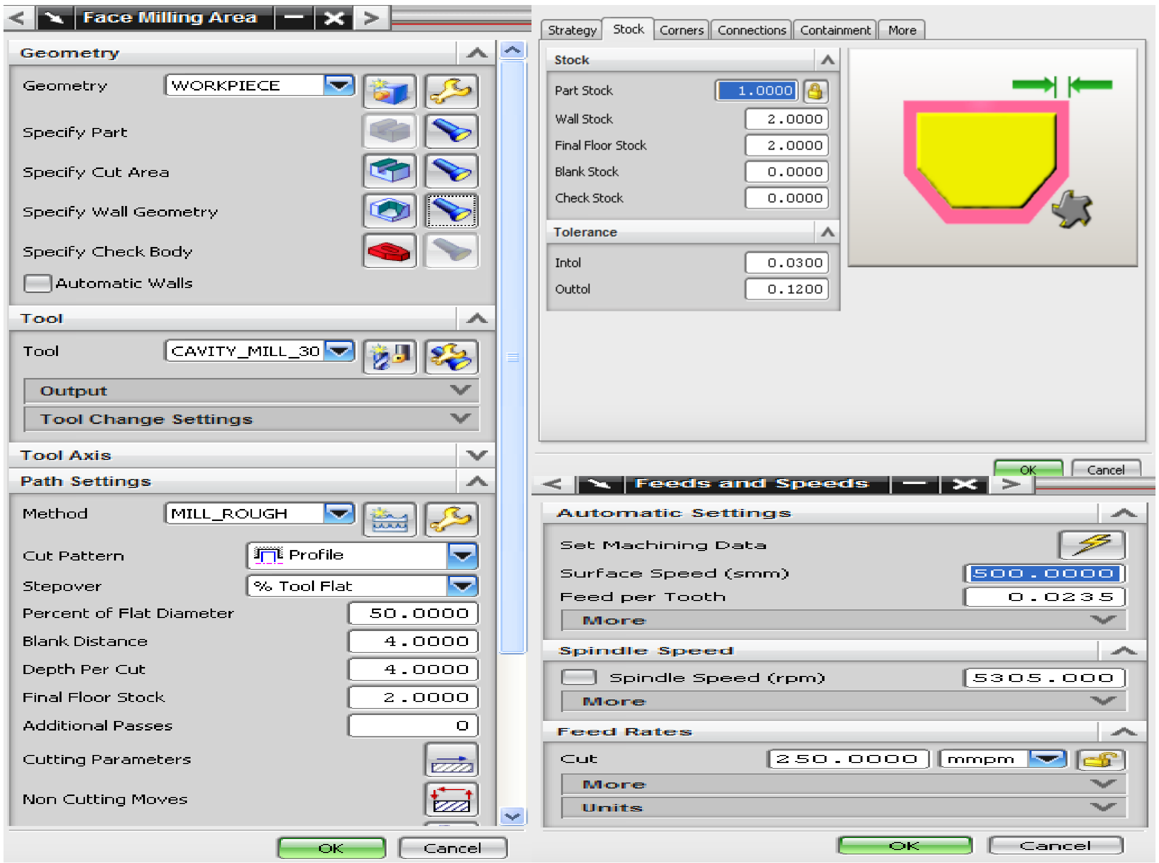


Figure 43

Tool	30 diameter
Cut pattern	Profile
Stepover	Tool flat
Percent of flat diameter	%50
Blank distance	4
Depth per cut	4
Final floor stock	2
Surface speed	500
Feed per tooth	0.0235
Spindle speed (rpm)	5305

Cut	250 mmpm
Wall stock	2

Table 10

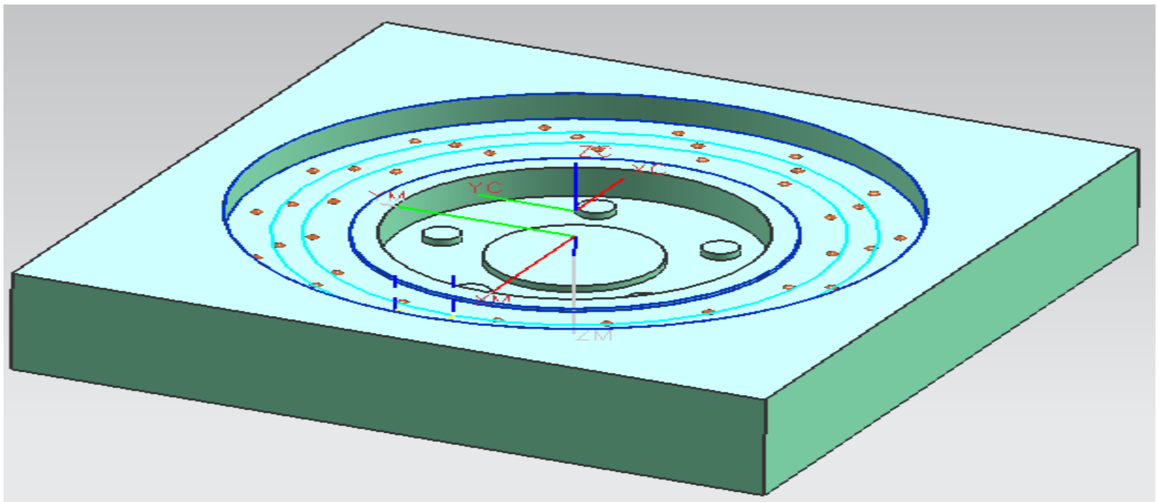


Figure 44

11.4.3 Face Mill Roughing Area 3

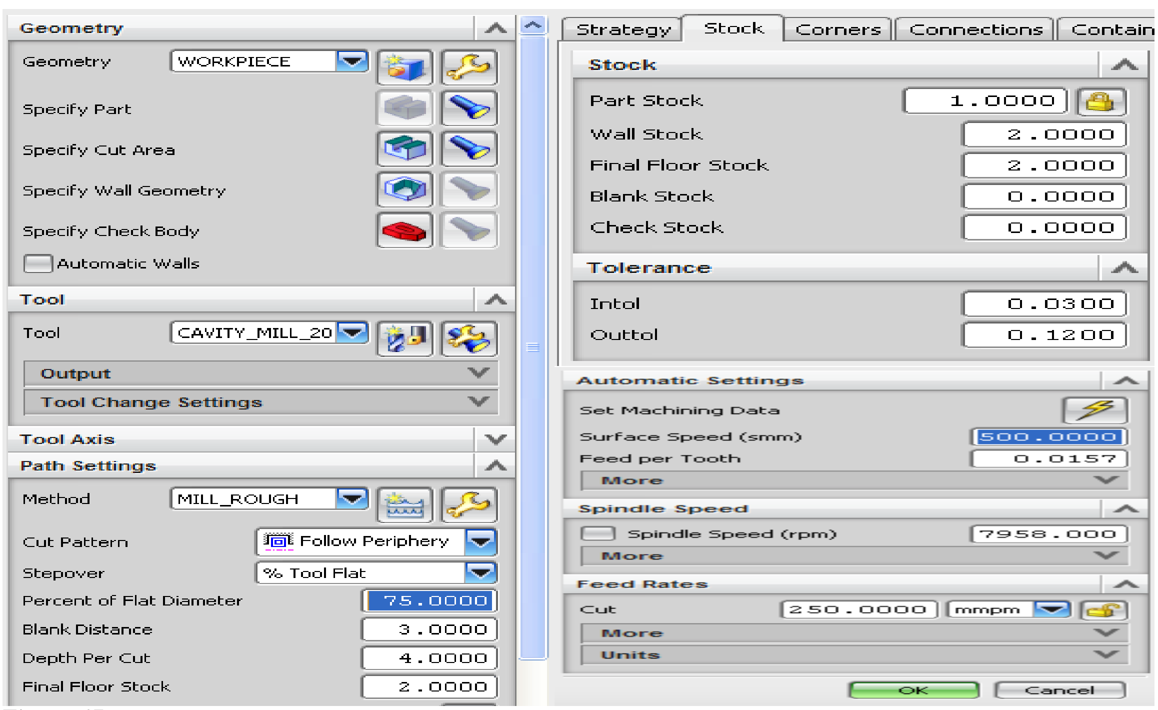


Figure 45

Tool	20 diameter
Cut pattern	F0llow periphery

Stepover	Tool flat
Percent of flat diameter	%75
Blank distance	3
Depth per cut	4
Final floor stock	2
Surface speed	500
Feed per tooth	0.0157
Spindle speed (rpm)	5305
Cut	250 mmpm
Wall stock	2

Table 11

11.4.4 Cavity Mill Roughing Area 4

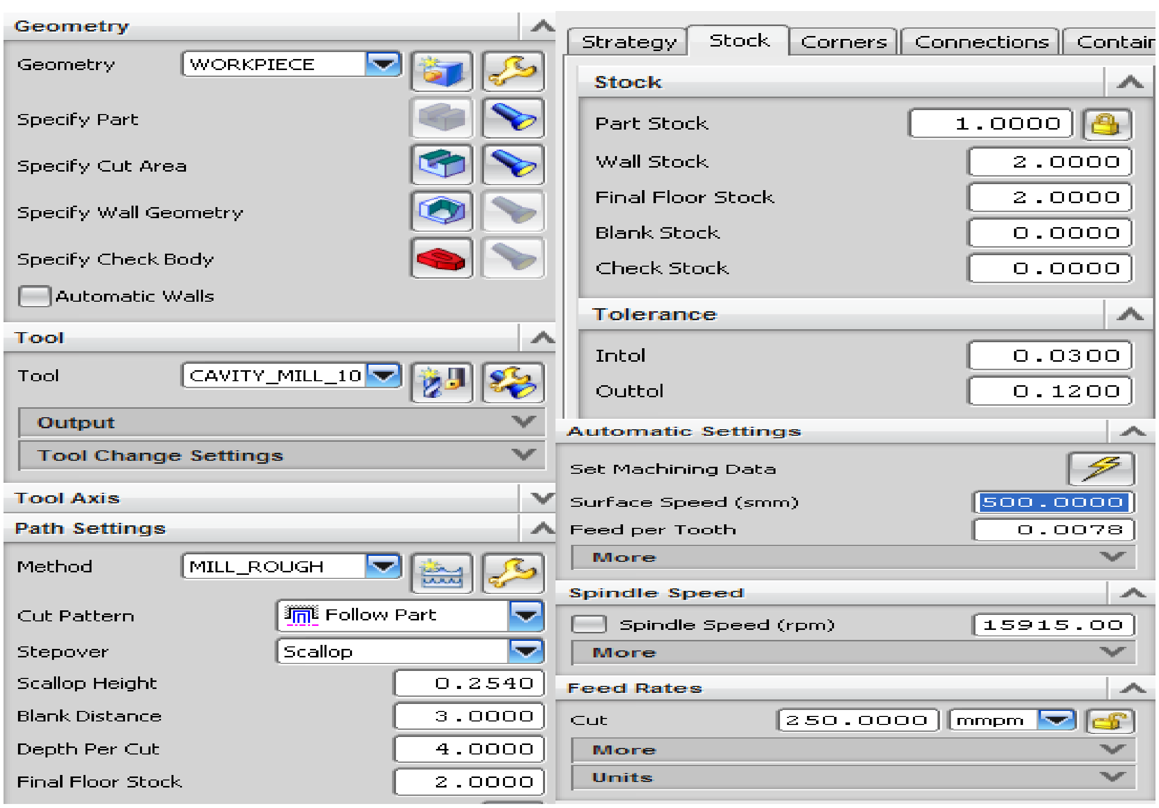


Figure 46

Tool	**10 diameter**
Cut pattern	**Follow part**
Stepover	**Scallop**
Scallop height	**0.2540**
Blank distance	**3**
Depth per cut	**4**
Final floor stock	**2**
Surface speed	**500**
Feed per tooth	**0.0078**
Spindle speed (rpm)	**15915**
Cut	**250 mmpm**
Wall stock	**2**

Table 12

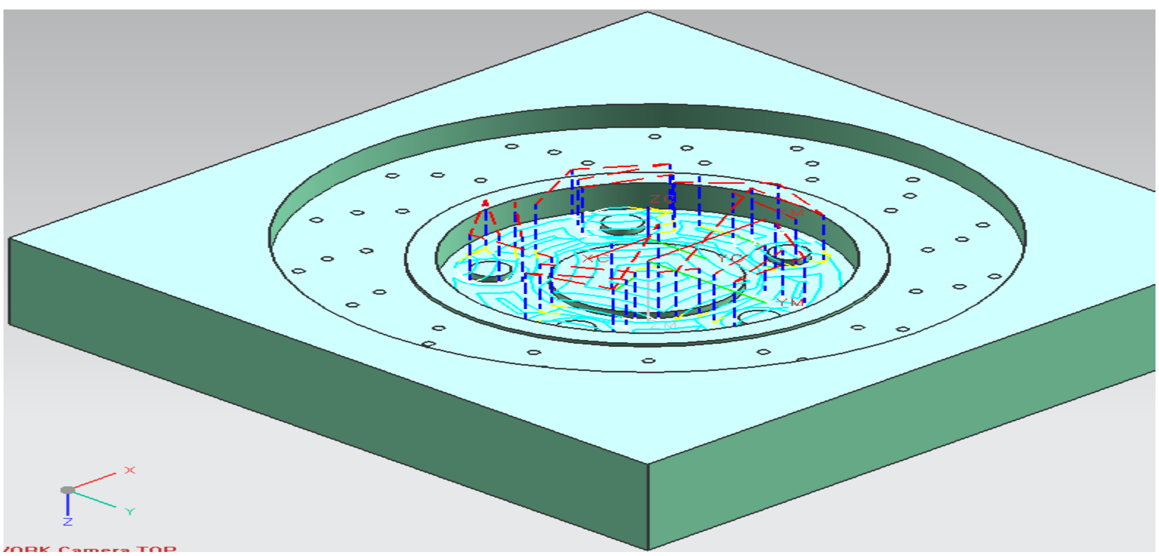


Figure 47

11.4.5 Floor Mill Roughing Area 5

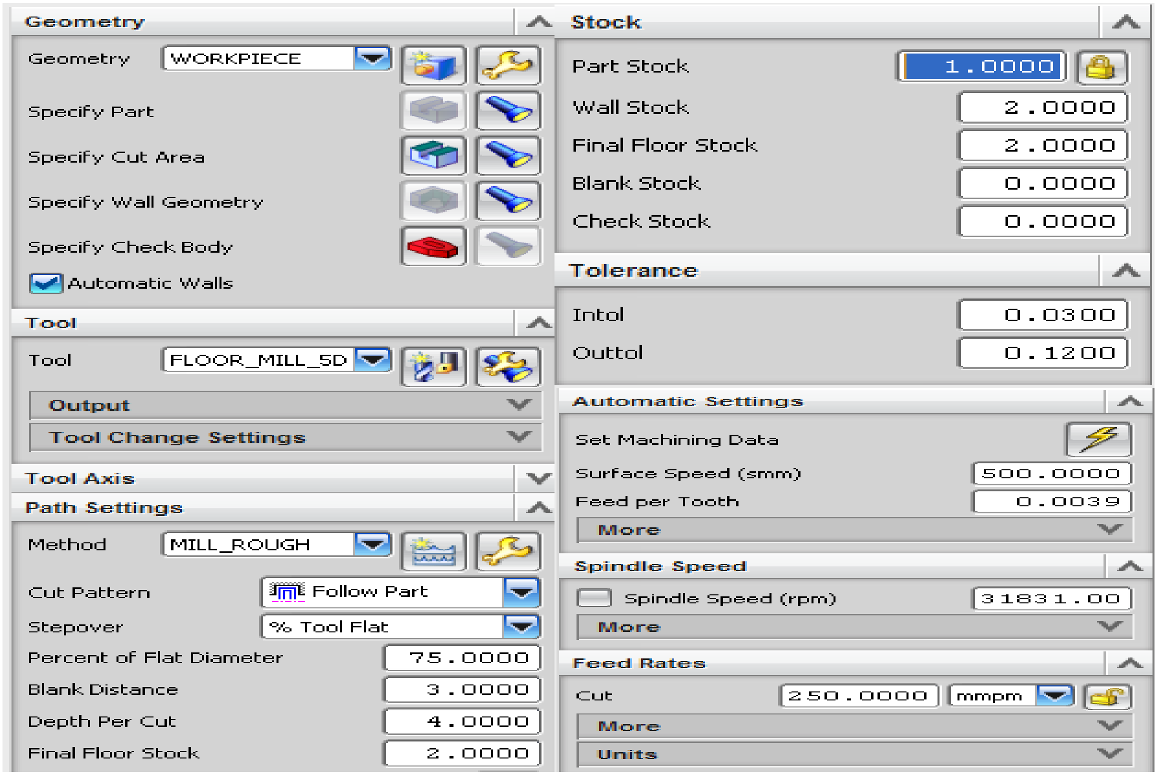


Figure 48

Tool	**5 diameter**
Cut pattern	**Follow part**
Stepover	**Tool flat**
Percent of flat diameter	**%75**
Blank distance	**3**
Depth per cut	**4**
Final floor stock	**2**
Surface speed	**500**
Feed per tooth	**0.0039**
Spindle speed (rpm)	**31831**
Cut	**250 mmpm**
Wall stock	**2**

Table 13

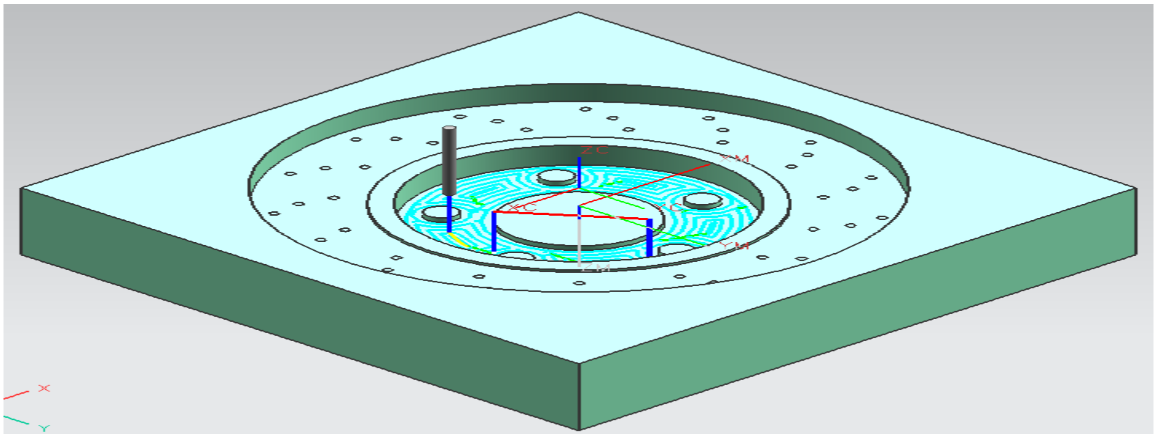


Figure 49

11.5. Cavity Semi-Finish

The semi-finish and finish stage was follow as roughing stage with the same selected tools but different operation settings which can be seen from below tables. The final floor stack has been set to 0.1 which means 1.9mm of material will be remove at the semi-finish stage.

11.5.1 Semi-Finish Area 1

Tool	50 diameter
Cut pattern	Zig Zag
Stepover	Tool flat
Percent of flat diameter	%75
Blank distance	2
Depth per cut	1.45
Final floor stock	0.1
Surface speed	500
Feed per tooth	0.0392
Spindle speed (rpm)	3183
Cut	250 mmpm
Wall stock	0

Table 14

11.5.2 Semi-Finish Area 2

Tool	30 diameter
Cut pattern	Profile
Stepover	Tool flat
Percent of flat diameter	%75
Blank distance	2
Depth per cut	1.45
Final floor stock	0.1
Surface speed	500
Feed per tooth	0.0235
Spindle speed (rpm)	5305
Cut	250 mmpm
Wall stock	2

Table 15

11.5.3 Semi-Finish Area 3

Tool	20 diameter
Cut pattern	Follow periphery
Stepover	Tool flat
Percent of flat diameter	%75
Blank distance	2
Depth per cut	1.45
Final floor stock	0.1
Surface speed	500
Feed per tooth	0.0157
Spindle speed (rpm)	7958
Cut	250 mmpm
Wall stock	1

Table 16

11.5.4 Semi-Finish Area 4

Tool	**10 diameter**
Cut pattern	**Follow part**
Stepover	**Tool flat**
Percent of flat diameter	**%75**
Blank distance	**2**
Depth per cut	**1.45**
Final floor stock	**0.1**
Surface speed	**500**
Feed per tooth	**0.0078**
Spindle speed (rpm)	**15915**
Cut	**250 mmpm**
Wall stock	**0.1**

Table 17

11.5.5 Semi-Finish Area 5

Tool	**5 diameter**
Cut pattern	**Follow part**
Stepover	**Tool flat**
Percent of flat diameter	**%75**
Blank distance	**2**
Depth per cut	**1.45**
Final floor stock	**0.1**
Surface speed	**500**
Feed per tooth	**0.0039**
Spindle speed (rpm)	**31831**
Cut	**250 mmpm**
Wall stock	**0.1**

Table 18

6. Finish

Finally the final operating for the cavity machining is Mill-Finish. For the mill-finish stage again all above been repeated with same tool sizes and numbers which been use in roughing and semi-finish operation. Different for the finish stage is the operation method. Additional to that there is only 0.1mm of material left to be remove in order to achieve the final product with high quietly and small tolerances.

Appendix 1 shows more details regarding the Mill-finish setup operation.

7. Cavity Machining Time

The total machining time for the break disc cavity part is 3:43:24 and the machining length is 55703.

Name	Toolc...	Path	Tool	Tool Number	Time	Length	Geometry	Method
NC_PROGRAM					03:43:24	55703		
Unused Items								
CAVITY_MACHINING					03:43:24	55703		
MILL_ROUGHING					01:04:52	16117		
FACE_MILL_ROUGHING_AREA1		✔	FACE_MILL_50D	1	00:27:56	6971	WORKPIECE	MILL_ROUGH
CAVITY_MILL_ROUGHING_AREA2		✔	CAVITY_MILL_30D	2	00:05:21	1336	WORKPIECE	MILL_ROUGH
FACE_MILL_ROUGHING_AREA3		✔	CAVITY_MILL_20D	3	00:05:55	1478	WORKPIECE	MILL_ROUGH
CAVITY_MILL_ROUGHING_AREA4		✔	CAVITY_MILL_10D	4	00:14:09	3457	WORKPIECE	MILL_ROUGH
FLOOR_MILL_ROUGHING_AREA5		✔	FLOOR_MILL_5D	5	00:11:30	2872	WORKPIECE	MILL_ROUGH
MILL_SEMI_FINISH					01:43:00	25716		
FACE_MILL_SEMI_FINISH_AREA1		✔	FACE_MILL_50D	1	00:27:56	6971	WORKPIECE	MILL_SEMI_FI...
CAVITY_MILL_SEMI_FINISH_AREA_2		✔	CAVITY_MILL_30D	2	00:10:40	2665	WORKPIECE	MILL_SEMI_FI...
FACE_MILL_SEMI_FINISH_AREA3		✔	CAVITY_MILL_20D	3	00:11:50	2957	WORKPIECE	MILL_SEMI_FI...
CAVITY_MILL_SEMI_FINISH_AREA4		✔	CAVITY_MILL_10D	4	00:24:54	6218	WORKPIECE	MILL_SEMI_FI...
FLOOR_MILL_SEMI_FINISH_AREA5		✔	FLOOR_MILL_5D	5	00:27:37	6902	WORKPIECE	MILL_SEMI_FI...
MILL_FINISHING					00:55:31	13869		
FACE_MILL_FINISH_AREA1		✔	FACE_MILL_50D	1	00:13:56	3485	WORKPIECE	MILL_FINISH
CAVITY_MILL_FINISH_AREA2		✔	CAVITY_MILL_30D	2	00:16:28	4112	WORKPIECE	MILL_FINISH
FACE_MILL_FINISH_AREA3		✔	CAVITY_MILL_20D	3	00:06:05	1521	WORKPIECE	MILL_FINISH
CAVITY_MILL_FINISH_AREA4		✔	CAVITY_MILL_10D	4	00:05:10	1290	WORKPIECE	MILL_FINISH
FLOOR_MILL_FINISH_AREA5		✔	FLOOR_MILL_5D	5	00:13:50	3459	WORKPIECE	MILL_FINISH

Figure 50

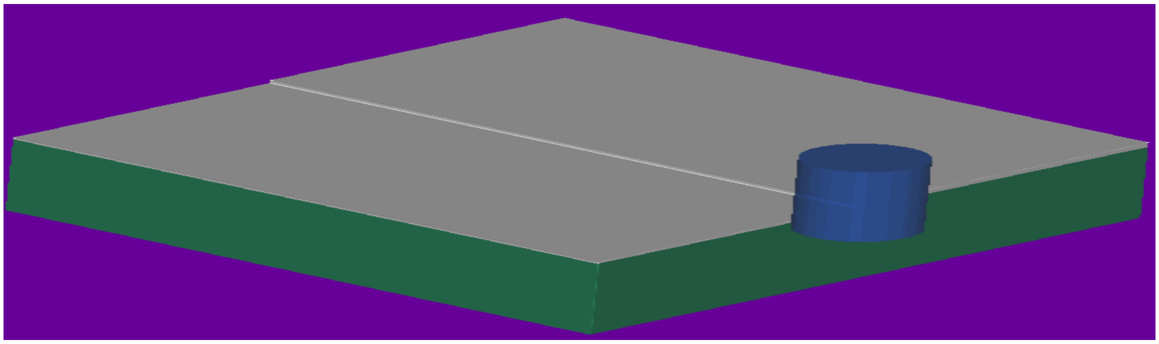


Figure 51

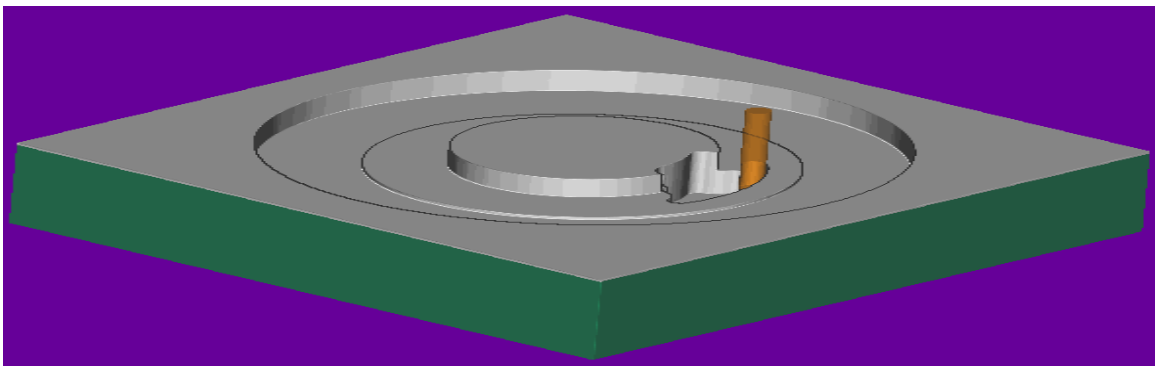


Figure 52

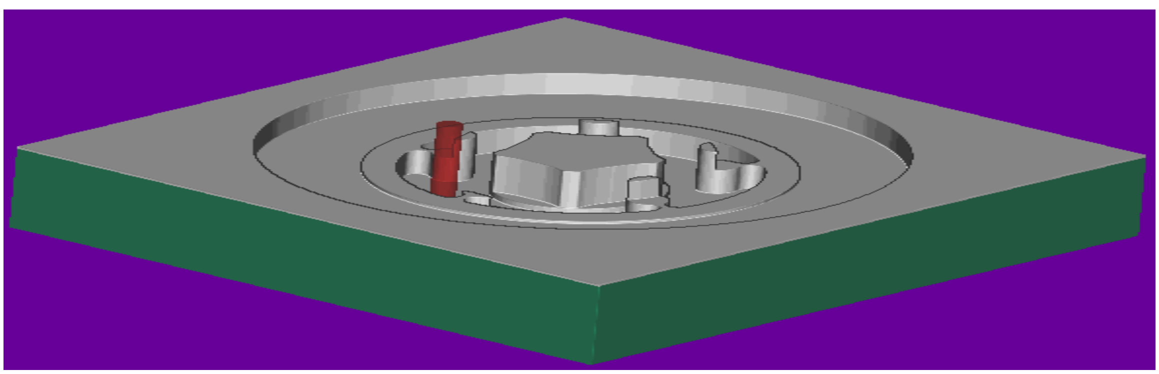


Figure 53

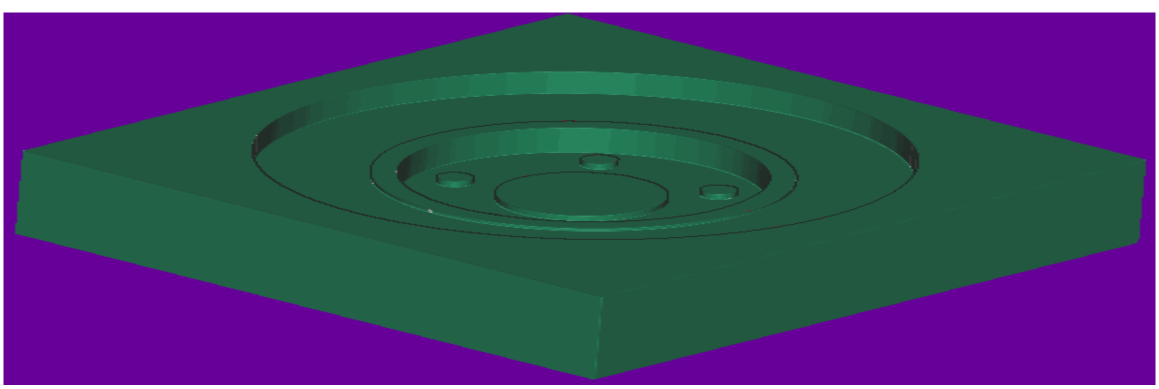


Figure 54

12. Core Machining

The method for this stage is almost same as cavity machining with 5 different tools and different operation setting for each step. As explained before there are three stages for the core machining:

- Roughing
- Semi-finish
- Finish

Each of the above steps been divided to 3 deferent area of machining. in the pervious section (cavity machining) method of the roughing and semi-finish been explain therefore in this section the final method of Mill-finish for the final product of the core machining will be explain.

MILLING_30D
MILLING_20D
MILLING_15D
MILLING_10D
MILLING_5D

Table 19

12.1 Finish

For the finish stage which was the final process of the core machining the part been divided to three deferent areas such as (lower surface; upper surface and wall)

12.1.1 Lower Surface or Floor

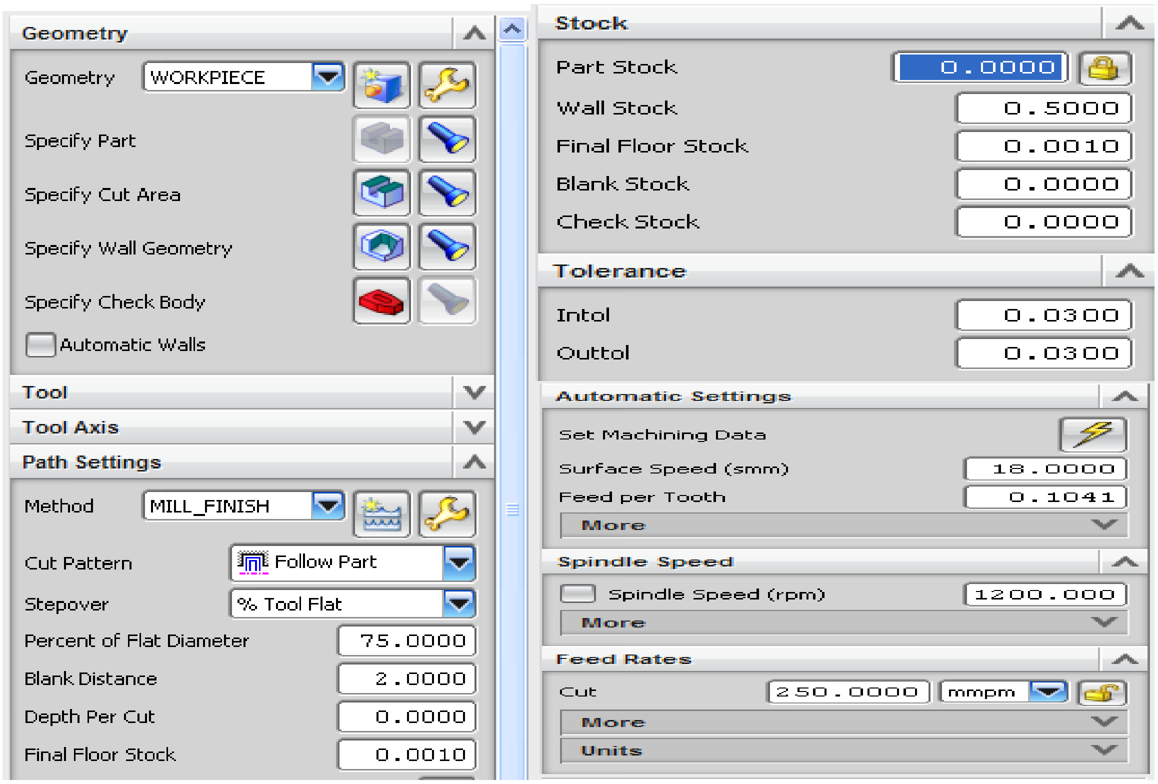


Figure 55

Tool	**5 diameter**
Cut pattern	**Follow part**
Stepover	**Tool flat**
Percent of flat diameter	**%75**
Blank distance	**2**
Depth per cut	**0**
Final floor stock	**0.001**
Surface speed	**18**
Feed per tooth	**0.1041**
Spindle speed (rpm)	**1200**
Cut	**250 mmpm**
Wall stock	**0.5**

Table 20

12.1.2 Upper Surface or Top Faces

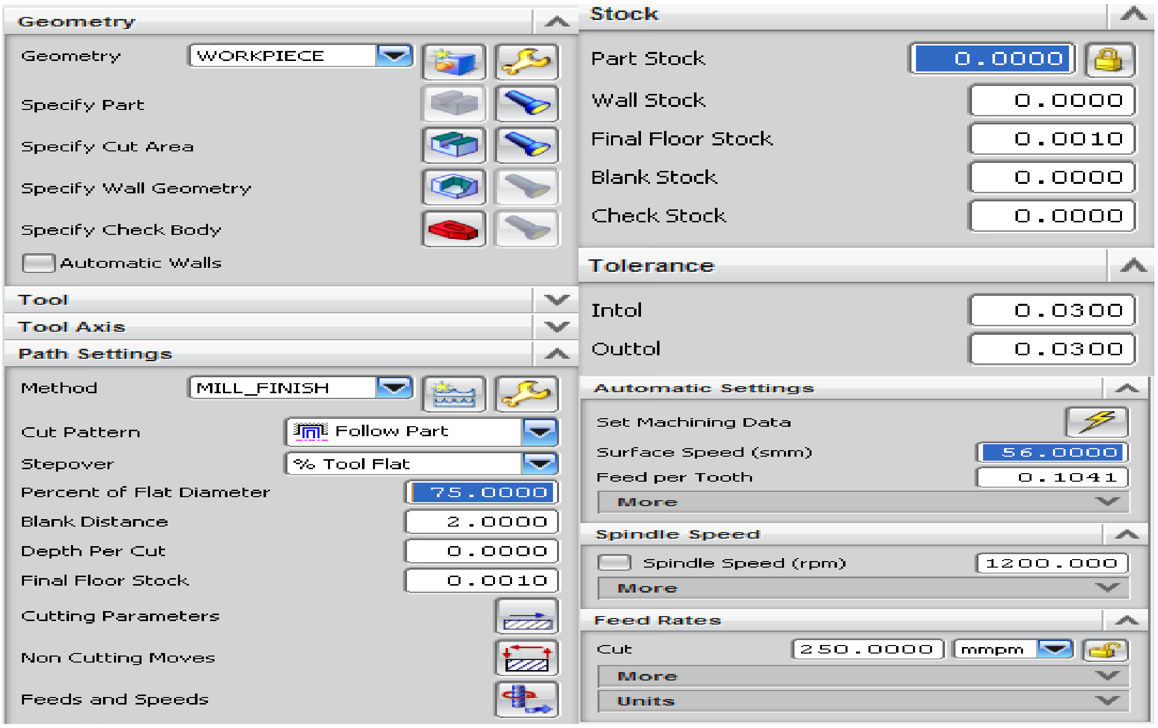


Figure 56

Tool	**15 diameter**
Cut pattern	**Follow part**
Stepover	**Tool flat**
Percent of flat diameter	**%75**
Blank distance	**2**
Depth per cut	**0**
Final floor stock	**0.001**
Surface speed	**56**
Feed per tooth	**0.1041**
Spindle speed (rpm)	**1200**
Cut	**250 mmpm**
Wall stock	**0**

Table 21

12.1.3 Wall

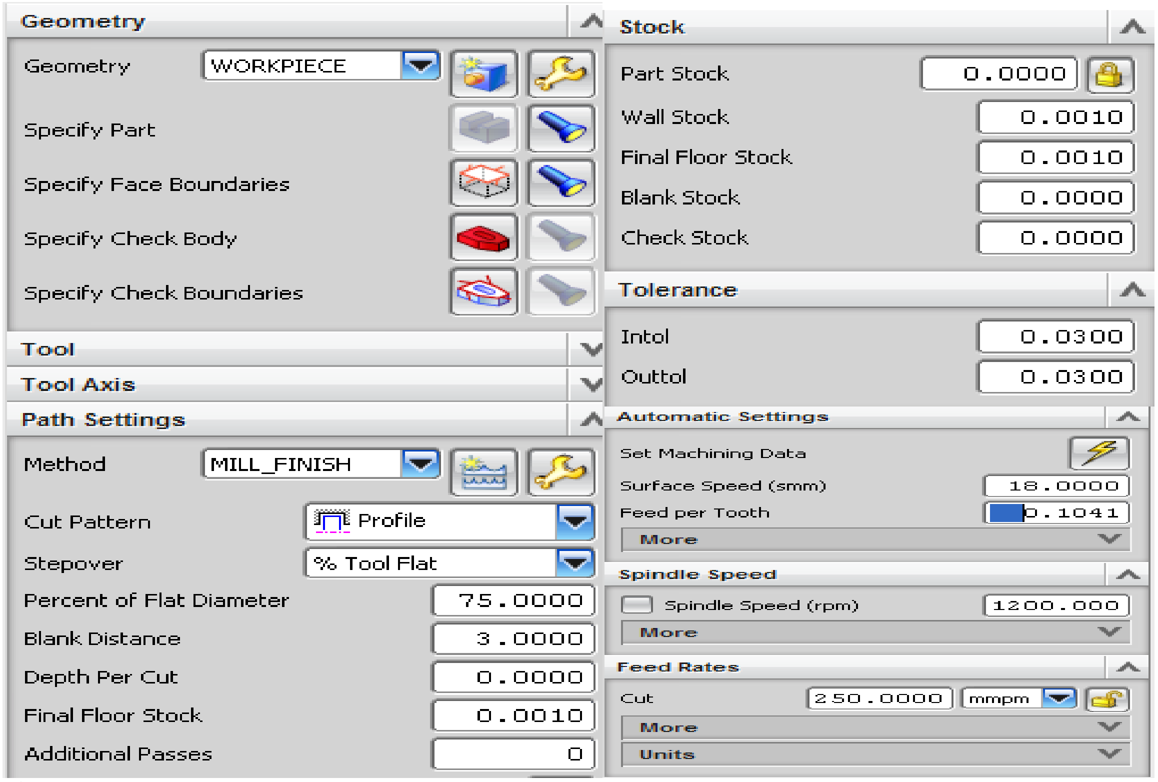


Figure 57

Tool	**5 diameter**
Cut pattern	**Profile**
Stepover	**Tool flat**
Percent of flat diameter	**%75**
Blank distance	**3**
Depth per cut	**0**
Final floor stock	**0.001**
Surface speed	**18**
Feed per tooth	**0.1041**
Spindle speed (rpm)	**1200**
Cut	**250 mmpm**
Wall stock	**0.001**

Table 22

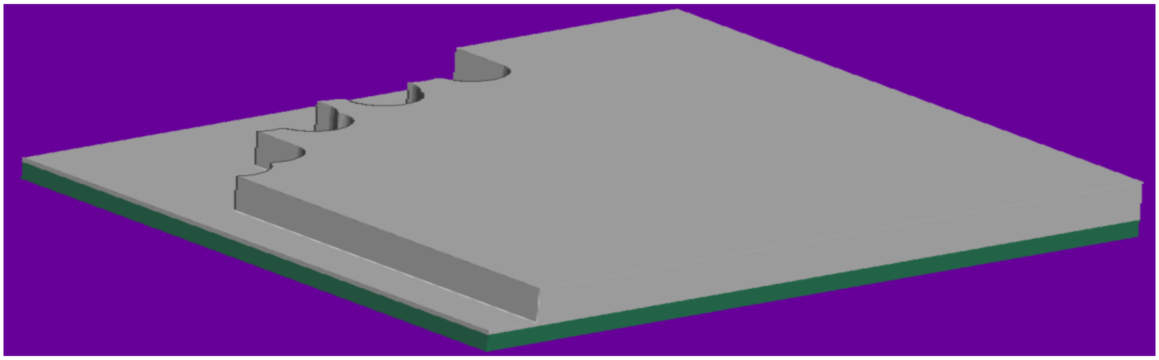


Figure 58

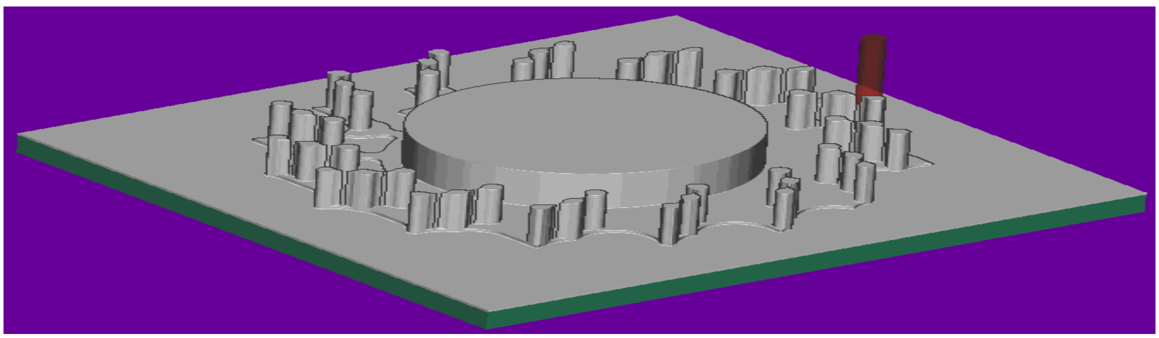


Figure 59

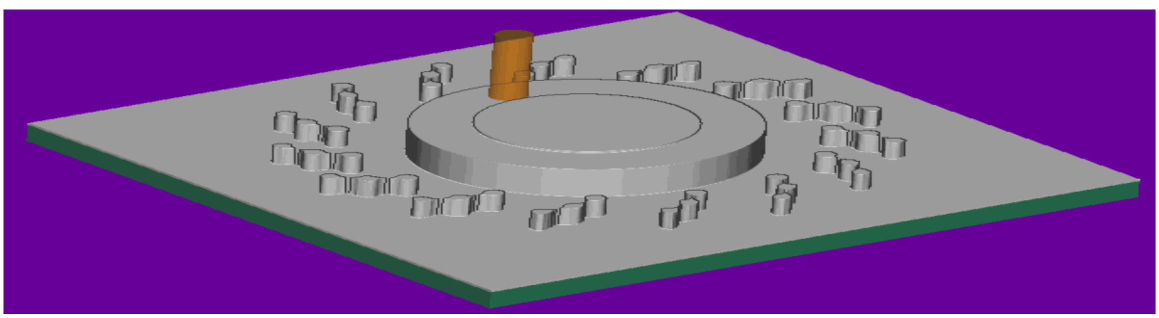


Figure 60

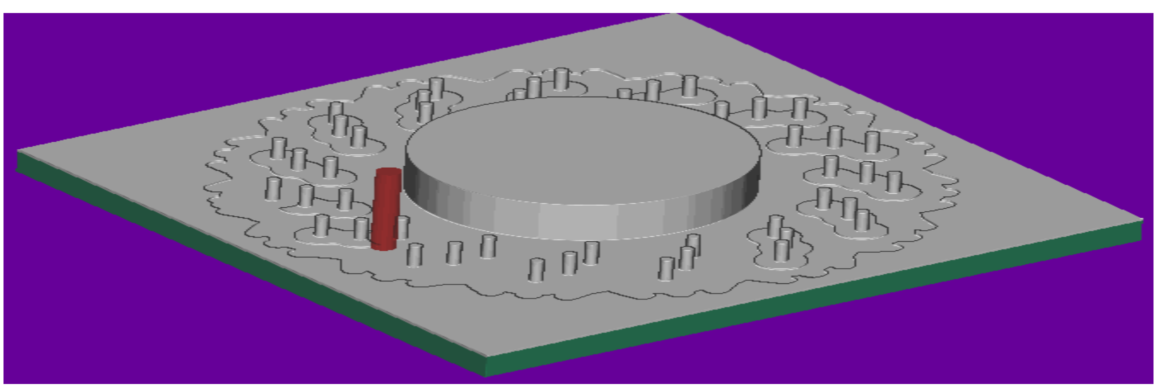


Figure 61

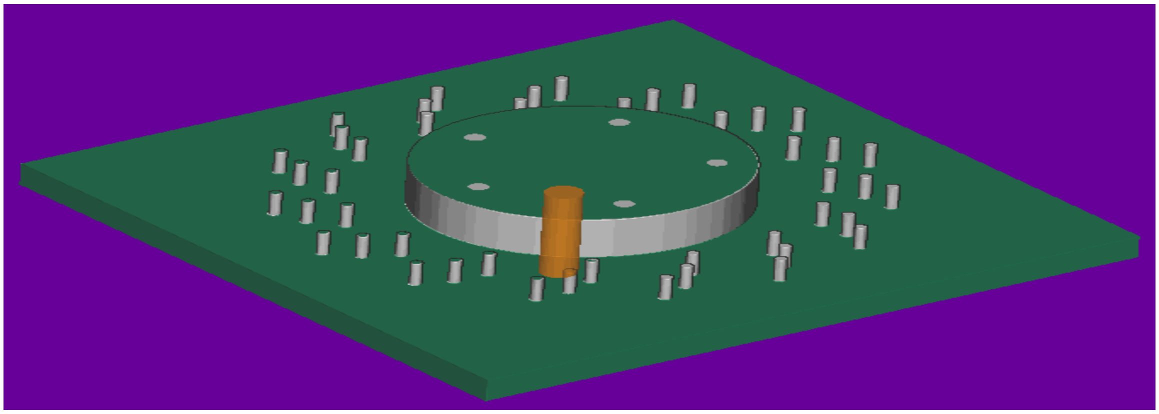


Figure 62

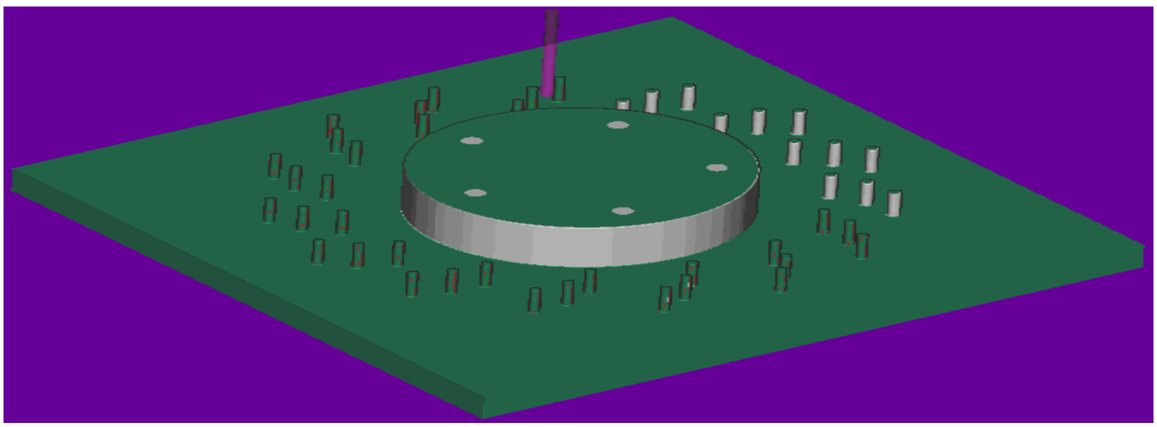


Figure 63

12.1.4 Core Machining Time

The total machining time for the break disc core part is 06:06:59 and the machining length is 90324.

Name	Toolc...	Path	Tool	Tool Number	Time	Length	Geometry	Method
NC_PROGRAM					06:06:59	90324		
Unused Items								
CORE_MECHINICNG					06:06:59	90324		
ROUGHING					01:58:30	29228		
FLOOR_MILLING_AREA_1			FACE_...	1	00:27:26	6720	WORKPIECE	MILL_ROUGH
FLOOR_MILLING_AREA_2			FACE_...	2	00:49:33	12139	WORKPIECE	MILL_ROUGH
FACE_MILLING_AREA_3			FACE_...	3	00:41:30	10368	WORKPIECE	MILL_ROUGH
SEMI_FINISH					02:03:08	30242		
FACE_MILLING_SEMI_FINISH			MILL_S...	4	00:21:29	5333	WORKPIECE	MILL_SEMI_FI...
FLOOR_SEMI_FINISH_AREA_2			MILL_F...	5	00:59:12	14362	WORKPIECE	MILL_SEMI_FI...
FLOOR_SEMI_FINISH_AREA_1			MILL_S...	4	00:42:26	10546	WORKPIECE	MILL_SEMI_FI...
FINISH					02:05:19	30853		
FLOOR_FINISH_AREA_2			FLOOR...	6	01:34:49	23370	WORKPIECE	MILL_FINISH
FACE_FINISH_AREA_3			MILL_S...	4	00:21:18	5285	WORKPIECE	MILL_FINISH
WALL_FINISH			FLOOR...	6	00:09:12	2197	WORKPIECE	MILL_FINISH

Figure 64

Once the machining part for the core and cavity was completed the CLS (Cutter locations data) and G code (CNC machining language) were produce according to the all above processes. Please see appendix 1 and 2 for the G code and CLS data.

13. Conclusion

Molding and machining are two different processes. But the nature of engineering combines them together all the time. Therefore engineers are constantly asked to perform in harmony and balance regarding design processes. It is known in the filed as DFMA or design for manufacturing.

By creating the Break disc with the different software (solid works 2010) and importing the model to NX6 the process of molding and machining been continued which proved that today technology allows the engineers to combine different data, from design to manufacturing in order to achieve the final product with minimum tolerances to satisfy the customer's needs and requirements.

Today wouldn't exist without the current technology of the CAD/CAM, however engineers still pushing to achieve the higher and most advanced technology to derive the CAD/CAM more efficiency and accrete without the human work force. That will allows the manufacturing process such as CNC to produce the product with minimum tolerances which been design, without the human control simply by sending the data from final design to the machine for manufacturing.

Reference

Fuh J.Y.H, Computer-aided injection mould design and manufacture, 2004,
ISBN: 0824753143.

McMahon C & Browne J, CADCAM: Principles, Practice and Manufacturing Management, 2000, ISBN: 0201565021

Wise Geek (2010) what is injection molding [Online] Available from: http://www.wisegeek.com/what-is-injection-molding.htm [Accessed: 05 May, 2010].

Injection molding (2010) info, help, resource [Online] Available from: http://www.what-is-injection-molding.com/Default.aspx?tabid=36 [Accessed: 07 May, 2010].

Adigitaldreamer (2010) what is computer aided design or CAD. [Online] Available from: http://www.adigitaldreamer.com/articles/what-is-computer-aideddesign.htm [Accessed: 15 May, 2010].

Efunda (2010) CNC Fabrication [Online] Available from: http://www.efunda.com/processes/metal_processing/cnc.cfm [Accessed: 18 May, 2010].