# COMPLETE AUTOMATION OF MACHINING CYCLE FOR A PARTICULAR OBJECT AND THE ALGORITHM

**[1]PRATIK SONI, [2]R.R. LEKURWALE**

[1]M.E. (Mechanical) Second year, K.J. Somaiya College of Engineering, M.Tech (IITB), Ph.D(Pursuing at VJTI)
[2]Associate Professor, Department of Mechanical Engineering. K.J.Somaiya College of Engineering, Vidyavihar(E)Mumbai
Email: [1]Pratik.soni@somaiya.edu, [2]rameshlekurwale@somaiya.edu

**Abstract**—Segmented Object Manufacturing (SOM) is a machine which can be a substitute to conventional 3D printing machines. The machine is used to prepare prototypes out of expanded polystyrene. It uses three processes to manufacture the object. Two subtractive processes being conventional machining and hot wire slicing and one additive process being gluing. All the three processes needed to be run manually until now. This paper proposes to integrate all the three processes into one automatic program. It outlines the steps used to create the program and describes the tools required to create the program. (Abstract)

**Keywords**—Segmented, Manufacturing, Thermocol, Slicing, Automation.

## I. INTRODUCTION

Manufacturing has been dominated by subtractive manufacturing till the mid-1980s. Material was removed from a pre-defined block of raw material. But this process had various disadvantages like generation of a lot of scrap material, long build times, costly tool replacements and long tool design times. Manufacture of a single prototype could take several weeks. With the advent of three dimensional printing, a lot of these aspects like raw material, tool design, noisy machines became obsolete. The principal of three dimensional printing is the same as that of two dimensional printing. In a two dimensional printer, the image is printed line by line. In a three dimensional printer, the image is printed slice by slice.

Many technologies exist in the market for three dimensional printing. Notable amongst them are,

- SLS (Selective Laser Sintering) – it uses polyamide powder as a raw material and lasers to selectively sinter parts of the powder bed.
- SLA (Stereo-Lithography) – It uses liquid as a raw material and lasers to selectively harden parts of the liquid bed
- FDM (Fused Deposition Modeling) – It uses molten plastic to build objects from the bottom up.

However, all these technologies are expensive and require extensive training to use. Another drawback of all printed objects is long build times and the staircase effect. The SOM machine overcomes these. It is a machine designed and developed to make objects out of expanded polystyrene (popularly known as thermocol).

The design of the machine is based on a conventional 3 axis machine. But it has additional features which make it a truly hybrid machine. It does both types of manufacturing operations, the conventional subtraction and the modern addition. The subtraction is done in two ways, by machining the thermocol using an end mill cutter and by a nichrome wire which slices thermocol when current is passed through the wire. The addition is accomplished by two mechanisms, one is the drop table mechanism and the other is a glue gun. The machine is called a Segmented Object Manufacturing (SOM) machine.

It overcomes the drawbacks of conventional three dimensional printers in two ways. It builds objects in thick slices instead of thin slices. This significantly reduces build times as compared to conventional three dimensional printers. Another advantage is almost total elimination of the staircase effect. Both these are significant advantages over the conventional process.

The machine works in the following way: A thermocol block (raw material) is stuck on to the drop table. It is at the top. The machining is done with the tool inverted. The drop table releases the brakes and the entire table is brought down. The hot wire slices through the thermocol block. The drop table is taken back up and locked. Machining now takes place with the tool pointed downwards. Once finished, the tool is inverted and taken up to the drop table. The second slice is machined from the bottom. Now application of glue takes place on the bottom slice. After the application of glue, the drop table is released and the second slice gets stuck on the first slice. The hot wire slices through. The drop table is taken back up and locked. Finally the second slice gets machined from the top. The entire process gets repeated for the subsequent slices.

The machine that existed previously has completely broken down and was unused since the past three years. Our first task was to get the machine into running condition. This required a lot of study and work, replacing components, getting components repaired and checking for faults throughout the machine. During this process we gained in depth knowledge about machine building, interfacing the controller with a computer and performed tweaks to make the machine functional

Segmented Object Manufacturing (SOM) is a variant of the rapid prototyping technology. Conventional rapid prototyping has significant disadvantages like (1) long build times and (2) the staircase effect. SOM is an on-going project at IIT-Bombay that seeks to develop fully automatic operation from art (i.e. the CAD model) to part (i.e. A prototype of the object built using high density polystyrene)

## II. THE SOM MACHINE AND ITS WORKING PRINCIPLE

The SOM machine manufactures objects out of thermocol. Instead of conventional rapid prototyping using thin slices, SOM builds objects in thick slices. This results in considerable reduction in build time and almost total elimination of the staircase effect. The machine has two worktables, one at the top and one at the bottom. It machines the polystyrene using conventional milling. It slices the thermocol using a heated nichrome wire and it glues the slices using a glue gun

## III. CONCEPT OF VISIBLE SLICING

Any object that is required can be built in thick slices. These slices are called visible slices. They are called so because the object has to be cut at a plane where the internal features become visible when the object is looked from both above and below. If we consider the figure as shown, in-order for the hole in the middle to be visible, the object has to be sliced. At present the location of the slices needs to be determined manually.

## IV. OBJECTIVE OF THE WORK

The authors have carried out a complete over-hauling of the machine and restored it to working condition. The objective of the work was to achieve a single button operation for a particular component. The component is indicated below:

The component has to be prepared in two slices because of the presence of the lateral hole. Machining lateral holes is not possible in conventional 3-axis machining because of the restriction in tool axis movement. In-order to machine this component, two different settings need to be used which may result in errors. The author proposes to build the entire object in two slices as follows:

**Slice 2** **Slice 1**

## V. PROCEDURE TO MAKE THE OBJECT

The object would be made in four major steps. Begin by attaching a polystyrene block to the upper table. In the first step, slice one is machined from the bottom. Second step, slice one is machined from the top. Step three, slice 2 is machined from the bottom and step four, slice 2 is machined from the top. The accessory operations of slicing and gluing have to be added at appropriate places.

The tools that were used to make the program were as follows:

### A. DelCAM Powershape
This program was used to slice the object into two parts. The steps to be followed are:
1. Import the complete object to powershape
2. Create planes at the required heights
3. Create slices

### B. DelCAM Powermill
This program was used to create the programs for individual slices both for the upper and the lower table machining. The software creates generic programs to machine the object on any machine. The output format can be changed according the machine controller being used. In this case fanuc, series Oi-Mate-MC. The programs that are created are not ready to be used as it is. They need to be edited.
The steps to be followed are as follows

1. Import all slices of the object into DelCAM Powemill. (powermill accepts .stl and .iges files only)
2. Create a boundary of the object under consideration.
3. Create a block using the boundary
*blocks can be created in two ways, one is to directly create a block using the box option. This takes into account the maximum dimensions of the object in the x,y and z directions. This feature is unnecessary while using thermocol as raw material. Machining can take place along the boundary and when the object gets sliced, the non-useful part gets separated. This saves precious machining time and quickens the entire process considerably.
4. Define work planes using the center of the block option. (two work planes need to be defined, one at the top of the object,I and one at the bottom of the object, II)
5. Orient the work planes such that the slicing planes are perpendicular to the z-axis.

6. Create a ball nosed tool using the create tool option and give the dimensions according to requirements.
7. On the left panel. There is a tree which shows ‘model’ and a plus sign beside it, click on it, you shall be able to see all the slices in it, delete all slices except the one you intend to make the program for.
8. Once the above steps are done, we can start the process to make the program. Start by choosing a roughing strategy. For our case we choose 2D area clearance since there are no complex contours along the surface of the object.
9. Next we select the block, the work plane, thickness of material left on the object after machining and the tool safe heights.
10. Since we are creating a program for machining from the top, we choose work plane I.
11. Click on calculate, the program calculates the tool path.
12. Simulate and check if the tool path is accurate and provides the required surface finish.
13. In the tree on the left hand side pane, there is a title called toolpath, click on the ‘+’ sign beside it, the newly created program is labeled as 1, change the name suitably.
14. The program needs to be converted to a CNC code. Right click on the program and select “generate individual NC program”.
15. Go to NC programs, right click and select settings.
16. Select the option file as “standard fanuc machine option file” ,and click on write.
17. The code gets saved in a file with a .tap extension.
18. Change the .tap extension to .ncc.
19. Repeat the entire process for work plane 2
20. This will be the program for machining from below.
21. Import the next slice, delete the current slice and repeat all the steps. Do not change the position of the origin

### C. Microsoft notepad

The program created by DelCAM is for conventional 3-axis machining. It assumes that the tool is above the raw material. In case of the SOM machine, the machining takes place from the bottom as well. So the program needs to be tweaked using MS-Notepad. It was done by using the find and replace feature in notepad. Z- (which stands for the negative z-axis) was replaced by ‘@’ and Z (which stands for the positive z-axis) was replaced by ‘*’. Then ‘*’ was replaced with Z- and ‘@’ was replaced with ‘@’. This resulted in the mirror image of the object being machined which suited the authors purpose. The notepad was also used to compile the programs into one program to make a completely automatic cycle.

### D. CIMCO V5

This software simulates the tool path. It was used to check the final program after it had been edited and compiled.

## VI. THE ALGORITHM

1. Set the origin at the center of the thermocol block
2. Run the first program
3. Park the ATC in the hot wire slot
4. Take the ATC near the top table
5. Release the brake
6. Take the brake table down till the thermocol block touches the bottom table
7. Lock the brake table
8. Adjust the hot wire at the slicing height
9. Slice on and slice the thermocol block
10. Take the ATC back to coordinates of "7"
11. Release the brake
12. Take the table back up
13. Lock the brakes
14. Take the ATC down sufficiently and park the hot wire in the hot wire slot.
15. Take the ATC to the origin and shift the origin lower (the origin will shift by "the distance between the top and bottom table(742) - (the thickness of the complete block + the thickness of the first slice + distance between the two tool tips)"
16. Run the second program
17. Take ATC back to origin.
18. Origin shifts up as compared to the first origin by 10 + Thickness of the first slice (We add 10 because the origin was 5 mm below for the first slice and 5 mm above for the second slice)
19. Run the third program
20. Shift the origin lower to the same coordinates as "15"
21. Take the glue gun to the origin and 5mm along z positive
22. Take glue gun (35, -6)
24. Start glue gun
25. Take glue gun 40 mm along x +ve
26. Take glue gun 12mm along y +ve
27. Take glue gun 40mm along x -ve
28. Take glue gun 12 mm along y -ve
29. Take glue gun to (136.02, -6)
30. 3mm along x +ve
31. 12 mm along y +ve
32. 3mm along x -ve
33. 12mm along y -ve
34. Reset to original origin
35. Park the ATC in the slot
36. Take the ATC to the top table
37. Release the brakes
38. Take the top table down such that the top slice sticks to the bottom slice (the block rests on the bottom table)
39. Lock the brakes
40. Adjust hot wire to the the height of the second slice

41. Slice on and slice the thermocol block. same as "9".
42. Take the ATC to coordinates of "39".
43. Release the brakes
44. Take the brake table back up
45. Lock the brakes
46. Come sufficiently down and park the hot wire again.
47. Go to the origin
48. Run the fourth program.
49. The component is ready

## CONCLUSION

Thermocol prototyping is a viable alternative to conventional expensive machines. In addition it has been developed in-house and also does not have major drawbacks associated with 3-D printing. However at present, we can make automatic code for only specific objects and the iterations take a long time. A program which generates code for any general object would be the ultimate goal for this SOM Machine.

## ACKNOWLEDGMENT

I would like to express my gratitude towards IIT-Bombay and Prof. K.P. Karunakaran to provide me the opportunity to work at IIT. I would also like to thank my collegues who provided invaluable support during the course of this project. I would also like to thank Prof. R.R. Lekurwale for his valuable guidance during the tenure of this experiment.

## REFERENCES

[1] K.P.Karunakaran, Saurabh Agarwal, Pankaj Vengrulekar, Sahasrabude, Vishal Pushpa; "Segmented Object Manufacturing" IIE Transation, 23 Feb 2007

[2] Anjali Kumar Pandey, Mtech thesis, "Integration of Segmented Object Manufacturing Machine", 2007

★★★