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Analysis of Different Parameters on Tool Path for Machining Sculptured Surfaces

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1. Abstract –

In this paper effect of different parameters on tool path is described. This paper shows that, for machining a surface an appropriate cutter diameter, step over percentage, is required. If they are not in proper range, than machining time increases. So for creating a sculptured surface in CNC milling process effect of different parameters are analyzed and the effect of parameters (like feed rate, step down, effect of tool containment boundaries etc.) on machining time is shown. In this analysis, main purpose is to obtain the minimum machining time for machining process, so different parameters are analyzed with respect to machining time because if machining time is optimal than our production time reduces and production rate increases. This paper analyzed different parameters with respect to machining time and conclusions are given based on the results.

For this analysis all the data is obtained from the software MASTERCAM and analysis is based on the CNC end milling process. Experiments are performed on "MSME Tool Room, Jamshedpur" under the guidance of "Mr. Jyoti" for MASTERCAM and "Mr. Koyal Mohamed " for the CNC end milling process.

Keyword- Sculptured surfaces, CNC milling, MASTERCAM, Tool paths, Simulation, Computer integrated manufacturing.

2. Introduction –

In the present time sculptured surfaces are very widely used in different industries like automobiles in which different type of parts generally created with sculptured surfaces are used. These surfaces are used for increasing the performance and giving a good look for the car or other part. A great variety of products, from dies for machining automotive body panels to turbine blades all rely on this technology. Sculptured surface machining (SSM) on a multi-axis NC machine requires application of efficient methods of tool path generation. So an analysis of different parameters which are effecting the machining of tool path is presented in this paper.

In previous paper "Simulation of tool path for machining sculptured surface" [1] basic idea of creating a surface with the help of basic dimensions and simulation methodology of machining a sculptured surface was given. Effect of parameters on the machining time and various relationships were not analyzed in that paper. So this paper gives the various relationships and effect on parameters on the machining time. Machining time is very important in manufacturing process because if machining time decreases than our production rate increases and cost of the component decreases. So analysis is done for obtaining optimal machining time in roughing operation because in roughing surface finish does not matters.

3. Literary survey -

There is a massive body of previous work in the area of cutting tool-path planning in machining sculptured surfaces on multi-axis NC machines. Dragomatz and Mann compiled a comprehensive overview of scientific publications in the field. The problem of tool-path generation was examined by Marciniak [2]. Choi and Jerard proposed a tool-path generation method called the "C-space method" [3]. A brief overview of the recent publications in the field of tool-path generation for SSM is presented below. The tool-path generation problem for the NC grinding operation was investigated by Sarma and Dutta [4]. A tool-path generation method for three-axis milling by using the guide surface was developed by Kim and Choi [5]. Five-axis roughing tool paths generated directly from a tessellated representation of a body were investigated in [6]. A cutter-path scheduling method is developed for milling of concave and/or wall-bounded surfaces [7]. An accurate and efficient method to generate a NC tool path for a smooth free-form surface in terms of planar cubic B-spline curves was developed by Lartigue et al [8]. Kim and Sarma proposed a heuristics-based approach to the problem of tool path generation along directions of maximum kinematic performance. Efficient tool-paths in SSM using three-axis ball-end milling are determined in [9]. Forthe Z-constant contour machining, a tool-path generation procedure is presented in [10].

4. EXPERIMENTATION –

In this paper all the experiment are performed on a sculptured surface for roughing operation. Details of generating of this surface and applying simulation are given in paper "Simulation of tool path for machining sculptured surface". in actual machining process for generating a surface different parameters are required like optimal diameter of tool, step over percentage, feed rate, depth of cut, step down etc. So for finding the optimal values of these parameters simulating software is used and after applying the experiments for different parameters results are obtained. Here dimensions of the part are given which is used in this experiment as follows-

4.1 Dimensions of the part-

Figure: 1 shown below gives dimension of the part used for machining operation. With the help of these dimensions a sculptured machining surface is created which is discussed in previous paper and after creating surface simulation is performed for roughing operation. So dimensions are as follows-

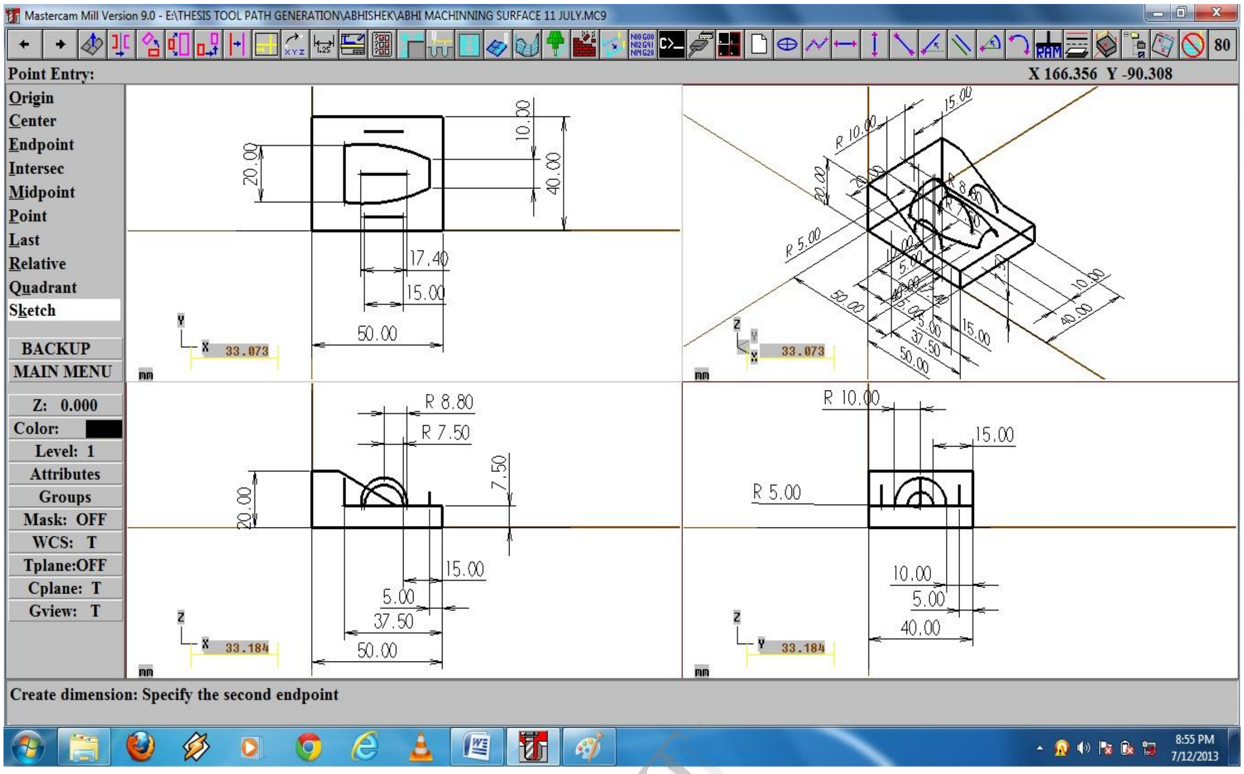


Figure1: Dimension of the Machining Surface

In this figure: 1 top view, front view, side view and isometric view of the part is shown. All the experiments are performed on the surfaces generated by this part this model is created in MASTERCAM software and machining operations are simulated for CNC end milling process. Firstly roughing operation is performed on the surface for removing the excess material than finishing operation is performed.

4.2 ROUGHENING OPERATION

Roughening operation is mainly perform for removing the excess material so for this operation appropriate strategy is that which can remove excess material in less time. While removing the material it is very important that the work piece and tool would prevent, from any unwanted defect or damage**.** In the present investigation various strategies applied on the work piece for the roughing operation, these strategies are available in the machining software MASTERCAM.

There are seven strategies which are followed by the software MASTERCAM. While applying these strategies input data like feed rate, spindle speed, plunge rate, retract rate are constant. Applying these strategies gives the result that which strategy is suitable for roughing operation and also its gives the optimal diameter of the cutter because it is done with different diameter range. These strategies are suitable for different operation for different machining condition the data obtained after applying these strategies are given in the table no 5.1.

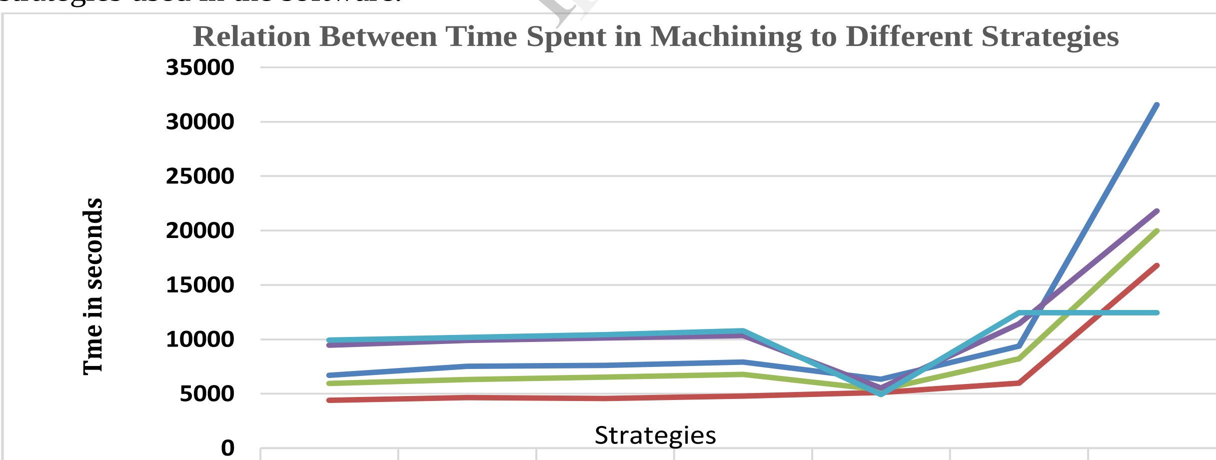
4.2.1 EFFECT OF DIAMETER ON DIFFERENT STRATEGIES

There are two parameters are analyzed by this experiment first one its gives appropriate strategy for the operation and second it gives the optimal cutter diameter for machining. Data obtain by simulating software by applying these strategies are given in table no.1. MASTERCAM gives us machining time in hr. min. and sec. but for plotting graphs this is converted into seconds.–

TABLE NO. 1 MACHINING TIME FOR DIFFERENT STRATEGIES

Sr. no.	Tool path strategies	Machining time (Sec.)				
		Dia 4	Dia 5	Dia 6	Dia 7	Dia 8
1	Zigzag	6680	4405	5947	9461	9934
2	Constant overlap spiral	7526	4650	6296	9917	10166
3	Parallel spiral	7605	4581	6522	10115	10414
4	Parallel spiral clean corners	7903	4781	6773	10336	10779
5	High speed	6332	5111	5366	5532	4918
6	True spiral	9373	5980	8228	11429	12448
7	One way	31582	16795	19976	21810	12448

Machining time for these seven strategies with different diameter range are available in seconds. So with the help of this data a graph is plot between machining time and different strategies used in the software.



	1	2	3	4	5	6	7
Diameter" 4"	6680	7526	7605	7903	6332	9373	31582
Diameter" 5"	4405	4650	4581	4781	5111	5980	16795
Diameter"6"	5947	6296	6522	6773	5366	8228	19976
Diameter "7"	9461	9917	10115	10336	5532	11429	21810
Diameter "8"	9934	10166	10414	10779	4918	12448	12448

Figure 2: Relationship between Time spent in Machining to Different Strategies

Figure :2 show that for a sculptured surface machining time is minimum for a specific diameter of a tool. For this diameter, machining operation gives minimum time. If diameter is varying from this diameter range than machining time increases. As in this study of graph no.1 diameter 5 gives us minimum machining time. So diameter 5 is suitable for machining.

For maximum production less time in machining required. As shown by the graph no.1 minimum machining time is obtained from zigzag tool path strategy. As shown in table no.1 seven strategies used for removing the material from the work piece but Zigzag motion of tool path takes less time so for roughing operation zigzag tool path selected. High speed strategy also gives minimum machining time at some places but it is not suitable for machining because after analysis we check it will not remove the material properly. So high speed strategy is not selected for this analysis.

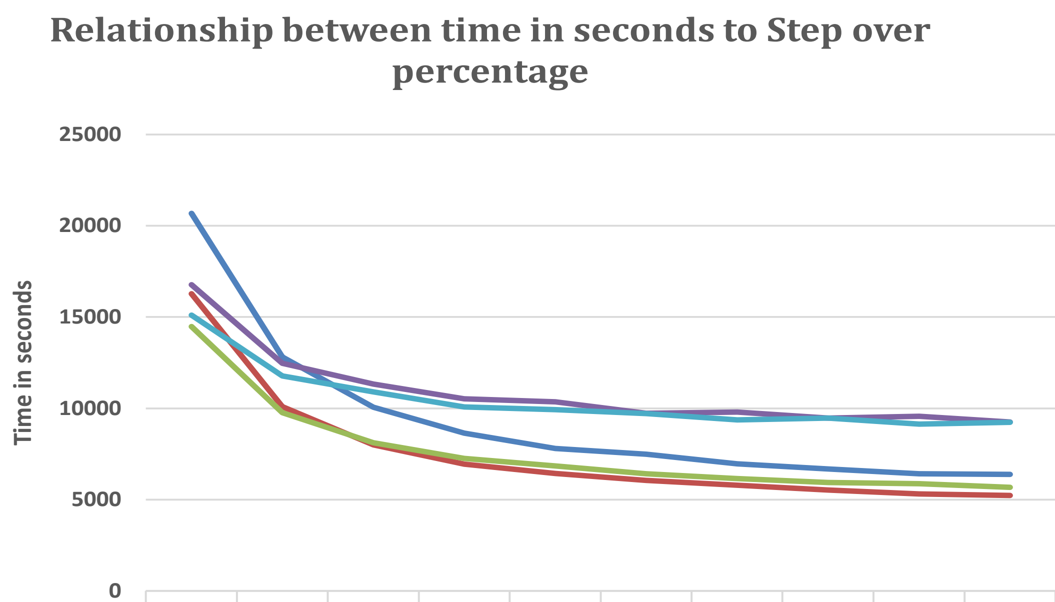
4.2.2 EFFECT OF STEP OVER PERCENTAGE ON THE MACHINING TIME

From above study, diameter and strategies which is followed for creating the surface is selected. Other parameters like step over percentage for Zigzag motion study is observed in this operations and its data is given in table no. 2 which is shown below-

TABLE NO. 2 MACHINING TIME DUE TO STEP OVER PERCENTAGE

Sr. no.	Step over percentage	Machining time (Sec.)				
		Dia 4	**Dia 5**	**Dia 6**	**Dia 7**	**Dia 8**
1	10	20673	16267	14478	16773	15105
2	20	12811	10088	9766	12465	11784
3	30	10054	7996	8116	11326	10909
4	40	8647	6948	7253	10520	10082
5	50	7796	6430	6854	10344	9934
6	60	7488	6058	6420	9725	9715
7	70	6953	5801	6152	9797	9368
8	80	6680	5536	5947	9461	9481
9	90	6415	5321	5870	9552	9144
10	100	6381	5234	5678	9244	9249

In table no. 2 machining time with varying step over percentage is shown, machining time is in seconds. Step over controls the surface finish of the machining material so for in roughing operation surface finish does not have more importance so its high value which gives less machining time safely is considered. Graph between machining time and step over percentage is given in figure: 3 -



	10	20	30	40	50	60	70	80	90	100
Diameter"4"	20673	12811	10054	8647	7796	7488	6953	6680	6415	6381
Diameter"5"	16267	10088	7996	6948	6430	6058	5801	5536	5321	5234
Diameter"6"	14478	9766	8116	7253	6854	6420	6152	5947	5870	5678
Diameter"7"	16773	12465	11326	10520	10344	9725	9797	9461	9552	9244
Diameter"8"	15105	11784	10909	10082	9934	9715	9368	9481	9144	9249

Figure 3: Relationship between Time (seconds) to Step over percentage

This figure: 3 show that when the value of step over percentage is less it takes more machining time. Its vale is almost same for the 70% to 90% range some deflection is occurs in between 80% to 90%. So 80% step over is selected for further analysis of surface.

After selecting the diameter of the tool its step over percentage and strategy follows during machining. Different other parameters effect on the machining time is analyzed these are given below-

4.2.3 EFFECT OF TOOL CONTAINMENT BOUNDARIES

Tool containment boundary is that boundary in which tool done its cutting action during the machining. In other words it is like a fence in between tool move. So for analyzing its effect on machining time two boundaries are selected one is lies on the wok piece outer boundary and other is having greater area than outer boundary of work piece. The data obtained from the software are given in table no.3-

TABLE NO. 3 MACHINING TIME DUE TO TOOL CONTAINMENT BOUNDARIES

Sr. no.	Tool path strategies	Machining time (Sec.)	
		Tool containment boundary 1 (lies outside)	Tool containment boundary 2 (lies on the work piece)
1	Zigzag	5536	4405
2	Constant overlap spiral	5743	4650
3	Parallel spiral	5868	4581
4	Parallel spiral clean corners	6144	4781
5	High speed	5754	5111
6	True spiral	8094	5980
7	One way	22568	16795

This data shows that if tool containment boundary increases than machining time increases so it is profitable to use optimal tool containment boundary. Relationship between tis data is shown in figure: 4-

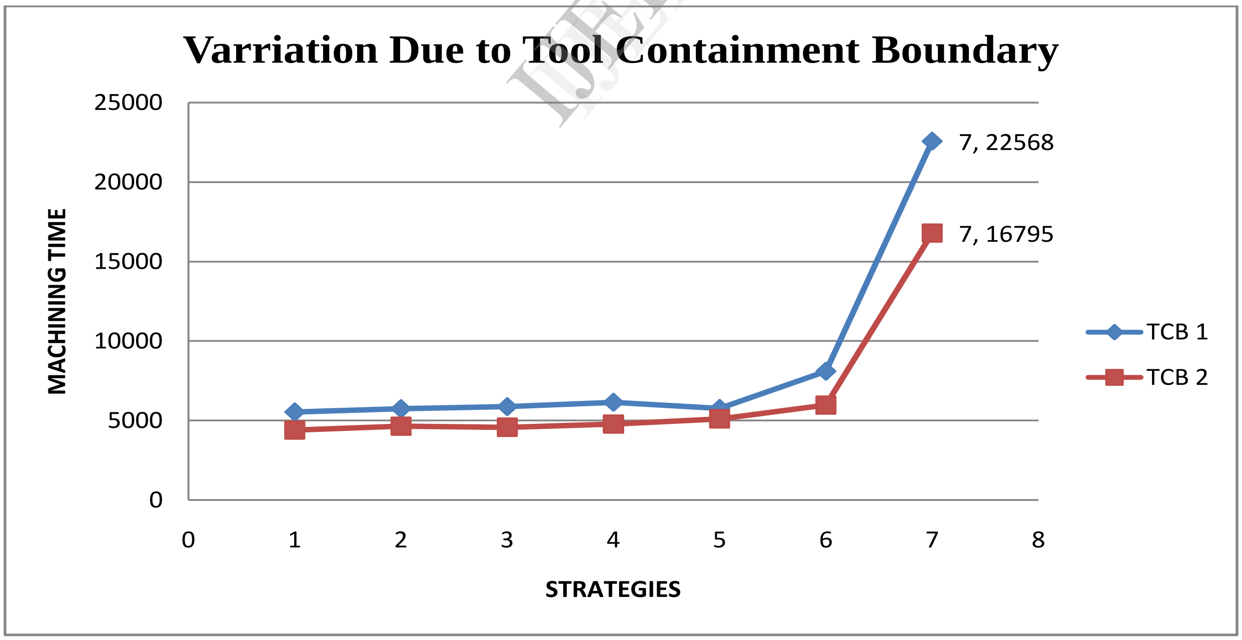


Figure 4: Relationship between Tool Containment Boundaries

This Figure: 4 shows that if tool containment boundary lies in the outer boundary of the work piece than it is taken less time and for increase in the tool containment boundary is more than it is taken more time.

4.2.4 RELATIONSHIP BETWEEN FEED RATE AND MACHINING TIME

Another parameter which is analyzed for the study is feed rate and machining time. Effect of feed rate on machining time is analyzed in table no. 4 and its relationship is given in graph no.4.

TABLE NO. 4 MACHINING TIME FOR DIFFERENT FEED RATES

Feed rate (mm/ min)	100	200	300	400	500	600	700	800	900	1000
Machining time(sec.)	20846	11277	8087	6493	5536	4898	4442	4100	3858	3620

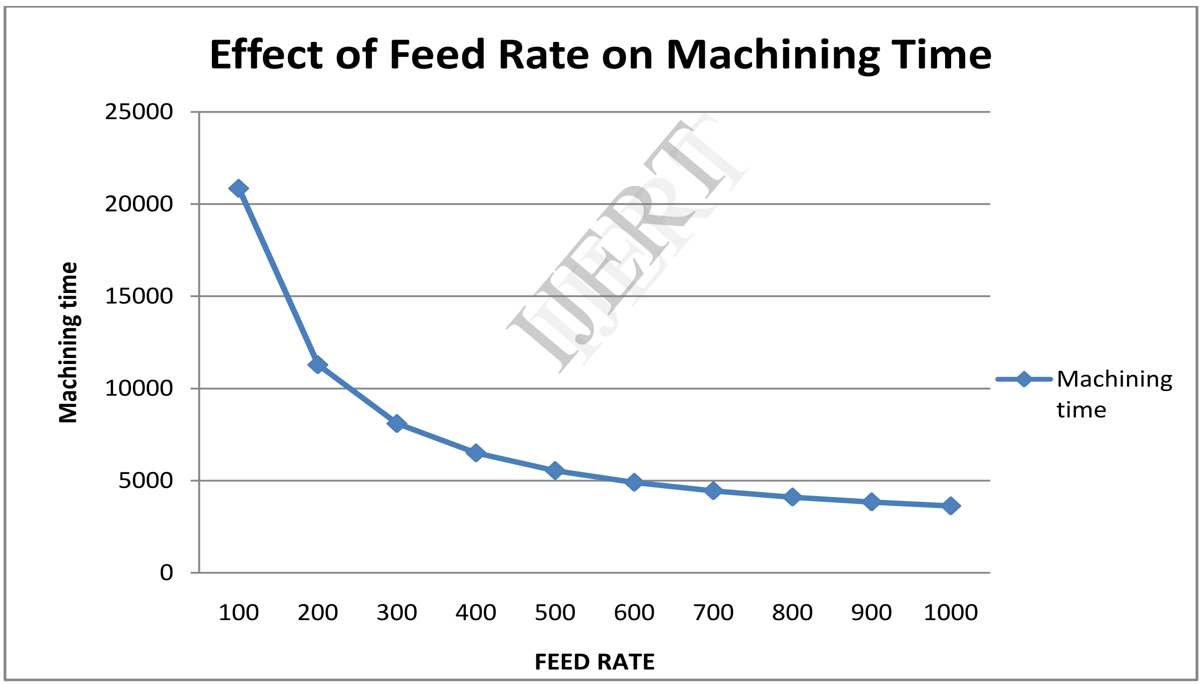


Figure 5: Relationship between Feed rate and Machining time

This Figure: 5 show that at lower feed rate machining time increases. As shown in the graph at lower fed rate slope of the graph is more so greater difference in machining time but at increase in feed rate slope of graph decreases and it is low at high values**.**

4.2.5 EFFECT OF STEP DOWN ON MACHINING TIME

Effect of step down or depth of cut is studied with the help of software and for different vales machining time is calculated the value of step down and corresponding machining time is given in the table no. 5 and its effect is given in graph no. 5-

TABLE NO. 5 MACHINING TIME FOR DIFFERENT STEP DOWN

Step down (mm.)	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1
Machining time(sec.)	9144	6101	4735	3816	3221	2768	2441	2143	1998	1680

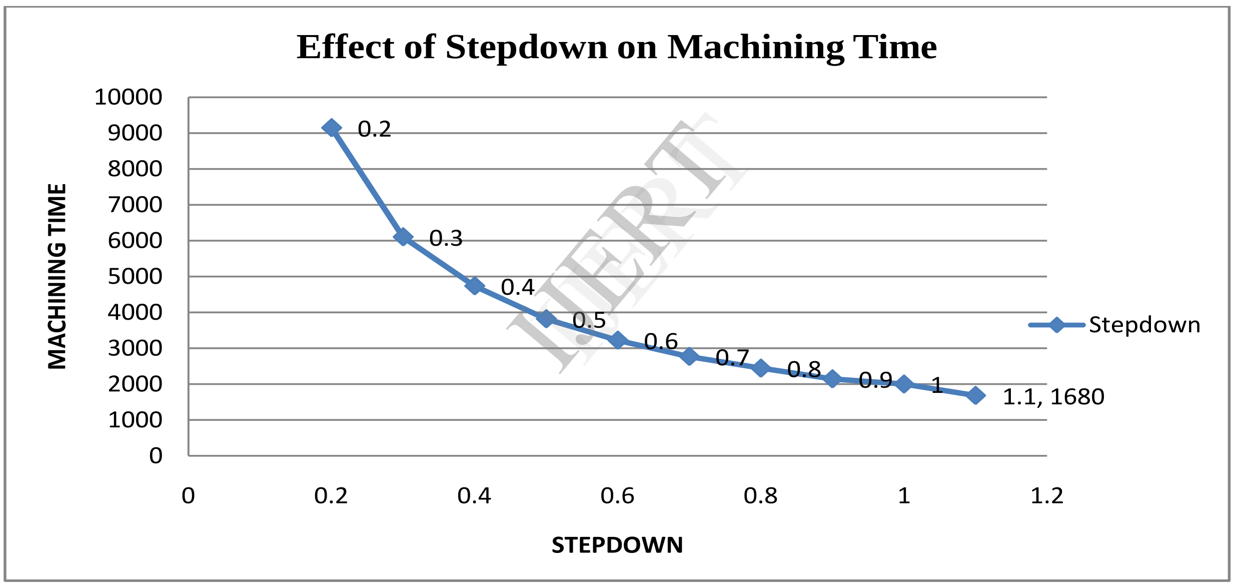


Figure 6: Relationship between Step down and Machining time

This Figure: 6 show that at lower depth of cut or step down machining time is maximum. At higher depth of cut machining time is minimum but in actual cutting process depth of cut are not increases for a maximum level because if depth of cut increases from the maximum level it can harm the tool. For greater depth of cut greater energy released during cutting so for maximum depth of cut according to a given tool coolant is used during machining process.

5. Results & Conclusions-

In this paper tool path generation strategy for sculptured surface machining has been analyzed and effects of different parameters are checked. Selection of suitable tool path generation strategy for a sculptured surface, with minimum machining time shows the effectiveness of using software in manufacturing process. For creating a surface in CNC milling various strategies has checked as shown in table no.1 and table no.2 with the help of software MASTERCAM in very less time. So selection of proper strategy is very easy for manufacturer. With the help of machining time for a given surface different parameters are checked like diameter of tool used (figure no.2), step over percentage (figure no. 3), and effect of tool containment boundary (figure no. 4). Other parameters like effect of feed rate and effect of step down are also analyzed (figure no. 5 and figure no. 6). So by using these results optimal tool path selected. So it is analyzed by the above data that use of software in manufacturing process save our time, money, material and manufacturing cost. Tools and work pieces are also prevented from unwanted wear and damage. It is very helpful for creating NC codes of irregular and intricate shapes. Depending upon the above results there are some important points which conclude this paper as follows-

1. Tool path generations strategies for roughening and finishing operation directly depend upon the type of surface and the machining time obtain from strategies are different for different diameter of tool used, for an appropriate diameter of tool gives minimum machining time (figure no.2).
2. In most of the cases Zigzag motion strategy is tacking least machining time. But it is not applicable for all surfaces. High speed strategy also gives minimum machining time but for this strategy defects are generated so before machining model is checked with the help of simulation as shown in figure no.2& 3.
3. Values of feed rate & step down are depend upon the nature of the work piece material and tool material if work piece material is hard than it is as low as possible for softer material its value is high with respect to the hard material but for finding a better shape its optimal value is used (figure no. 5 & 6).
4. For least machining time value of step over percentage should be as high as possible as shown by figure no. 3.
5. Tool containment boundary of work piece is lie on the outer boundary for finding minimum machining time as shown in figure no. 4.
6. Codes are automatically generated after finishing the process so actual machining of any part is very easy.
7. For actual machining process offset is set on the top level of the work piece and cutting is done in negative Z axis so in simulating software work piece is situated at negative z plane.
8. Codes are generated for machines which are having automatic tool changer so if machine is not having automatic tool changer than codes are modified according to machine.

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