IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 11, Issue 4 Ver. V (Jul- Aug. 2014), PP 17-22
www.iosrjournals.org

A Generic Framework to Optimize the Total Cost of Machining By Numerical Approach

M. Siva Surya
Assistant Professor [1] (Mechanical Engineering, Gitam School of technology/Gitam University, India)

Abstract: *Manufacturing industries are trying to minimize the Total cost of machining in order to get profit. There are many techniques used to minimize the Total cost of machining using different optimization techniques. The present work has been carried out to optimize the Total cost of Machining numerically and to the find the optimum cutting parameters responsible for minimum Total cost of manufacturing. A generalized program has been developed to find the Total cost among the given process variables using different set of combination of process variable. The total cost is estimated using Numerical Approach and optimum parameters are obtained and the step turning operation carried out on mild steel is checked for surface finish by using surface roughness tester and validated based upon the surface roughness values. Taguchi technique has been employed to determine signal to noise ratio which forms an integral part of validation process of this project.*
Keywords: *Numerical approach, Total cost, Taguchi,*

I. Introduction

As we are aware that every manufacturer aims for profit, but to get profit in manufacturing of any component we have to choose either to decrease the total cost of manufacturing or increase the productivity. The above two parameters depends on the machining process. The manufacturer has to choose any one of the above method to get the profit. In today's manufacturing environment, many large industries have attempted to minimize the manufacturing cost as it depends on machining process. In my work, I want to develop a numerical model which can be used to optimize the Total cost of machining for any kind of work piece material using any kind of cutting tool and using optimal cutting parameters. For example, during the manufacturing of automobiles in order to increase the productivity it will take weeks of time to manufacture each automobile, So if the size of manufactured part is large then we have to choose the first method instead of second, because the individual cost of each automobile will be high as it consists of number of components, so we have to concentrate on the cost reduction of each and every component. The total cost of manufacturing is going to be reduced due to less manufacturing price and total selling price. When you are manufacturing the small size of parts/components increasing the productivity method is used instead of decreasing the total cost of manufacturing because in small size parts the cost of margin is very less so we cannot get good profit. Example of manufacturing of pens you have to concentrate only on the productivity increase only, Not on decreasing the cost of manufacturing because even if we stress more on the cost reduction still the profit margin is less, so we have increase the productivity if we are going to produce maximum number of components with less margin profit we can get maximum profit. In order to conduct any experiment we need to have cutting speed, feed and depth and if we are machining generally available materials, we can start the experiment at any parameters with respect to that we change the cutting parameters. But while machining hard materials like EN 8 steel, NIMONIC 75, we don't know at what cutting parameters we have to start our work and ultimately tool life is also important as the tool is going to fail very quickly the total cost of machining increases. So we need certain process variables where we can perform the experiment such that variables should give less total cost when compared with other cutting parameters.

II. Form Of Analytical Model

Total Cost Estimation
In order to calculate the Total cost of Machining we need variables like:
1. Cost of Raw material.
2. Loading and setting cost of work piece and cutting tool.
3. Unloading and inspection cost of work piece and cutting tool.
4. Cost of machining.
5. Cost of Tooling.

Total cost of machining(T_C) = Cost of Raw material+ Cost of Loading and setting+ Cost of Unloading and inspection+ Cost of machining(C_m)+ Cost of Tooling(C_t) (1)

The cost of Raw material, Loading and setting cost, unloading and inspection cost of work piece and cutting tool are independent of cutting parameters like cutting speed feed and depth of cut so the cost of above parameters can be treated as constant. Which will not change throughout the machining operation and their cost can be vary depends on the automation and know we are trying to calculate the cost of machining and cost of tooling, because these two are the dependent cost on cutting parameters as the cutting parameters changes the cost of machining and cost of tooling will change, so in order to decrease the cost of machining and cost of tooling we need to find the optimal parameters.

Total cost

$$(Tc) = k + C_m + C_t \quad (2)$$

Where K= cost of Raw material + Cost of loading and Setting + Cost of unloading and inspection.

Calculation of cost of machining:

$$C_m = T_m \times L_m \quad (3)$$

C_m = Cost of machining
T_m = Machining Time
L_m = Machining Labor charges per unit volume

$$T_m = L/(f \times N) \quad \textbf{(4)}$$

Where L= length of the work piece (mm)
f= feed (mm/rev)
Speed (rpm)

$$N = (v \times 1000)/(\Pi \times D) \quad (5)$$

D= diameter of work piece (mm)

Calculation of cost of Tooling:

$$C_t = (Tm/T) \times C \quad (6)$$

Where $C_{t =}$ Cost of Tooling,
T_m = Machining time of work piece
T = Tool life
C_g = Cost of regrinding the Tool

$$T_m = L/(f \times N) \quad (7)$$

$$T = (C/(v^x \times f^y \times d^z))^{(1/n)} \quad \textbf{(8)}$$

Where V = Cutting speed (m/min)
F = Feed (mm/rev)
D = Depth of cut (mm)

The S/N ratio with a LB characteristic can be expressed as:

S/N = - 10 log ((1/n) $\sum y^2$)

III. Numerical Approach Methodology

1. Enter no of experiment, as per the number of experiments enter the cutting speed, feed and depth of cut values.
2. Here we have to enter variables like Diameter (D) of work piece, Length of work piece (L).
3. Cost of Raw material, Cost of loading and Setting, Cost of unloading and inspection. These values are treated as constant throughout the process.
4. Enter Machining Labor charges per unit volume (Lm), cost of regrinding the Tool (Cg).
5. Enter Tool life constant n, C values as per the cutting material used.
6. Here the Cost of machining (C_m) is calculated for various v, f values.
7. Cost of Tooling(Ct) is calculated Keep the v,f as constant for various depth of cut values(d)
8. Like this Total Cost of Machining is calculated for various combination of cutting speed feed and depth of cut.
9. Minimum Total cost of machining is found among the various Total cost of machining values and cutting process like speed, feed, depth of cut responsible for minimum Total cost of machining is known

3.2.1 Example
Input values:
V1, f1, d1
V2, f2, d2
Various combinations are:
V1, f1, d1 T_{C1}
V1, f1, d2 T_{C2}
V1, f2, d1 T_{C3}
V1, f2, d2 T_{C4}
V2, f1, d1, T_{C5}
V2, f1, d2 T_{C6}
V2, f2, d1 T_{C7}
V2, f2, d2 T_{C8}
Among the many Total cost of machining (T_C), Minimum T_C values are calculated and parameters responsible for minimum T_C are known.
Problem:
The input values for calculation of Total cost of machining are
$V_1^{x1}, f_1^{y1}, d_1^{z1} = 20^1, 0.2^1, 0.1^1$
$V_2^{x2}, f_2^{y2}, d_2^{z2} = 30^1, 0.3^2, 0.2^2$
Diameter of work piece (D) = 30mm, Length of work piece (l) = 200mm
Cost of raw material= 4 Rs
Loading and setting cost of raw material = 3 Rs
Unloading and inspection cost of finished work piece = 3 Rs
Cost of ideal machining time (k) = 10
Machining Labor charges per unit volume ($L_{m)} =$ 5 Rs
Taylor's constant(C) = 10
Cutting Tool material index (n) = 1.2
Cost of regrinding the tool (Cg) = 5 Rs
Hence the above example is shown in figure.1, the form of a Program executing Numerical Approach.

```
****************** MINIMUM COST CRITERIA *******************

 Enter Number of Expertiments :2
Enter Cutting speed(v) :20
30
Enter Constants for speed(x1,x2...) :1
1
Enter Feed Value(f) :0.2
0.3
Enter Constants for Feed Value(y1,y2.....) :1
2
Enter Depth of cut(d):0.1
0.2
Enter Constants for depth of cut(z1,z2,......) :1
2

 ############### Unmachining cost(k) calculation ################
Cost of Raw Material :4
Cost of cost of loading_setting :3
Cost of unloading_inspection :3
1st :4.000000 --> 2nd :3.000000 --> 3rd :3.000000#### k value :10.000000

 ##### Calculation of Machining Cost(Cm) ############
Enter Diameter of work piece(D) :30
Enter Length of work piece(l) :200_
Enter Machining Labour Charges per unit volume(lm) :5

 Enter taylors constant(c) :10
Enter Taylors Tool Life Constant for cutting Tool Material(n) :1.2
Enter Cost of GridingTool Cost(cg) :5_
```

Fig.1. Input values in "C" programming

The Output values are:

```
================= CM(v1=20.000000,f1=0.200000) = 23.549999
 TC(v1=20.000000,f1=0.200000,d1=0.100000,x=1.000000,y=1.000000,z=1.000000) : 35.
160797
 TC(v1=20.000000,f1=0.200000,d2=0.200000,x=1.000000,y=1.000000,z=2.000000) : 34.
300625_
```

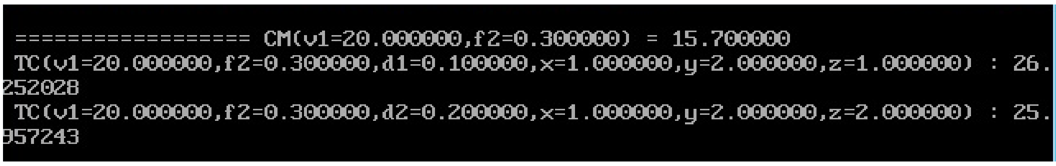

Fig.2. Output values in “C” programming

Procedure:

1. Firstly the mild steel work piece is clamped with the three jaw chuck and HSS cutting tool is clamped to the tool post of the NAGMATI-175 lathe machine and arrangements are made by turning the knobs in required direction near the thread and feed chart as shown in fig 3.

Fig. 3. Input values in “C” programming

2. The required speed (RPM) and feed and depth of cut are noted down as per experiment requirement and total cost is calculated using numerical approach using computer program in each case of different combinations speed, feed and depth of cut.


Fig. 4. Step turning operation on lathe


Fig. 5. Mild Steel bars after step turning

1) The machining operation of step turning is performed on the mild steel work piece as shown in figs. 4 and 5 for all the eight cases of different feeds, speeds and depth of cuts as shown in the table.1. Below.

Table .1: Input values of V,F,D

COMBINATION	SPEED N (RPM)	CUTTING SPEED V (mm/min)	FEED F (mm/rev)	DEPTH OF CUT D (mm)
$V_1F_1D_1$	325	30.63	0.382	0.5
$V_1F_1D_2$	325	30.63	0.382	0.25
$V_1F_2D_1$	325	30.63	0.409	0.5
$V_1F_2D_2$	325	30.63	0.409	0.25
$V_2F_1D_1$	500	47.12	0.382	0.5
$V_2F_1D_2$	500	47.12	0.382	0.25
$V_2F_2D_1$	500	47.12	0.409	0.5
$V_2F_2D_2$	500	47.12	0.409	0.25

2) After the turning and facing operation on the mild steel work piece, the surface of the finished work piece is tested for surface roughness using Mitutoyo SJ-310 surface roughness tester as shown in figure 6.
3) The values of Ra, Rq and Rz are noted down from the surface roughness tester.

Where, Ra = Roughness Average
Rq = Root Mean Square (RMS) Roughness
Rz = Average Maximum Height of the Profile

Fig 6: Surface Roughness measurement using Surface Roughness Tester

4) After obtaining the values from surface roughness tester, Taguchi method is applied to determine performance characteristic which is done by calculating S/N ratio in each of the combinations obtained.
5) The calculations are done and the best combination according to numerical approach and taguchi method is validated.

IV. Analysis

1) As seen from the table 5.1, the least total cost (TC) by Numerical Approach is obtained in the combination $V_2F_2D_1$ with the cost as 49.87902.
2) From table 5.2, the roughness average (Ra) value is least for the combination $V_1F_2D_1$ and the value is 4.760 µm which is determined by surface roughness tester, however the total cost in this case is 75.1935.
3) It can also be inferred from table 5.2 that value of Root Mean Square Roughness (Rq) and Average Maximum Height of the Profile (Rz) are least for the combination $V_1F_2D_1$.
4) From table 5.3, The S/N ratio is least for the combination $V_1F_2D_1$ and the value is -16.4755 which is determined by using taguchi method.
5) Hence from the analysis it is clear that best combination in term of total cost is $V_2F_2D_1$ and best combination in terms of roughness average, Average Maximum Height of the Profile, Root Mean Square Roughness and according to S/N ratio after applying taguchi method is $V_1F_2D_1$.
6) Hence even though the cost is greater in the case of $V_1F_2D_1$, as the surface finish obtained is of greater quality so $V_1F_2D_1$ is the best combination and is validated by means of taguchi method.
7) Hence the total cost of machining is optimized when:

V = 30.63 mm/min
F = 0.409 mm/rev
D = 0.5 mm

V. Conclusion

A Generic Framework for total cost optimization is developed in this investigation. Turning process is considered to evaluate its minimum operational cost. The process variables viz., cutting speed, feed and depth of cut are taken in to the consideration. In view to optimize the total cost of the operation, different sets of the cutting variable combination are obtained and given input to the developed frame work. The resulted combination optimal turning parameters are then checked with Taguchi method to check its validity and found good correlation between them. Therefore, the developed framework is proved its potentiality to adapt to any of the machining process to minimize the total production cost

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