International Journal of Engineering, Science and Mathematics
Vol.6Issue 6, October2017,
ISSN: 2320-0294 Impact Factor: 6.765
Journal Homepage: http://www.ijesm.co.in, Email: ijesmj@gmail.com Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

SCENARIO OF SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE OF H 13 MOULD STEEL IN CNC END MILLING PROCESS

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Abstract:
Milling is the most common form of machining process used in the production of moulds/ dies, due to the high tolerances and surface finishes by cutting away the unwanted material. The selection of Air hardening tool steel is widely used in production of moulds/ dies because of less wear resistance are used for large components. Due to extensive use of highly automated machine tools in the industry, manufacturing requires reliable models and methods for the prediction of output performance of machining processes. The major objective of the present study is modeling and analysis of machining parameters in end milling for material removal rate and surface roughness by considering the input parameters such as cutting speed, feed rate, axial-depth of cut, radial depth of cut and nose radius. The design of experiment (DOE) technique has been implemented to conduct the experiments which in turn reduced the number of experiments. The most accurate prediction models were developed using response surface methodology. The predicted results were analyzed through experimental verification. To have more precise investigation in to the models, a regression analysis of experimental and predicted outputs was performed. In order to study the main effects and interaction effects of machining parameters, analysis of variance (ANOVA) was performed. To judge the ability efficiency of the developed models, percentage deviation and average percentage deviation has been used.
Keywords : DOE, H 13mould steel**.**

I. INTRODUCTION

The Air hardening tool steel(H-13) is widely used material in production of molds/dies because of less wear-resistant and are used for large components. Milling is the most common form of machining process used in the production of moulds/dies, due to the high tolerances and surface finishes by cutting away the unwanted material. A serious attention is given to accuracy and surface roughness of the product by the industry these days. Surface finish has been one of the important considerations in determining the machinability of materials. Surface roughness and dimensional accuracy have been important factors to predict machining performances of any machining operation. In the past, Abbas Fadhel Ibraheem *etal*. (2008) investigated the effect of cutting speed, feed, axial and radial depth of cut on cutting force in machining of modified AISI H 13 tool steel in end milling process. They concluded that, higher the feed rates, larger the cutting forces. They also developed the genetic network model to predict the cutting forces. Abou-El-Hossein *etal*. (2007) developed the model for predicting the cutting forces in an end milling operation of modified AISI H 13 tool steel using the response surface methodology. Rahman *etal*. (2001, 2002) compared the machinability of the H 13 mould steel (357 HB) in dry and wet milling conditions. They considered a range of 75–125 m/min for the cutting speed and a feed ranging between 0.3 and 0.7 mm/tooth they found the cutting forces in both processes to be similar, but with the flank wear acceleration higher in dry milling. Furthermore, they observed a better surface finish with wet milling. Liao & Lin (2007) studied the milling process of H 13 steel with MQL lubrication. The cutting speeds were from 200-500m/min and the feed between 0.1-0.2mm/tooth. The authors found that the tool life is higher with MQL, due to an oxide layer formed on the tool inserts that helped to lengthen the tool life. Saurav Datta*etal*. (2010) optimized the CNC end milling process parameters for surface finish and material removal rate using PCA based Taguchi method. In the present work, an attempt has been made to develop the PCA based artificial neural network model to predict the surface roughness in end milling of H 13 steel by considering the input parameters such as nose radius, cutting speed, feed rate, axial-depth of cut, and radial depth of cut. The developed model is tested using test data. The predicted results were analyzed through experimental verification. To have more precise investigation into the model, a regression analysis of experimental and predicted outputs was performed. It was found that the R2 value is 1. To judge the ability efficiency of the developed model, percentage deviation and average percentage deviation has been used.

II.MATERIALS AND METHODS

The work piece material used for the present investigation is H 13 mould steel of flat work pieces of 120mm ×120mm ×12mm and the density of the material in metric units is 7.9 g / cc. The chemical composition of the work piece material is given in the Table 1. In statistical modeling to develop an appropriate approximating model between the response 'Y' and independent variables {x1, x2, ------- Xn} in general, the relationship is written in the form of Y = f(x1, x2, -------Xn) + ε. Where the form of the true response function Y is unknown and perhaps very complicated, and ε is a term that represents other sources of variability not accomplished for in Y. usually ε includes effects such as measurement error on response, back ground noise, the effect of the other variables and so on. Usually ε is treated as statistical error, often assuming it to have a normal distribution with mean zero and variance σ2 E(y) = Y= E [f(x1, x2, ------- Xn)] + E (ε) = f(x1, x2, -------Xn) The variables x1, x2, ------- Xn are usually called the natural variables, because they are expressed in the natural units of measurements such as degrees, Celsius, pounds/ square inch etc. in much RSM work it is convenient to transform the natural variables to coded variables x1, x2, ------- xn, which are usually defined to be dimensionless with mean zero and the same standard deviation. In terms of the coded variables the response function will be written as

Y = f(x1, x2, -------Xn);

III.EXPERIMENT DETAILS

A detailed survey has been carried out to find out how machining parameters affect surface roughness of H 13 mould steel material (Rahman, 2001, 2002; Saurav Datta, 2010). Based on this, the five parameters, namely nose radius, cutting speed, feed rate, axial depth of cut and radial depth of cut were selected for experimentation. Taguchi's L50 (21*511) orthogonal array in design of experiments (DOE) technique has been implemented to conduct the experiments. Nose radius with two levels and cutting speed, cutting feed, axial depth of cut and radial depth of cut with five levels each and then 2×5×5×5×5=1250 runs were required in the experiments for five independent variables. But using Taguchi's orthogonal array, the number of experiments reduced to

50 experiments from 1250 experiments. All the experiments were conducted on CNC Vertical milling machine 600 II as shown in Figure 1.

The specifications of the Vertical milling machine are: The tool holder used for milling operation was KENAMETAL tool holder BT40ER40080M, Table clamping area: 20 TOOLS ATC STANDARD, Maximum load on the table: 700 kgs, Spindle taper: BT-40, Spindle speeds range: 8-8000rpm, Power: 13 kW, Feed rates range: 0-12 m/min and the too material used for the present study was coated carbide cutting tool. The machining parameters used and their levels chosen are presented in Table 2. The average surface roughness (Ra, μm) which is mostly used in industrial environments is taken up for the present study. The average surface roughness is the integral absolute value of the height of the roughness profile over the evaluation length and was represented by the Eq. (5).
Where L is the length taken for observation and Y is the ordinate of the profile curve. The surface roughness was measured by using Surtronic 3+ stylus type instrument manufactured by Taylor Hobson with the following specifications. Traverse Speed: 1mm/sec, Cut-off values 0.25mm, 0.80mm and 2.50mm, Display LCD matrix, Battery Alcaline 600 measurements of 4 mm measurement length. The experimental layout and results are given in Table 3

SPECIFICATIONS FOR FIGURES, TABLES, AND EQUATIONS

Table 1. Chemical Composition of H 13 mould steel

Carbon	0.35-0.45
Silicon	0.8-0.9
Manganese	0.2-0.4
Chromium	2.8-4.5
Molybdenum	0.15-1.30

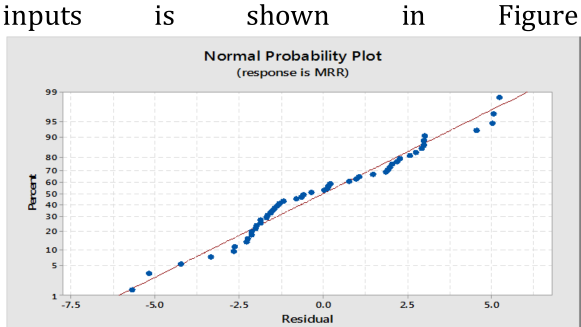
IV.PARAMETRIC DETAILS

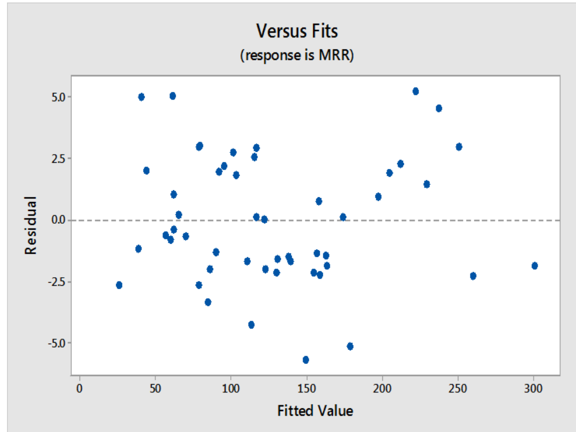
The sensitivity test was performed to obtain the variables that affect the surface roughness as shown in figure

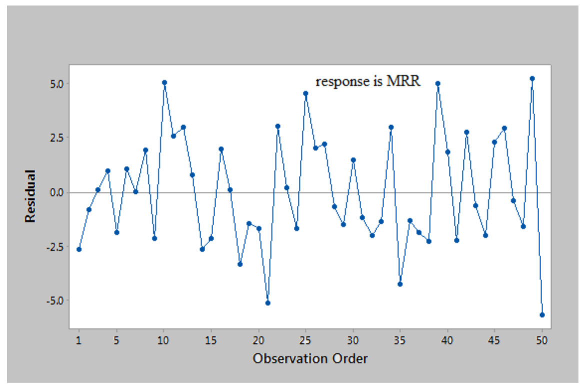
Order of Data	Experimental Ra(μm)	RSM Ra (μm)
1	0.94	0.962
2	1.16	1.162
3	1.12	1.191
4	0.86	1.049
5	0.66	0.736
6	0.82	1.01
7	1.44	1.141
8	0.7	1.101
9	0.92	0.934
10	1.28	1.068
11	1.08	0.906
12	1.3	1.013
13	1.48	0.903
14	1.44	1.139
15	1.54	1.033
16	0.56	0.695
17	0.46	0.688
18	0.42	1.025
19	0.58	1.021
20	0.5	0.891
21	0.46	0.288

22	1.1	0.727
23	0.86	0.87
24	0.48	0.797
25	0.74	0.553
26	0.98	1.139
27	1.2	1.339
28	1.68	1.412
29	1.06	1.27
30	0.52	0.957
31	1.14	1.232
32	2.48	1.362
33	1.74	1.322
34	1.48	1.111
35	1.72	1.244
36	0.52	1.128
37	0.92	1.189
38	0.76	1.08
39	0.64	1.36
40	0.96	1.254
41	0.8	0.872
42	0.5	0.909
43	1.54	1.246
44	1.27	1.243
45	1.32	1.068
46	0.87	0.509
47	1.1	0.948
48	0.78	1.046
49	1.14	0.973
50	0.87	0.77

The test shows that feed rate is the most significant effect parameter on surface roughness followed by radial depth, nose radius, axial depth, and cutting speed. The variation of surface roughness for varied inputs is shown in Figure







It is concluded that, the surface roughness increases with the increase of nose radius, cutting feed and axial depth of cut, because the increase of feed rate and axial depth of cut increased the heat generation and hence, tool wear which resulted in the higher surface roughness. The increase in federate also increased the chatter and produced incomplete machining at a faster traverse which led to higher surface roughness. The surface roughness decreases as the cutting speed and radial depth of cut increases.

V. CONCLUSIONS

Using Taguchi's orthogonal array design in the design of experiments, the machining parameters which are influencing the surface roughness in the end milling of H 13 mould steel has been modeled using RSM. Based on experimental and results predicted by RSM, the following conclusions are drawn.

1. Relatively small number of experimental runs could be possible using Taguchi's orthogonal array and hence reduces the cost of experimentation.
2. The feed is most dominant parameter for the surface roughness and MRR. The cutting speed shows the minimal effect on the surface roughness and MRR.
3. For achieving good surface finish of H 13 mould steel low feed rates higher cutting speeds and smaller depth of cuts are preferred.
4. For achieving higher MRR of H 13 mould steel higher feed rates higher cutting speeds and higher depth of cuts are preferred.
5. Using design of experiment, the machining parameters which are influencing the surface roughness and MRR on the machining of H 13 mould steel, the second order model has been modeled using response surface methodology for CNC end milling of H 13 mould steel. This technique is convenient to predict the effect of different influential combinations of machining parameters.
6. The second order response model can be used to predict the surface roughness of H 13 mould steel at 95% confidence level. The predicted and measured values are quite adequate, which indicates that the developed model can be effectively used to predict the surface roughness and MRR of H 13 mould steel.
7. The verification test results revealed that the developed models for surface roughness and MRR can be effectively used for predicting the surface roughness and MRR in machining of H 13 mould steel.
8. In Response Surface Methodology the regression value for surface roughness and MRR is 30.4% and 99.8%. Where as in the regression value for surface roughness and MRR is 99.9993494% and 99.9975327%.
9. The predicted values are fairly close to the experimental values, which indicate that the developed model can be effectively used to predict the surface roughness and MRR of H 13 mould steel.
10. The model could predict the surface roughness and MRR with average percentage deviation of 0.132642% and 0.333992% from training data set.

11. The model could predict the surface roughness and MRR with average percentage deviation of 4.3785%and 17.45823% from test data set.
12. The correlation coefficient for surface roughness was 0.999993494, which shows there is a strong correlation in modeling surface roughness.
13. The correlation coefficient for MRR was 0.999975327, which shows there is a strong correlation in modeling MRR.

VI. FUTURE SCOPE

1. Further study could consider factors as materials, different nose radius of tool inserts and different shapes, cutting angles, lubricants, by more number of levels of cutting conditions would affect on the surface roughness and MRR. In addition, artificial intelligent system such as the fuzzy logic system, simulated annealing, genetic algorithms might be used to enhance the ability of the prediction system.
2. The accuracy of the developed model can be improved more number of parameters and levels.
3. Further study could also consider the tool wear that would effect on the surface roughness and MRR.

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