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Experimenting and Predicting Flatness and Surface Roughness during Face Milling Operation of CF8M Grade A-351

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Abstract

Surface flatness and roughness has a pivotal role in the functioning of any kind of check valve. These two parameters are mainly obtained by face milling [16] during the manufacturing process of valves. The values of these affect during leakage rejection and redesign of check valves. To achieve the desired values of surface flatness and roughness here analysis is carried out. A regression model is generated to predict the values of surface roughness and flatness. ANOVA is also developed to see the effect of machining process parameters on the surface roughness and flatness.

Keywords— Face milling, Surface roughness, Flatness, CF8M material, Dual plate check valve, Coordinate Measuring Machine.

1 Introduction

There are various materials used for manufacturing of valves but one of worldwide used material is CF8M. During making of any check valves material plays crucial role and depending upon it further factors are decided. CF8M material mainly possesses high resistance towards corrosion so it has been preferred for making valves. The flatness on the milling components is of prime importance as in case of dual plate check valve, so that the components (body and door) assemble together properly and create metal to metal seal without significant rocking. So, the investigation of flatness and surface roughness of CF8M material creates new scientific domain in the machining. The selection of proper cutting parameters for milling process becomes a vital requirement for reduction of rework and to increase the productivity. Few main parameters like Spindle speed, Feed rate and Depth of Cut are considered for the present investigation. Their right selection may optimize the surface flatness and roughness error during machining.

1.1 Valve Manufacturing Process

Step -1 Designing of the valve as per customer requirements, **Step- 2** Selection of material to be used in manufacturing of the valve, **Step- 3** Valves made by casting, forging etc., **Step- 4** Machining of valves using HMC, VMC and CNC machines, **Step- 5** Grinding and finishing of the valve, **Step- 6** Inspection and leakage testing of the valve, **Step- 7** Color coating, coding and final dispatch of the valve.

1.2 Literature review

Milon et al found the use of Taguchi technique and Genetic Algorithm (GA) for minimizing the surface roughness by machining mild steel with three zinc coated carbide tools inserted into a face miller of 25 mm diameter.[4]. The face milling operation is to be performed on the hard

faced surfaces, which is obtained through MIG welding [1,2] Flatness and surface roughness play a vital role in achieving the metal to metal seal. Now the value of flatness as geometric tolerance is highly process dependent. The Flatness values may be measured using dial indicator, CMM or by other indirect methods [3]. Sheth et al. investigate the effect of cutting parameters on flatness and surface roughness for dual plate check valve for WCB material for face milling operation[5,6].Patel et al. investigate the effect of various parameters on Material removal rate and spread in flashing operation of precision steel ball manufacturing process[6,8,9]. Sheth et al. investigate the effect of cutting parameters during drilling of WCB material using grey relational analysis [12]. Surasit Rawangwong, Jaknarin Chatthong, Romadorn Burapa, and Worapong Boonchouytan et al. investigate the main factors on the surface roughness in semi-solid AA 7075 face milling.[15]

2 Experimental Design Setup

2.1 Workpiece Material

The test work piece material is CF8M with grade A -351 with 50×40×40 size. Its chemical composition is given below. It is widely used material in manufacturing of valves due to its less cost as compared to other materials. Chemical composition and mechanical properties of CF8M material: -

TABLE-1: Chemical composition of CF8M material

Steel type	Stainless steel
Metal code, Standard	CF8M, ASTM A316
C	0.30%
Si	1.50%
Mn	1.50%
P	0.040%
S	0.040%
Cr	21.00%
Ni	18.00%
Mo	0.30%
Cu	0.30%
V	0.03%

2.2 Machine and cutting tool

Face milling was performed on the 3-axis CHIRON FZ 16 L/CNC milling machine having spindle motor power of 5.8kw with Cubic Boron Nitride (CBN) coated inserts where six inserts tool were used. Tool diameter is of 50mm.

CBN is the second hardest material after synthetic diamond which is synthesized from hexagonal boron nitride. It possess excellent hot hardness that can be used for machining at very high cutting speed while it also shows good toughness and high thermal shock resistance. Another physical advantage of CBN as compared to the conventional abrasive is that in addition to keep hardness at normal temperature it maintains hardness over a wide temperature range. Other advantage includes improved surface finish and the production of more favourable compressive residual surface stresses [13].

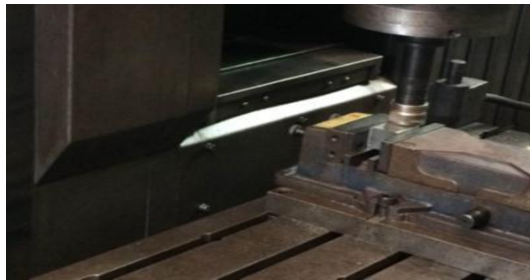


Fig-1: Face milling process on CF8M square piece

2.3 Experimental Procedure

Experiments (milling operation) was carried out on four cube blocks of CF8M material having dimensions, length=50 mm, breadth= 40mm & height= 40mm. Spindle speed, feed and depth of cut were selected as input variables to perform experiments according to 2³ full factorial experimental design [7]. The blocks were clamped with the help of hydraulic vice as shown in Figure-1. Two faces of every four blocks were initially machined and then face milling operation was carried out on the machined surfaces of the blocks. During the operation, number of passes and coolant flow rate were kept constant. The machined components are shown in Figure2-

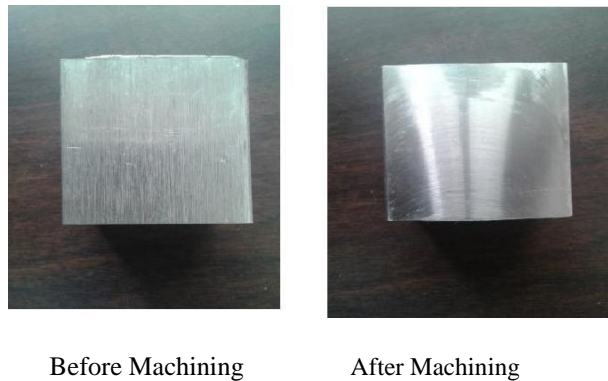


Fig-2: Machined Blocks

2.4 Design of Experiments

DOE is performed onto a process to improve its capability. It is carried out by conducting a series of experiment to study the change in output variable by bringing intentional and measured changes in the input variable of process which is always desirable to a quality problem. For design of experiment three variables speed, feed and depth of cut with two levels were selected as shown in table below:

TABLE -2 Variables with maximum and minimum range

Code d Facto r	Variables	L ow le vel (-)	Hi gh lev el (+)
A	Speed(rpm)	84 0	10 50
B	Feed(mm/min)	15 0	25 0
C	Depth of cut(mm)	0.3	0.5

2.5 Measuring Techniques

2.5.1 CMM

A Coordinate Measuring Machine is a basic device for measuring the physical geometrical characteristics of an object. Flatness measurement was carried out on manual Mitutoyo Crysta-Plus M443 [14] co-ordinate measuring machine as shown in Figure-3. For measuring flatness, 65 points were taken manually on the machined surface of the blocks and simultaneously readings were taken from the computer monitor.

2.5.2 Surface Roughness Tester

Surf Test sv-2100 column type surface roughness tester is a high precision and high performance tester with a dedicated controlled unit with user friendly display and simple operation. Surface roughness measuring was carried out on Surf test SV-2100 as shown in Figure-4. The machine gives roughness values in micro mm on a digital monitor display. Cut off length for measurement of surface roughness is approx 20mm.



Fig-3: Measurement of flatness by CMM (Mitutoyo Crystal-Plus M443)



Fig-4: Measurement of roughness by surface roughness tester (surf test sv-2100)

3. Result and Analysis

Following table shows design of experiment for various combinations.

TABLE-3 Experimental set up for flatness and roughness

Treatment combination	Speed (rpm) A	Feed (mm/min) B	Depth of cut (mm) C	Flatness (mm)	Roughness (μm)
<i>1</i>	840	150	0.3	0.03033	1.52
<i>a</i>	1050	150	0.3	0.01651	0.55
<i>b</i>	840	250	0.3	0.03061	0.51
<i>c</i>	840	150	0.5	0.02886	1.56
<i>ab</i>	1050	250	0.3	0.01584	0.48
<i>ac</i>	1050	150	0.5	0.01512	0.65
<i>bc</i>	840	250	0.5	0.03376	1.17
<i>abc</i>	1050	250	0.5	0.01578	0.48

Here 1, a, b, c, ab, ac, bc & abc are treatment combination of high and low level of speed, feed and depth of cut for Example-[1] has a low level of all variable, the combination [a] has a high level of speed and low level of feed and depth of cut.

According to above setup, experiments were performed for different combinations of speed, feed and depth of cut after which the obtained values of surface flatness and roughness for were jotted down in following tables:

TABLE-4 Effective estimate summary for flatness

Factor	Effect Estimate	Sum of square	% contribution
A	-0.00575	0.00006629	18.89
B	-0.00802	0.00000805	2.29
C	0.00005	0.00000061	0.01
AB	-0.00134	0.00000363	1.03
AC	0.00862	0.00014886	42.43
BC	-0.00783	0.00012269	34.94
ABC	-0.00082	0.00000135	0.38

TABLE-5 Effective estimate summary for Roughness

Factor	Effect Estimate	Sum of square	% contribution
A	-0.40	0.3321	44.58
B	-0.41	0.0210	2.82
C	0.02	0.0800	10.74
AB	0.29	0.1682	22.58
AC	-0.15	0.0450	6.04
BC	0.13	0.0338	4.53
ABC	-0.18	0.0648	8.70

In the above Tables- 4 and 5, percent contribution column has some black colored values, which indicates that the variable and its combination has significant effect on the machining operation

3.1 Regression model

Regression model widely used to predict the responses is an algebraic representation of the regression line and is used to describe the relationship between the responses and predictor variables.

Response = constant + coefficient (predictor) + . . . + Coefficient (predictor).

According to upper estimate effect the regression analysis will give two equations for Surface Roughness and Flatness given below:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \dots + \beta_{ijk} x_i x_j x_k$$

Here, x_1 = Speed variable
 x_2 = Feed variable

x_3 = Depth of cut variable

So, for Flatness:

$$Y = \beta_0 + \left(\frac{-0.0057}{2} \right) A + \left(\frac{0.0062}{2} \right) AC + \left(\frac{-0.00763}{2} \right) AB$$

And Similarly For Roughness:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \dots + \beta_k x_k$$

So, for Roughness:

$$Y = \beta_0 + \left(\frac{-0.0075}{2} \right) A + \left(\frac{-0.00763}{2} \right) C + \left(\frac{-0.00763}{2} \right) AB$$

4. ANOVA (Analysis of Variance)

Table-5: ANOVA for Flatness:-

Source	D.O.F.	Sum of square	Adj. Sum of square	Adj. mean square	P-value	F-value	% contribution
A	1	0.0006629	0.0006629	0.0003145	0.000142	4.60011	18.89
B	1	0.00000805	0.00000805	0.00000402	0.000142	4.60011	2.29
C	1	0.00000061	0.00000061	0.000000305	0.000142	4.60011	0.01
AB	1	0.00000363	0.00000363	0.000001815	0.000142	4.60011	1.03
BC	1	0.00014886	0.00014886	0.00007443	0.000142	4.60011	42.43
AC	1	0.00012269	0.00012269	0.000061345	0.000142	4.60011	34.94
ABC	2	0.00000135	0.00000135	0.000000675	0.000142	4.60011	0.38
Total	15	0.00035204					

Table-6: ANOVA for Roughness:-

Source	D.O.F.	Sum of square	Adj. Sum of square	Adj. mean square	P-value	F-value	% contribution
A	1	0.3321	0.3321	0.16605	0.001039	16.98163	44.58
B	1	0.0210	0.0210	0.0105	0.001039	16.98163	2.82
C	1	0.0800	0.0800	0.0400	0.001039	16.98163	10.74
AB	1	0.1682	0.1682	0.0841	0.001039	16.98163	22.58
BC	1	0.0450	0.0450	0.0225	0.001039	16.98163	6.04
AC	1	0.0338	0.0338	0.0169	0.001039	16.98163	4.53
ABC	2	0.0648	0.0648	0.0324	0.001039	16.98163	8.70
Total	15	0.7587					

5. Conclusion

From the results obtained it can be predicted that during face milling operation on CF8M material, Depth of cut with its combination with Speed and Feed has more effect for Flatness with 42.53% and 34.94% contribution respectively.

Similarly, for Surface Roughness it can be predicted that Speed has more significant effect and contributes to 44.58% while combination of Speed and Feed has less effect and it contributes to 22.58%.

The future scope of this research work: enhancing the results by performing more number of experiments and changing variables (for example cutter diameter and inserts) and then after plotting obtained results by Minitab or Fuzzy Logic software for comparison purpose.

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