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INVESTIGATION OF CHATTER DYNAMICS IN FACE MILLING TOOL USING DIFFERENT SHIM MATERIAL BY AMPLITUDE RATIO METHOD AND ANOVA

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Abstract: Face milling of AISI 2062 steel was applied an optimization technique by ANOVA based on optimal factorial method is proposed in this paper. Which cover dynamic behavior of facemill with different shim and cutting condition for reducing chatter by amplitude ratio method. To illustrate the effectiveness of this approach Experimental results are provided. Cutting tools Damping and stability of is very much essential now a day in VMC Milling Centre operations. During the experimental work we have done experiment with carbide shim followed by without shim and Stainless Steel shim to see drop in chatter. An experimental methodology was developed using the DOE (Design of experiment) technique. The optimal factorial method was used DOE for four factors having three levels. The main results are based on amplitude ratio and ANOVA analysis. Analysis of variance (ANOVA) was used to determine the effects of the cutting condition on vibration amplitude ratio in X, vibration amplitude ratio in Y .This is useful for evaluating This is useful for evaluating the stability of milling operations via time domain FFT and it validates with ANOVA by design expert 8.0.6. It is found that the most critical parameter in this study is Shim material. At high cutting speed and feed carbide shim and low and medium cutting speed and feed SS shim represent good result for reducing chatter.

Keywords: Chatter frequency, ANOVA, DOE, Shim, Amplitude ratio, Optimization, Tooth passing frequency

1. INTRODUCTION

In Machining noise and chatter is a considerable matter in VMC– as VMC causes additional vibrations at high speediness operation. In this period accuracy and precision with advanced speed machining is really critical to shear expenditure and extend productivity. The chatter is the highest obstacles in accomplishing the computerization of machining similar as milling, drilling, boring, and turning etc. The chatter in machining creates damages like inferior surface finish, redundant amount of noise; drop in life of tool and in worst case tool may break, which increase cost of product. Face milling is the utmost milling operation and can be performed using a wide range of different tools. Then Special Purpose face mill with (TNMG) Inserts and diameter Ø63mm and 5 inserts with shim and without shim is discussed.

Vladimir A. Rogov [21] inspected the excellence of machined apparent and the efficiency of turning using shim with high restraining properties in the fasten of insert. 5 shims made of granite, ceramic, chlorite schist ,epoxy granite and sandstone are planned. Computational and experimental examination are delivered to study the stress–strain in the fasten set structure of insert. Stationary and active features of cutting tool with shim made of dissimilar materials are studied

Rubeo & Schmitz, 2017 [11] defines a metric related to as the "amplitude ratio = AR" for assessing the steadiness of milling operations via time sphere simulation. The AR is used to produce shape graphs that recognize steadiness presentation above a choice of spindle speeds and axial depths of cut. The suitability of the amplitude ratio steadiness standard is predictable concluded evaluation to independently printed results attained using semi–analytical ways. The AR stability standard was presented. It was established that the AR steadiness standard is suitable for assessing the steadiness of milling processes simulated in the time sphere. Also, the AR provides a quantitative degree of the severity of chatter. It may be the case that a small chatter frequency element (ramp<<1) results insufficient work piece dimensional accuracy and surface finish making it acceptable for some machine shop operations. Still, as the amplitude ratio becomes larger chatter becomes increasingly severe and precious.

Our intention is to decrease vibration and chatter to enrich the surface finish in VMC. By using Shim Chatter can be diminished, which works as a damper for face milling. High– speed cutting of hard solid makes compression on the tip of the tool. Thus it is essential to improve a shim which deeds as a passive damper for the insert and work piece. The strategic shim should guard both tool holder and insert from destruction due to high cutting forces. In this investigation work, the Carbide shim, SS– Stainless Steel Shim and without shim face mill tool are analyzed to find possible methods to decrease Chatter. Experiment analysis was done by DOE and ANOVA was done for confirmation. This research paper includes experimental and ANOVA investigation of face mill tool using SS–Stainless Steel and Carbide shims and without shim (conventional) face mill tool.

2. EXPERIMENTAL METHODS

— Milling Experiments

The experiment is done on VMC– Vertical Milling Centre milling machine with CoCo 80 try axial dynamic signal analyzer to validate ANNOVA analysis. This Setup used for the collection of vibration signals is as shown in the Figure 1(a). The signals of Vibration are collected with use of CoCo 80 try axial dynamic signal analyzer attached to VMC– tool holder. Analyser gives the displacement– time, velocity– time, acceleration– time and frequency–

amplitude relations in reference to each other which help to plot stir study graphs. The trials were done on the VMC– Vertical Milling Centre with use of two Kyocera make special purpose face milling tool, 1st is with shim and 2nd is without shim face milling tool Ø 63 mm with 5 inserts.as shown in Fig 1 (b).Work piece Plate of 75*25*300 mm of 2062 mild steel 130 BH work material were used for the experiments. The machining was done using TNMG 120412 (Carbide) insert. The experiments were conducted at 3 Cutting speed (250m/min, 200m/min, 150m/min), 3 Feed Per Tooth (0.15mm/tooth,0.1mm/tooth , 0.05mm/tooth), 3 Depth of cut (1.2 mm, 1.0 mm, 0.8 mm), and 4 Shim Material (SS– Stainless Steel, Carbide & Without shim face mill)are taken for experiments.

Figure 1.(a) CVM milling Machine with CoCo80 Dynamic Signal analyzer with Try Axial Sensor

Figure 1.(b) Face milling tool 63 mm dia with shim and Without shim face mill

The expatriation data collected by using CO CO80 dynamic analyzer. EDM software is used to put up displacement data. MATLAB is used to create The Fast Fourier Transformation (FFT) graphs to find the actions of face mill tool. From FFT graphs we set up chatter frequency, Tooth passing frequency and amplitude ratio for face mill tool.

3. DATA COLLECTION OF VIBRATION AND DYNAMIC MOTION BEHAVIOR ANALYSIS

— Design of experiment

A strong way to appoint the effect of any given input parameter on the process from a series of experimental results is to use the design of experiment (DOE) method. The conclusions, concerning which parameters affect the response of inquired process, are made with the aid of various analytical techniques. The cutting speed, feed, depth of cut, and shim material of face mill tool also interactions among them on amplitude ratio of vibration in X , Y were examined using a four–factor/three–level Optimal factorial design. The factors and levels include cutting speed 250, 200, and 150 m/min, feed 0.05, 0.10 and 0.15 mm/tooth, depth of cut 0.8, 1.0, and 1.2 mm, and Shim carbide shim , without shim and SS shim used. By using DOE techniques any researcher can determine important factors which are responsible for output result variation of experiments. DOE can found optimum solution for particular experiments.

Input Parameter

- ≡ Cutting speed in m/min
- ≡ Depth of cut in mm
- ≡ Feed in mm / Tooth
- ≡ Shim (Carbide , Without Shim & SS)

Output Parameters

- ≡ Amplitude Ratio $r_{amp} = A_{cf} (\mu m) / A_{tpf} (\mu m)$ IN x
- ≡ Amplitude Ratio $r_{amp} = A_{cf} (\mu m) / A_{tpf} (\mu m)$ IN Y
- ≡ A_{cf} = amplitude of the chatter frequency (μm)
- ≡ A_{tpf} = amplitude of the tooth passing frequency (μm)
- ≡ F_c = Chatter frequency Amplitude in μm
- ≡ F_{tp} = Tooth passing frequency Amplitude in μm $= n \text{ (rpm)} * z/60$
- ≡ n = is the spindle speed (rpm),
- ≡ Z= is the number of teeth of the milling cutter

— Factors & Levels

By the selection of proper factors and their levels design of DOE table was available by design expert software with design expert 8.06. In this Paper four factors with three levels were selected for DOE and were shown in Table 1.

Table 1. Factors & Levels

Level	Cutting speed [m/min]	Depth of cut [mm]	Feed [mm/tooth]	Shim
1	250	1.2	0.15	3– SS shim
2	200	1.0	0.10	2– Carbide shim
3	150	0.8	0.05	1– without shim

Base on input parameter number of possible combination is select for experimental work. Experiments were carried out with Combination of without and with different Shim material, Cutting speed, feed and Depth of cut so there are total 35 experiments are done as shown in table 2.

- ≡ Model: Optimal Factorial model
- ≡ Run: 35
- ≡ Level: 3
- ≡ Factor: 4

Table 2 : DOE runs given by Design expert

Run	Speed [m/min]	DOC [mm]	FEED [mm/tooth]	shim	Amplitude Ratio r_{amp}=	
					X	Y
1	200	0.8	0.05	3	0.35483	0.10909
2	250	1	0.05	2	1.68539	0.0875
3	150	1.2	0.05	2	0.15	0.92
4	200	1	0.05	2	0.92	4.99
5	200	0.8	0.05	2	0.38	7.1
6	150	1.2	0.05	1	3.33	33.33
7	150	1	0.05	3	0.15	0.92
8	150	1.2	0.15	1	1.22	10
9	200	1.2	0.05	3	1.68539	0.0875
10	150	0.8	0.15	3	0.235	0.604
11	150	1	0.15	1	0.633	4.5
12	150	1	0.1	2	1.44	0.1638
13	250	1.2	0.05	1	2	18
14	150	1	0.05	3	0.09	0.38
15	200	1	0.05	1	0.3	3.2
16	200	1.2	0.05	2	0.49	7.73
17	200	0.8	0.1	1	0.3587	7.008
18	200	1.2	0.05	1	0.31	10
19	150	0.8	0.05	2	0.09	0.38
20	250	0.8	0.15	2	0.306	13.67
21	250	0.8	0.05	2	0.307	13.78
22	250	0.8	0.1	2	0.5143	3.73
23	250	1.2	0.05	2	2.23	20
24	250	1.2	0.05	3	11.25	250
25	150	1	0.05	1	0.4	25.64
26	250	1	0.05	3	25	83.3333
27	250	1	0.05	1	1	130
28	150	0.8	0.05	3	0.56	1.9
29	250	0.8	0.05	1	0.6666	130
30	200	0.8	0.05	1	0.19	1.67
31	150	0.8	0.05	1	0.61	3.9
32	150	0.8	0.1	1	0.2386	3.175
33	200	1	0.05	3	0.0538	0.09523
34	150	1	0.05	2	0.56	1.9
35	250	0.8	0.05	3	2.5	0.07142

— Data collection

Data collection is the process of converting the vibration signals of physical Components–(CoCo 80 dynamic signal analyser) into the numerical data which can be precisely studied and analyzed. To find out chatter, vibration signals are taken with double cut, with different cutting condition and with different shim. TDR (Time Displacement Response) and FFT (Fast Fourier Transformation) graphs were generated with the help of EDM and MATLAB software. Tooth passing frequency, Chatter frequency, amplitude ratio and Dynamic Motion Behavior for above conditions have been studied and analyzed by using TDR and FFT graphs.

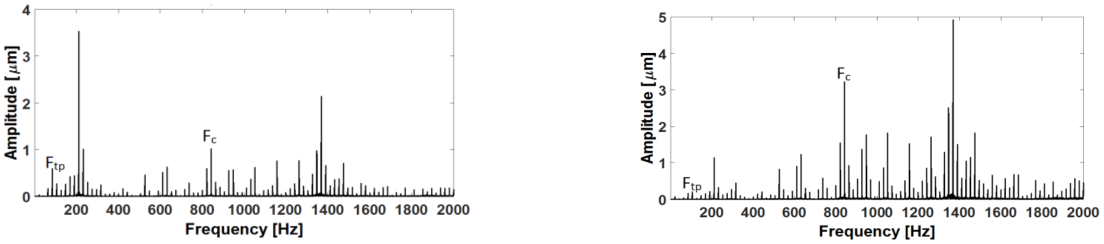
— Dynamic motion behaviour analysis

To find dynamic motion behavior, different combination of depth of cut, Feed and cutting speed, for Without shim face mill and with shim face mill (Carbide shim and SS shim} are used and experiments has been carried out and obtained Time domain graphs and FFT graphs. Time varying signal is given as input to FFT spectrum analyzer; FFT computes the magnitude of its sine and cosine components and displays the spectrum of these frequency components. These FFT graphs are Amplitude vs. Frequency (Hz). This graph consists of X–longitudinal feed direction and Y–cross feed direction. Thus Motion analysis done with the help of Time domain graphs, FFT graphs to analyze the dynamic motion behaviour and to find out rotational frequency and chatter frequency. The two types of Pattern of FFT responses which are discussed for face mill tool dynamic motion behavior are analyzed. Figure 2 [(a–b), (c–d), (e–f)] Shows the different FFT graphs for carbide shim , SS shim and without shim face mill tool with cutting speed 250 m/min , Depth of cut 0.8 mm and feed 0.05mm/tooth.

By using figure 2–a to 2–f Tooth passing frequency, chatter frequency and amplitude ratio for carbide shim, without shim and SS shim is find out as shown in Table 3.3.

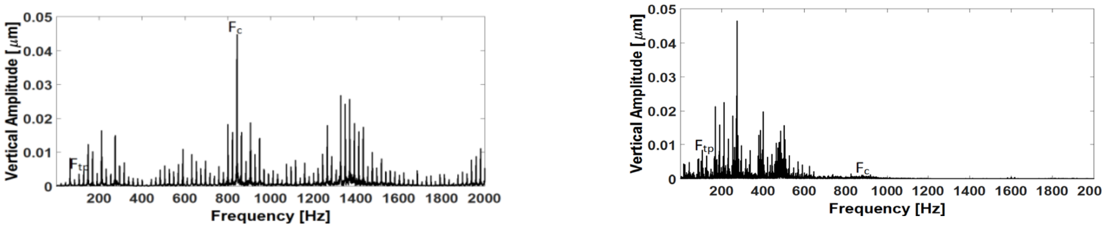
By observing above Table 3.3 it is clear that amplitude ratio in X is minimum for carbide shim and amplitude ratio in Y is minimum for SS shim, so Carbide shim and SS shim can give better result than without shim face mill tool irrespective of cutting parameters. Without shim face mill on VMC gives chatter in cross over feed irrespective of its cutting parameters which increase probability of waviness and chatter. This is current scenario of VMC–Vertical Milling Centre operation of face mill. With SS shim vibration amplitude ratio have been significantly damped out

20 to 40 % in cross over direction at medium and low cutting speed than without shim and carbide shim. So SS shim is useful for reducing chatter at medium and lower cutting speed. Carbide shim gives 20 to 50 % lesser vibration amplitude ratio compare to SS and Without shim in all cutting conditions at higher cutting speed 250 m/min. Thus with carbide shim vibration amplitude ratio have been significantly damped out at higher cutting speed. So carbide shim is useful for reducing chatter at high speed.



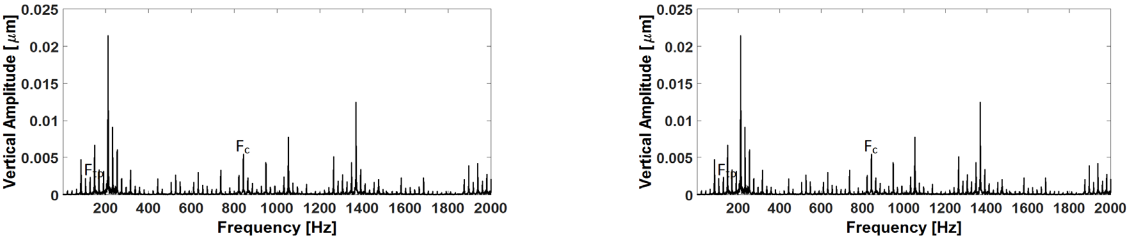
2–a Carbide FFT In X–Longitudinal Feed 2–b Carbide FFT In Y–Cross Feed

Figure 2–a Experimental FFT responses in X direction– longitudinal 2–b Experimental FFT responses in Y direction– Cross Feed for Carbide shim with cutting speed 250 m/min , Depth of cut 0.8 mm and feed 0.05mm/tooth



2–c SS FFT In X–Longitudinal Feed 2–d SS FFT in Y– Cross feed

Figure 2–c Experimental FFT responses in X direction– longitudinal; 2–d Experimental FFT responses in Y direction– Cross Feed for SS shim with cutting speed 250 m/min , Depth of cut 0.8 mm and feed 0.05mm/tooth



2–e Without shim FFT In X–Longitudinal Feed 2–f Without shim FFT in Y– Cross feed

Figure 2–e Experimental FFT responses in X direction– longitudinal 2–f Experimental FFT responses in Y direction– Cross Feed for without shim with cutting speed 250 m/min, Depth of cut 0.8 mm and feed 0.05mm/tooth

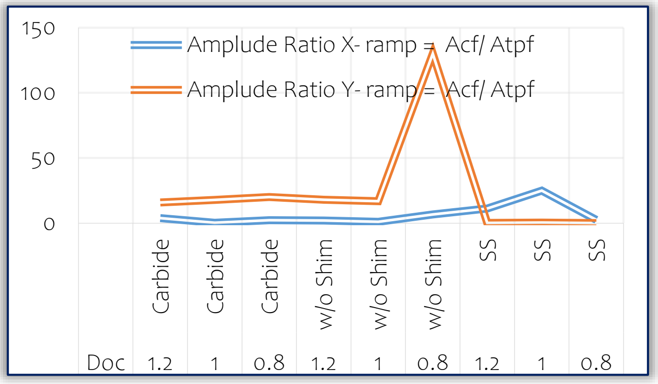
Table.3.3 Face mill Amplitude Ratio of Chatter frequency V/S Tooth passing frequency for cutting speed 250m/min

Sr.No	Cut. Speed (m/min)/Doc(mm)/ Feed(mm/ tooth)	Face mill cutting condition	Tooth passing frequency F_{tp}(109H_z) Amplitude (µm) A_{tpf}		Chatter frequency F_c(840H_z) and Amplitude (µm) A_{cf}		Amplitude Ratio r_{amp}= Acf/ Atpf	
			x	y	x	y	x	y
1	250/1.2/0.05	Carbide	0.266	0.203	1.016	3.2216	1.819549	15.86
2	250/01/0.05	Carbide	0.53	0.044	0.163	0.786	0.307547	17.86364
3	250/0.8/0.05	Carbide	0.21	0.071	0.47	1.465	2.238095	20
4	250/1.2/0.05	w/o Shim	0.00015	0.00005	0.0003	0.0009	2	18
5	250/01/0.05	w/o Shim	0.0004	0.00008	0.0004	0.0013	1	16.85
6	250/0.8/0.05	w/o Shim	0.00009	0.00001	0.0006	0.0013	0.6666	130
7	250/1.2/0.05	SS	0.004	0.023	0.045	0.005	11.25	0.2174
8	250/01/0.05	SS	0.012	0.0077	0.3	0.0032	25	0.4155
9	250/0.8/0.05	SS	0.002	0.0084	0.005	0.0006	2.5	0.07142

4. FINDINGS OF EXPERIMENTAL ANALYSIS – Amplitude Ratio Diagram

The face mill tool behavior is observed for different machining conditions for this research. The result of FFT graphs shows amplitude of Chatter frequency, tooth passing frequency in X– Longitudinal and Y– cross feed of face mill tool for different depth of cut (1.2mm, 1.0mm, 0.8mm) with Cutting speed (250, 200, 150 m/min) and feed (0.015,0.01 and0.05 mm/tooth). By using this value the amplitude ratio of amplitude for Chatter frequency Fc (µm) to amplitude for Tooth passing frequency Ftp (µm) is calculated. To find out the effect of (depth of cut) DOC– Amplitude ratio for different cutting condition is shown in Table 4.1, Table 4.2, Table 4.3 for cutting speed 250,200 and 150m/min respectively. By using these tables, graphs are generated which shows in Graph: 1, Graph: 2 Graph: 3 respectively.

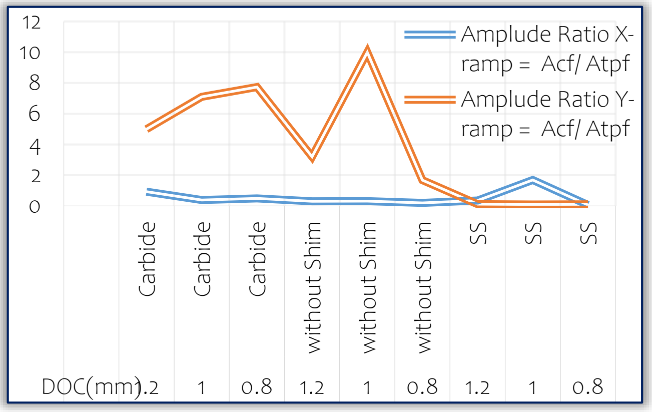
Purpose of this research is to find out which shim material give minimum chatter by investing amplitude ratio under machining behavior using FFT in form of frequency – amplitude which used to establish a new metric with help of generating Graphs of DOC(depth of cut) V/S Amplitude Ratio (ramp = Acf/ Atpf) . The amplitude ratio metric provides a quantitative measure of the occurrence and severity of chatter. The outcome of frequency domain FFT contains specific information Amplitude Ratio (ramp = Acf/ Atpf) combinations as shown in Table 4.1, Table 4.2 and Table 4.3. This chatter frequency is typically close to the natural frequency of the most flexible structure in the machine–tool workpiece system. Since chatter can be identified by the display of a chatter frequency and the severity of chatter can be forecast by the ratio of amplitude of the chatter frequency relative to amplitude of the tooth passing frequency.



Graph 1. for DOC– Amplitude Ratio A_{cf}/ A_{tpf} – CS 250 m/min

Table 4.1. DOC– Amplitude Ratio for CS 250 m/min

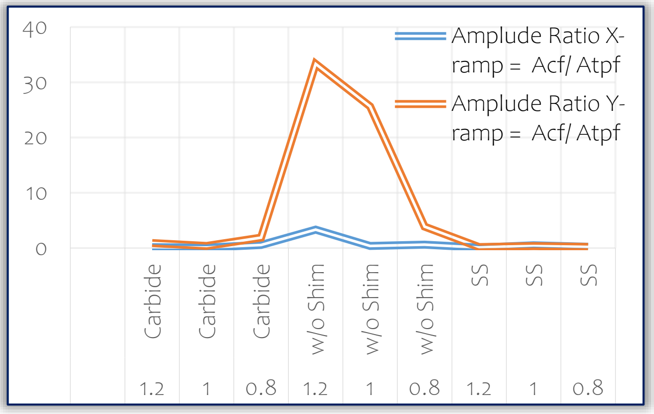
Doc (mm)	Shim	Amplude Ratio X– $r_{amp} = \underline{A_{cf/}} A_{tpf}$	Amplude Ratio Y– r_{amp} = Acf/ Atpf
1.2	Carbide	3.819549	15.86
1	Carbide	0.307547	17.86
0.8	Carbide	2.238095	20
1.2	w/o Shim	2	18
1	w/o Shim	1	16.85
0.8	w/o Shim	6.6666	130
1.2	SS	11.25	0.2174
1	SS	25	0.4155
0.8	SS	2.5	0.07142



Graph 2. for DOC– Amplitude Ratio A_{cf}/ A_{tpf} – CS 200 m/min

Table 4.2. DOC– Amplitude Ratio for CS 200 m/min

DOC (mm)	Shim	Amplitude Ratio X– $r_{amp}=\underline{A_{cf/}} A_{tpf}$	Amplitude Ratio Y– $r_{amp}=\underline{A_{cf/}} A_{tpf}$
1.2	Carbide	0.92	4.99
1	Carbide	0.38	7.1
0.8	Carbide	0.49	7.73
1.2	w/o Shim	0.3	3.2
1	w/o Shim	0.31	10
0.8	w/o Shim	0.19	1.67
1.2	SS	0.35484	0.109091
1	SS	1.68539	0.0875
0.8	SS	0.0538	0.095238



Graph 3. for DOC– Amplitude Ratio A_{cf}/ A_{tpf} – CS 150 m/min

Table 4.3. DOC– Amplitude Ratio for CS150 m/min

DOC (mm)	Shim	Amplude Ratio X–ramp=Acf/Atpf	Amplude Ratio Y– ramp = Acf/ Atpf
1.2	Carbide	0.15	0.92
1	Carbide	0.09	0.38
0.8	Carbide	0.56	1.9
1.2	w/o Shim	3.33	33.33
1	w/o Shim	0.4	25.64
0.8	w/o Shim	0.61	3.9
1.2	SS	0.1	0.1875
1	SS	0.5	0.35294
0.8	SS	0.25	0.2

By observing above 3 Graphs of DOC Vs Amplitude Ratio. It clearly shows that carbide shim has minimum Amplitude Ratio at high cutting speed 250 m/min so carbide shim has minimum chatter. carbide shim is useful for reducing chatter at high speed on VMC and It can give better result for face mill to reduce chatter than without shim and SS shim. While at medium 200 m/min and low cutting speed 150 m/min SS shim has minimum amplitude ratio. So SS shim has minimum chatter so It is useful for reducing chatter at medium and low cutting speed on VMC and SS shim can give better result for face mill to reduce chatter than without shim and SS shim at medium and low cutting speed.

5. ANOVA

For making a reliable and confident decision, we will need substantiation to support our approach. This is where the conception of ANOVA comes into play. Analysis of variance (ANOVA) is a statistical approach that's used to compare groups on possible differences in the average (mean) of a quantitative (interval or proportion, nonstop) measure. Analysis of variance(ANOVA) is an analysis tool used in statistics that splits an observed total variability set up inside a data set into two corridor methodical factors and arbitrary factors. The methodical factors have a statistical influence on the given data set, while the arbitrary factors do not.

— ANOVA for amplitude Ratio in X= R1 and Amplitude Ratio in Y= R2

The results of the analysis of variance (ANOVA) for the face mill tool at R1 Amplitude Ratio in X are shown in Table 5.1. This table also shows the degrees of freedom (DF), a sum of squares (SS), mean squares (MS), F–values (F–VAL.) and probability (P–VAL.) of each factor and different interactions. A low P–value (≤ 0.05) indicates statistical significance for the source on the corresponding response (i.e., $\alpha = 0.05$, or 95% confidence level), this indicates that the obtained models are considered to be statistically significant, which is desirable; as it demonstrates that the terms in the model have a significant effect on the response.

Table: 5.1 Analysis of variance (ANOVA) results of quadratic model

R1 Amplitude Ratio in X						R2 Amplitude Ratio in Y						
Source of variance	Sum of Squares	DF	Mean Squares	F Value	p–value Prob > F	Source of variance	Sum of Squares	DF	Mean Squares	F Value	p–value Prob > F	
Model	5337000000	14	381214285.	34952.6	0.0005	Model	243700000	14	17407142.85	3192.03	< 0.0001	significant
ACutting Speed	86950000	1	86950000	7972.23	0.0019	A–Cutting Speed	4760000	1	4760000	872.86	< 0.0001	significant
B–DOC	73190000	1	73190000	6710.61	0.0022	B–DOC	12330000	1	12330000	2261.016	< 0.0001	significant
C–Feed	115100000	1	115100000	10553.2	0.0014	C–Feed	5716000	1	5716000	1048.17	< 0.0001	significant
D–Shim	469800000	1	469800000	43074.8	0.0003	D–Shim	4501000	1	4501000	825.37	< 0.0001	significant
AB	203500000	1	203500000	18658	0.0016	AB	14260000	1	14260000	2614.93	< 0.0001	significant
AC	415300000	1	415300000	38077.8	0.0008	AC	25860000	1	25860000	4742.08	< 0.0001	significant
AD	546700000	1	546700000	50125.6	0.0006	AD	61230000	1	61230000	11228.06	< 0.0001	significant
BC	255600000	1	255600000	2344.81	0.0013	BC	26690000	1	26690000	4894.28	< 0.0001	significant
BD	508300000	1	508300000	46604.8	0.0006	BD	58510000	1	58510000	10729.28	< 0.0001	significant
CD	257000000	1	257000000	23563.7	0.0013	CD	50200000	1	50200000	9205.435	< 0.0001	significant
A^2	177010500	1	177010500	16229.6	0.054	A^2	13681030	1	13681030	2508.76	.0056	
B^2	187820400	1	187820400	17220.8	.0652	B^2	34750452	1	34750452	6372.37	0.065	
C^2	136810300	1	136810300	12543.7	.0723	C^2	17701050	1	17701050	3245.93	0.055	
D^2	347504520	1	347504520	31861.8	0.0521	D^2	34750452	1	34750452	6372.37	0.076	
Pure Error	163600	15	10906.6			Pure Error	81800	15	5453.3			
Cor Total	5337000000	29				Cor Total	24370000	29				

Table: 5.1 – Model Summary Statistics

R1 Amplitude Ratio in X					R2 Amplitude Ratio in Y			
Std. Dev.	0.085563173	R–Squared(R^2)	0.999966194		Std. Dev.	0.7	R–Squared	0.9710
Mean	1.544418024	Adj R–Squared	0.999425303		Mean	876.85	Adj R–Squared	0.9600
C.V. %	5.540156354	Adeq Precision(s/N)	157.8766565		C.V. %	0.08	Adeq Precision	30.514

Table 5.1 represents the ANOVA and the factor values. The suggested model provided Adj–R2(R1=0.9994 and R2=0.960) values. They demonstrated the fair accuracy of the data and the model. The projected model's standard deviation R2 (R1=0.9999 and R2=0.9710) value, means that just one of the total variation was not described by the model. The model fineness can be determined by measuring the signal–to–noise ratio (Adeq. Precision), this should be more than 4. This study's figures (R1=156.77665 and R2=30.514). Also the adjusted R2 (R1=0.9994 and R2=0.960) value was close to the R2 (R1=0.9999 and R2=0.9710) values. This shows that the model efficiency was unaffected by the removal of non–significant components. According to the ANOVA results in Table 5.1, the coefficients of variation (R1=5.50 and R2=0.08). This shows the strong reliability and accuracy of the experiments. All parameters had a considerable impact on vibration amplitude, in both linearly and cross feed direction and the interactive effect was also significant (p = 0.05) on vibration amplitude with quadratic properties. Larger F values of AD (R1=50125.6, R2=11228.06) and BD (R1=46604.8, R2=10729.28) indicate that the variation of the corresponding process parameter makes a big change in the amplitude ratio. From the ANOVA analysis, as shown in Table 5.1, it can be conditional that the AD and BD have more impact than the AB, AC and BC. Use that graphs to best illustrate how the process behaves.

— ANOVA Graphs for face mill tool

The best practice when looking at model graphs is to focus on the terms with significant effects. Use the graphs that best help explain the behavior of the process.

The analysis of variance was calculated for research parameters for factors and responses. In ANOVA analysis F–Test was conduct to compare a model variance with a residual variance. F value was calculated from a model mean square divided by residual mean square value (Error). If f value was approaching to one means both variances were same, according F value highest was best to find critical input parameter.

≡ ANOVA Graphs for face mill tool at R1 Amplitude Ratio in X for AD and BD

Here from above Figure 3 for AD, it is clear that at 250m/min cutting speed shim 2(Carbide shim) has minimum amplitude ratio and design points are available at 250m/min. At 200 and 150 m/min cutting speed (shim 3) SS shim has minimum amplitude ratio and design points are available for SS shim for cutting speed 200m/min and 150 m/min.

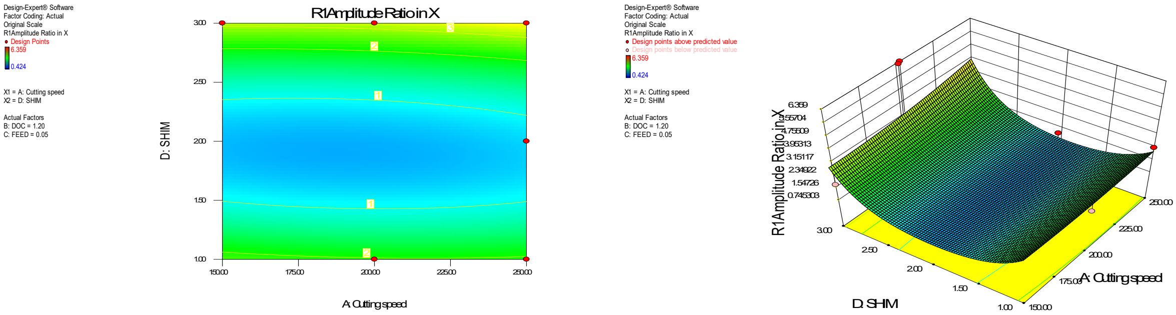


Figure 3. contour and 3D plots for AD DOC 1.2 mm Feed 0.05 mm/tooth at R1 Amplitude Ratio in X

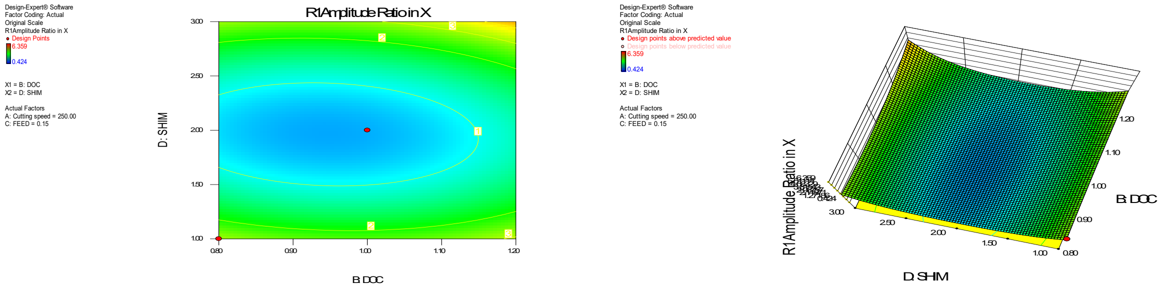


Figure 4. contour and 3D plots for BD Cutting Speed 250m/min Feed.15mm/tooth at R1 Amplitude Ratio in X

Also from above Figure 4 for BD, , it is clear that at high–speed (shim 2) carbide shim has given minimum Amplitude ratio in X so carbide shim is better for face mill tool at high speed No design points available for SS shim.

≡ ANOVA Graphs for face mill tool at R1 Amplitude Ratio in X for AD and BD

Here from above Figure 5 for AD, it is clear that at 250m/min cutting speed shim 2(Carbide shim) has minimum amplitude ratio and design points are available at 250m/min (shim 3) SS shim has no design points.

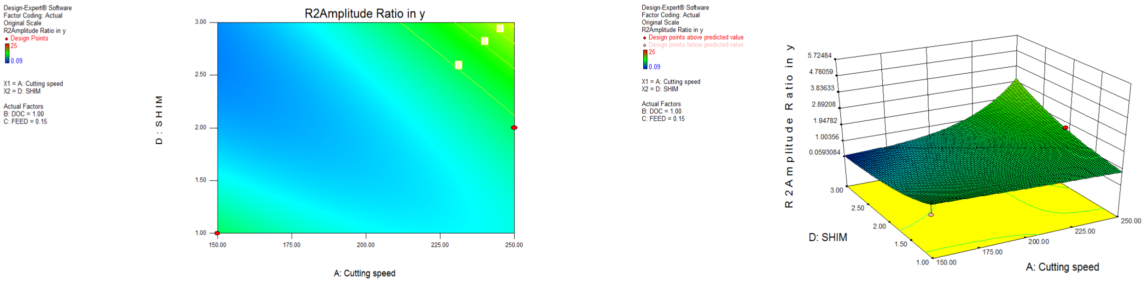


Figure 5. contour and 3D plots for AD DOC 1.2 mm Feed.15 mm/tooth at R2 Amplitude Ratio in Y

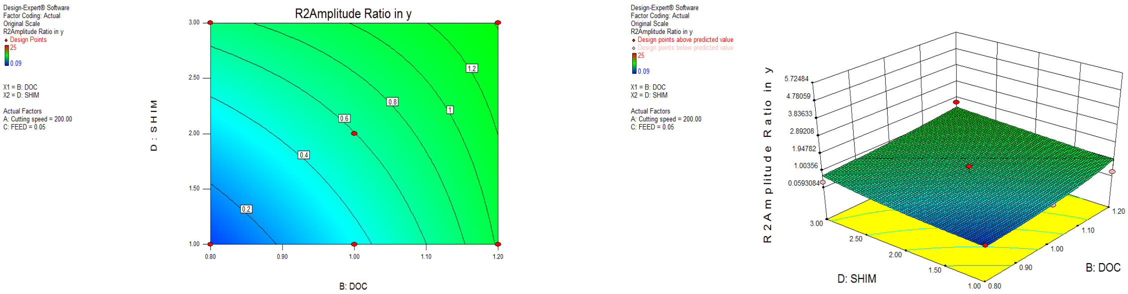


Figure 6. contour and 3D plots for BD Cutting Speed 200m/min Feed.05mm/tooth at R2 Amplitude Ratio in Y

Here from above Figure 6 for BD, it is clear that at 200m/min cutting speed shim 2(Carbide shim) has minimum amplitude ratio and design points are available at 200m/min. At 200 m/min cutting speed (shim 3) SS shim has minimum amplitude ratio and design points are available for SS shim for Depth of cut 0.8 and 1.2.

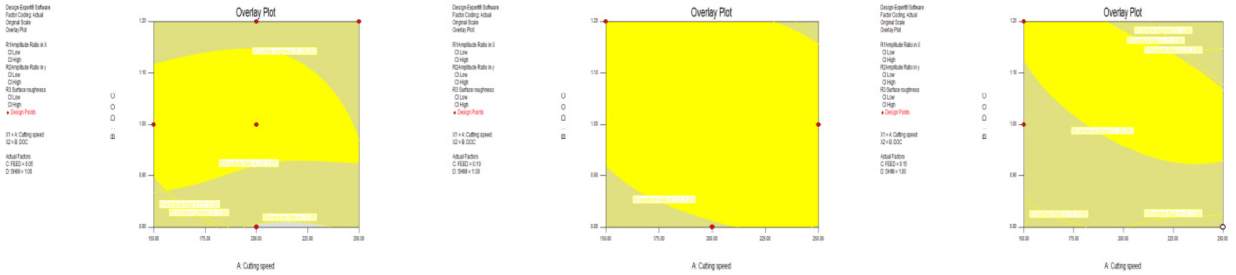
6. OPTIMIZATION

The optimization module in Design– Expert searches for a combination of factor situations that concurrently satisfy the situations placed on each of the responses and factors.

Graphical optimization uses the models to show the measures where suitable response results can be set up. With multiple responses, regions where situations concurrently meet the critical properties are essential. By overlaying critical response contours on a contour plot the finest concern can be picked (the sweet spot). Graphical optimization displays the area of realistic response values in the factor space.

— Graphical Optimization for Face mill tool based on overlay plot for – Without shim

From figure 7 it is observed that for (shim 1–) without shim at high feed no design points available at 250 and 200 m/min cutting speed, total 2 design points available for 250 m/min cutting speed.

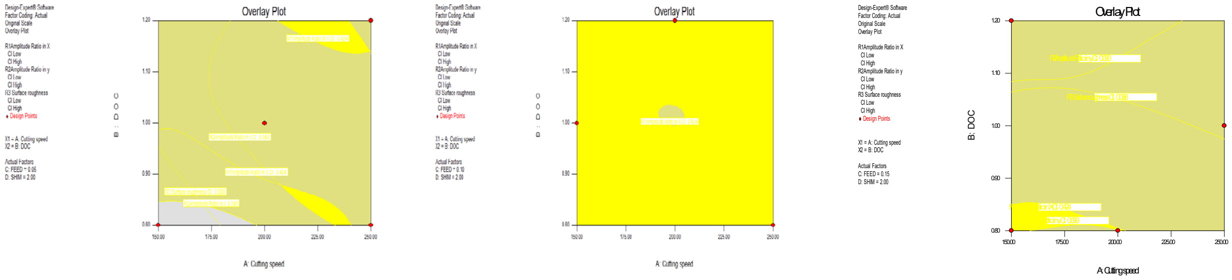


Shim 1 Feed 0.05 Shim 1 Feed 0.1 Shim 1 Feed 0.15

Figure 7. Graphical Optimization for Face mill tool based on overlay plot for without shim(shim 1)

— Graphical Optimization for Face mill tool based on overlay plot for – Carbide shim

From Figure 8 it is observed that for (shim 2–)Carbide shim Total 4 design points available at 250m/min cutting speed , at high feed(0.15mm/Tooth) at 150 m/min no design points available, carbide shim is useful for high cutting speed, which is validate with experimental analysis.

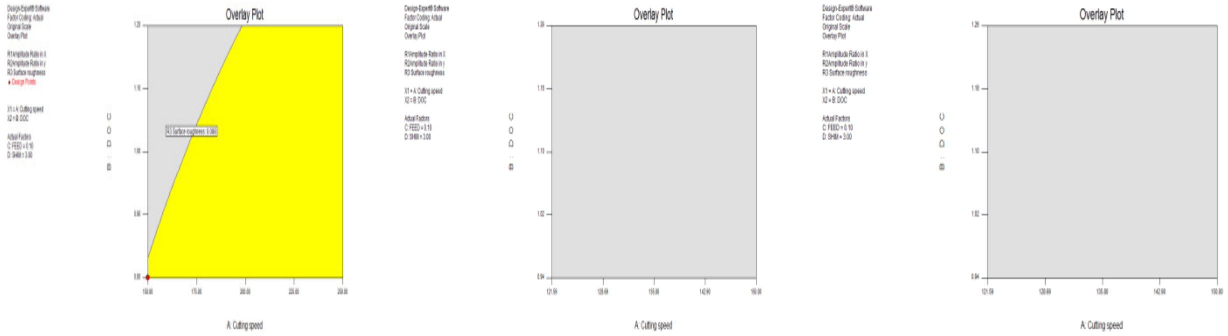


Shim 2 Feed = 0.05mm/tooth Shim 2 Feed = 0.1 mm/tooth Shim 2 Feed = 0.15 mm/tooth

Figure 8. Graphical Optimization for Face mill tool based on overlay plot for carbide shim(shim 2)

— Graphical Optimization for Face mill tool based on overlay plot for – SS shim

From figure 9 it is observed that for (Shim 3–) SS shim ,Design points available at cutting speed 150 and 200 m/min , which is validate with experimental analysis also. Total 4 design points available for SS shim at medium and low cutting speed, SS shim useful for low and medium cutting speed.



Shim 3 Feed = 0.05 mm/tooth Shim 3 Feed = 0.1 mm/tooth Shim 3 Feed = 0.15 mm/tooth

Figure 9. Graphical Optimization for Face mill tool based on overlay plot for shim 3 –SS shim

By graphical optimization, figure 8,9,10, it is clear that At higher cutting speed 250m/min Only 2 design points are available for without shim face mill tool , 4 design points are available for carbide shim face mill tool and 1 design point with constraint available for SS shim, So carbide shim is preferable for higher cutting speed and feed.3 Design points available for medium and lower cutting speed and feed for SS shim face mill tool, 2 design points available for carbide shim and 1 design point available for without shim face mill tool. So SS shim is preferable for lower and medium cutting speed and feed.

7. CONCLUSIONS

Physical 35 experiments may not be enough in a view of high level researchers academicians to conclude the use of shim and it need in face mill tool on VMC Hence here optimization based on optimum factorial method was executed using DESIGN EXPERT software in which 35experiments and its iterations with 70 populations are used to run the program. To reduce chatter; the author came to the following major conclusions.

Based on the computational and experimental analysis, with SS shim face mill tool vibration amplitude ratio was significantly damped out, 20 to 40% in crossover direction at medium and low cutting speeds, compared to without shim and carbide shim. Hence SS shim is useful for reducing chatter at medium and lower cutting parameters. With carbide shim face mill tool vibration amplitude ratio was significantly damped out, 20 to 50% compared to SS shim face mill tool and without shim face mill tool in all cutting conditions at a higher cutting parameters. Hence at carbide shim is useful for reducing chatter, at higher cutting parameters. Hence carbide shim is useful for reducing chatter at high cutting parameters.

Based on the DESIGN EXPERT ANOVA and the graphical optimization, for minimizing chatter carbide shim is preferable for higher cutting parameters while for lower and medium cutting parameters SS shim is preferable. This is validated with experimental analysis, Hence these shim designs endorse versatile solutions and proven by optimization.

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