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SURFACE FINISH ENHANCEMENT AND LEVEL OF VIBRATION REDUCTION USING TAGUCHI METHOD

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Abstract— Vibration is an unavoidable phenomenon observed in many machines, structures or systems. It is imperative for any researcher, designer or engineer to identify the sources of vibration and minimize the effect of it. There are many such techniques are available to identify the sources and severity of vibration. Frequency response analysis is one of the reliable and popular techniques of vibration measurement. Grinding operation is one of the critical manufacturing processes amongst many. Desired surface finish obtained on the object will helps to achieve good tribological properties and higher endurance limit against fatigue failure. As discussed vibration is one of the key factors which may deteriorate the surface finish obtained through grinding operation. In this paper a Taguchi method has been used to simultaneously optimize the minimum vibration level and minimum surface roughness. This is achieved by optimizing the process parameters (such as speed, feed, depth of cut), which are the sources of vibration. The vibration amplitude is measured in terms of frequency response using FFT analyzer. The vibration data obtained in the form of acceleration level is utilized to develop a mathematical model using regression analysis technique. This mathematical model will predict the levels of vibration as well as the surface finish for the input data.

Keywords— Vibration, Surface Roughness, FFT Analyzer, Taguchi method

I. INTRODUCTION

Machine Tool vibration is classified into two forms, forced vibration and self-excited vibration. Causes of forced vibration are usually simple, but those of self-excited vibration are complicated and not fully revealed yet. Self-excited vibration is generally more harmful because its amplitude is usually too large to continue cutting operation [1]. The search for higher productivity, cost reduction, production systems flexibility, better surface and/or dimensional quality, besides development of new materials, is becoming more and more important in the machined products industries, aiming to keep, or even increase, their market share, in the global world .Grinding is the indicated process when the work piece demands good surface, dimensional and geometrical quality. Due to this, the grinding process is, usually, one of the last steps in the machining operations chain. When the work piece reaches this point, it has high aggregated value, which makes a possible rejection very expensive [4]. To decide number of experiment to be carried out we have used partial factorial technique known as Taguchi system

II. EXPERIMENTAL ANALYSIS

To understand the correlation between the cutting forces and self-excited vibrations on the response (i.e. surface finish in this case), an experimental analysis was carried out. The experiments were carried out using planned technique called as DoE. The Figure (1) shows the experimental setup comprising Surface grinding machine, FFT Analyzer with accelerometer.

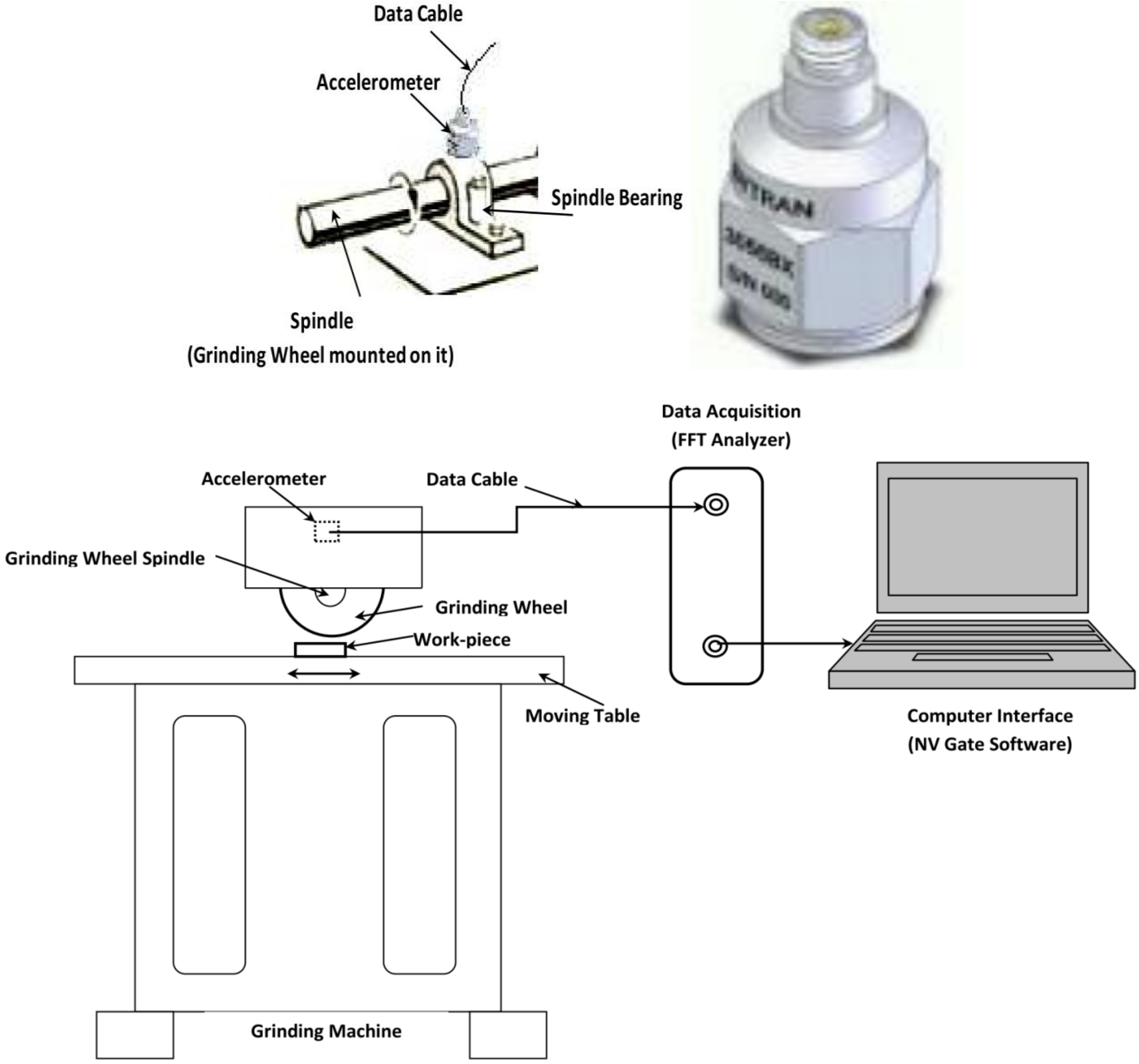

Figure 1. Grinding Machine, FFT Analyzer with Accelerometer

Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment [6]. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The major steps of implementing the Taguchi method are: (1) to identify the factors/interactions, (2) to identify the levels of each factor, (3) to select an appropriate orthogonal array (OA), (4) to assign the factors/interactions to columns of the OA, (5) to conduct the experiments, (6) to analyse the data and determine the optimal levels, and (7) to conduct the confirmation experiment

Table 1. Factor and its Level

Level	Grinding Wheel Speed	Feed Rate	Depth of cut
1	600 rpm	500 mm/min	0.1 mm
2	1200 rpm	1000 mm/min	0.2 mm
3	1800 rpm	1500 mm/min	0.3 mm

Table 2. Result Table

Test No.	Surface Roughness (µm)			Vibration Level (Acceleration)m/sec^2		
	Y_1	Y_2	S/N Ratio	Y_1	Y_2	S/N Ratio
T1	4.25	4.18	-12.4963	1.68×10^{-3}	1.67×10^{-3}	55.5197
T2	4.89	5.01	-13.8927	1.67×10^{-3}	1.68×10^{-3}	55.5197
T3	4.11	4.05	-12.2134	1.87×10^{-3}	1.78×10^{-3}	54.7721
T4	5.32	5.37	-14.5590	2.07×10^{-3}	2.11×10^{-3}	53.5967
T5	3.78	3.72	-11.4809	6.243×10^{-4}	6.34×10^{-4}	64.0247
T6	2.87	2.68	-8.8703	2.183×10^{-4}	2.024×10^{-4}	73.5350
T7	5.67	5.45	-14.9032	4.687×10^{-3}	4.786×10^{-3}	46.4904
T8	4.09	4.12	-12.2663	1.867×10^{-3}	1.768×10^{-3}	54.8073
T9	3.45	3.38	-10.6683	2.283×10^{-4}	2.176×10^{-4}	73.0334

As per L9 orthogonal array the tests were conducted .The results obtained in the form of surface roughness and vibration amplitude values are further processed to predict full factorial results. This 27 full factorial results are given in table 3

Test No.	A	B	C	Surface Roughness (µm)	Vibration Amplitude (mm/sec^2)
1	1	1	1	4.665555556	0.000991667
2	1	1	2	5.537222222	0.001126667
3	1	1	3	5.430555556	0.003411667
4	1	2	1	3.893888889	0.001418333
5	1	2	2	4.765555556	0.001553333
6	1	2	3	4.658888889	0.003838333
7	1	3	1	3.048888889	0.00021
8	1	3	2	3.920555556	0.000345
9	1	3	3	3.813888889	0.00263
10	2	1	1	4.207222222	0.00276
11	2	1	2	5.078888889	0.002895
12	2	1	3	4.972222222	0.00518
13	2	2	1	3.435555556	0.003186667
14	2	2	2	4.307222222	0.003321667
15	2	2	3	4.200555556	0.005606667
16	2	3	1	2.590555556	0.001978333
17	2	3	2	3.462222222	0.002113333

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18	2	3	3	3.355555556	0.004398333
19	3	1	1	4.610555556	0.002188333
20	3	1	2	5.482222222	0.002323333
21	3	1	3	5.375555556	0.004608333
22	3	2	1	3.838888889	0.002615
23	3	2	2	4.710555556	0.00275
24	3	2	3	4.603888889	0.005035
25	3	3	1	2.993888889	0.001406667
26	3	3	2	3.865555556	0.001541667
27	3	3	3	3.758888889	0.003826667

Table 3. Full Factorial Results

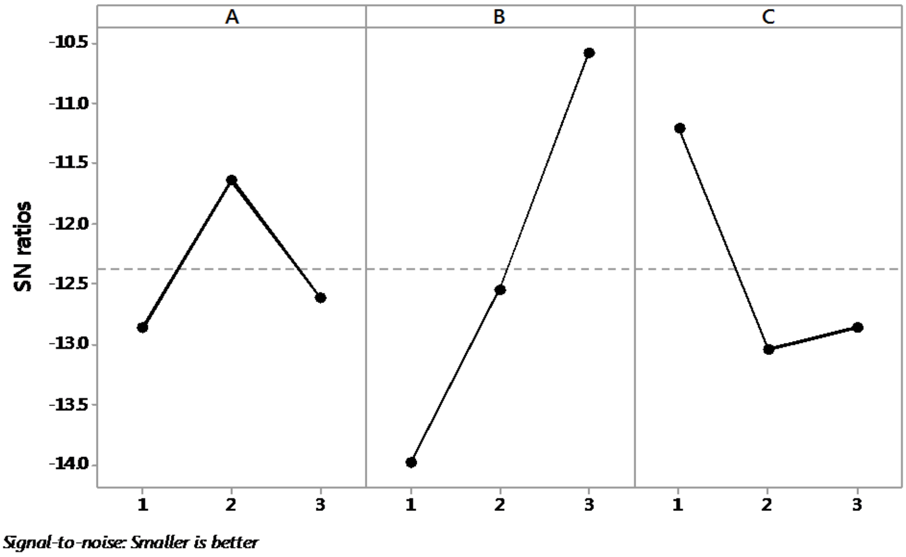

Figure 2. S/N Ratio for Surface Roughness

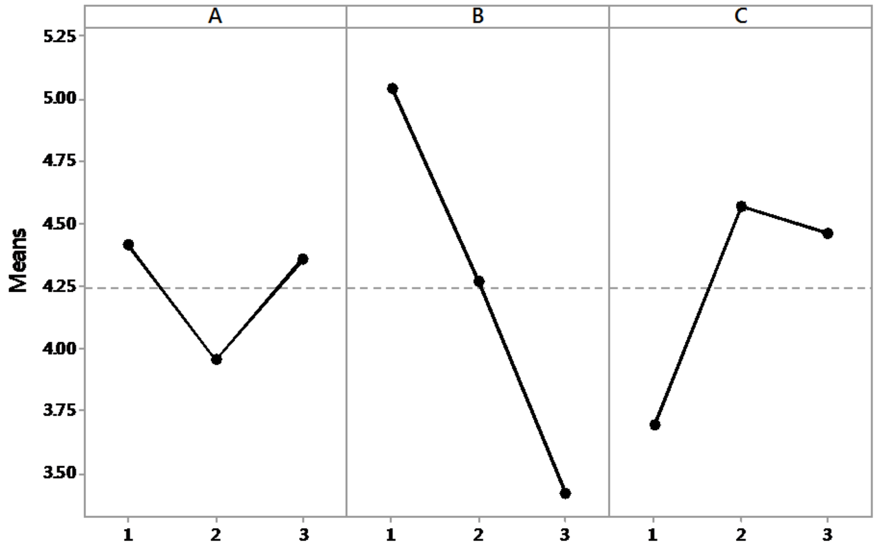

Figure 3. Main Effects for Surface Roughness

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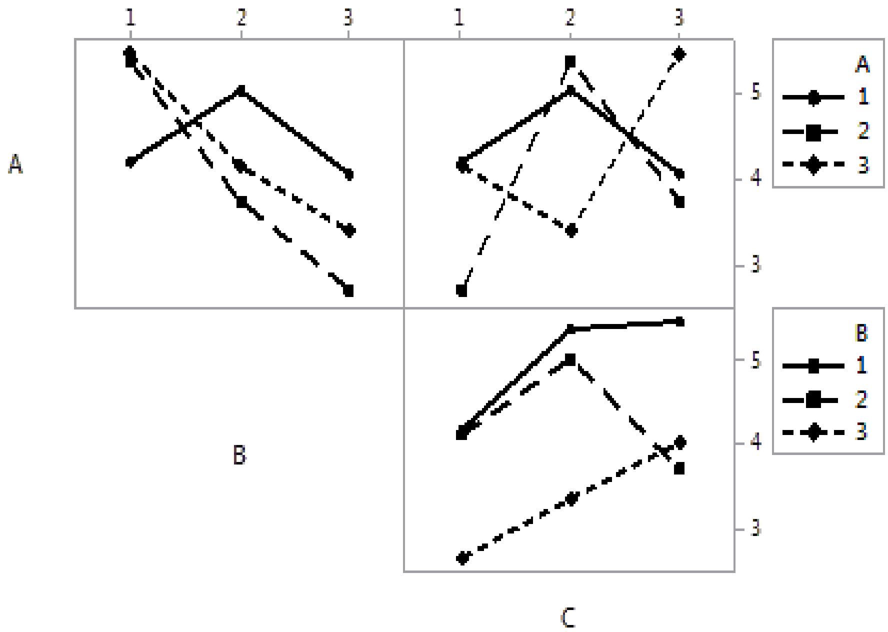

Figure 4. Interaction Plot for Surface Roughness

Contour Plot

Contour Plot for Surface Roughness

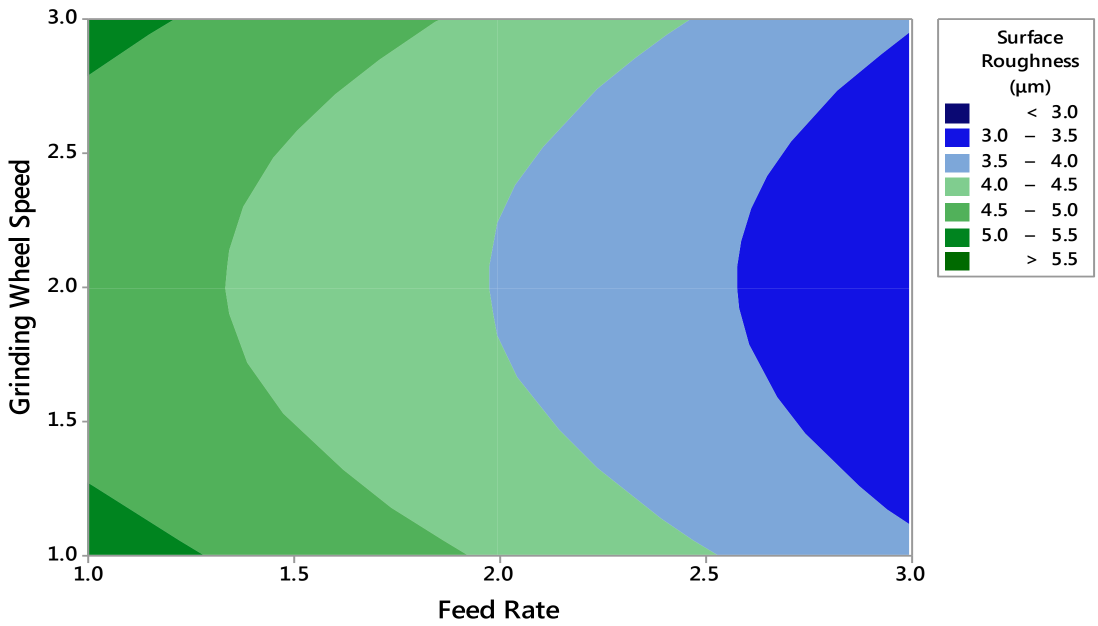

Figure 5 Grinding Wheel Speed Vs Feed Rate

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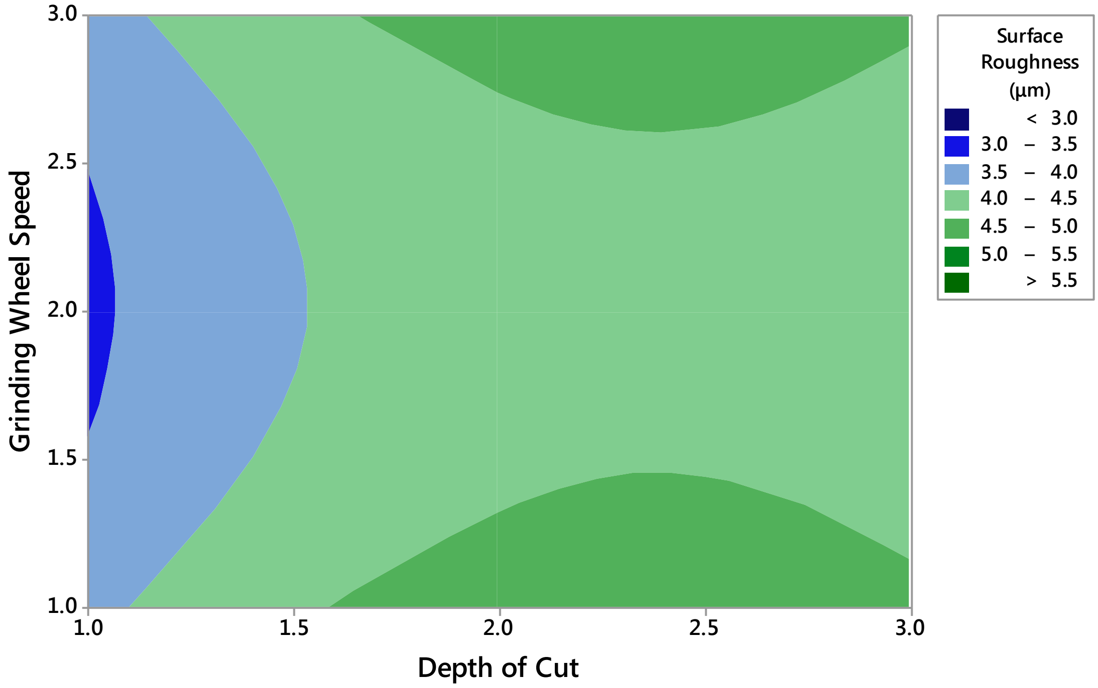

Figure 6. Grinding Wheel Speed Vs Depth of Cut

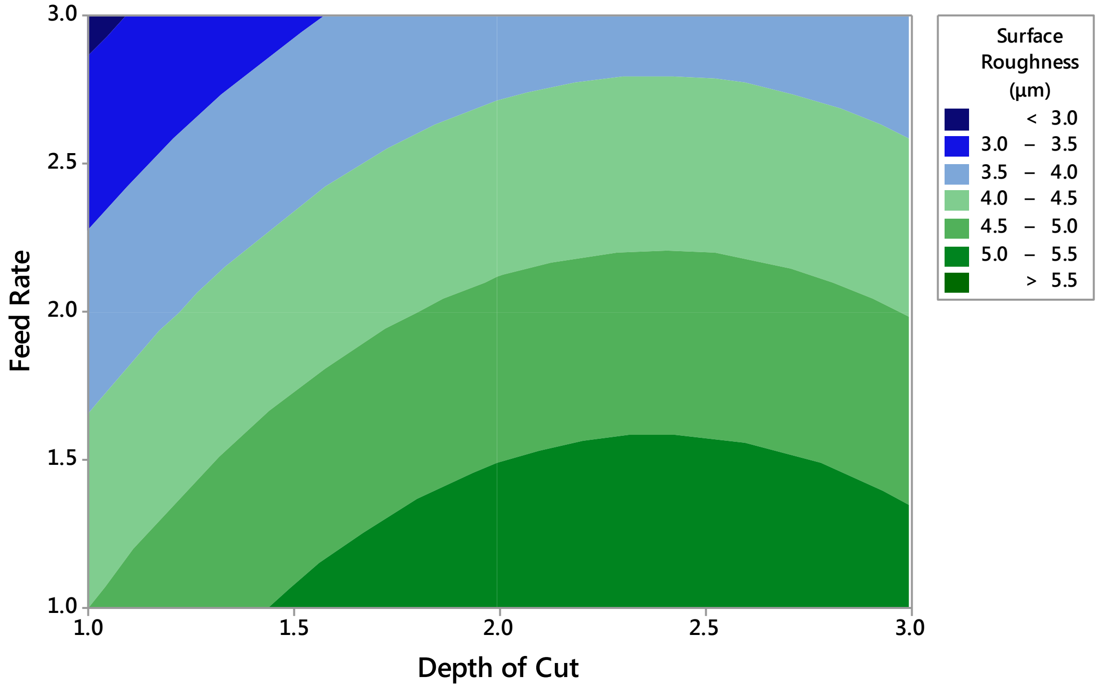

Figure 7. Feed Rate Vs Depth of Cut

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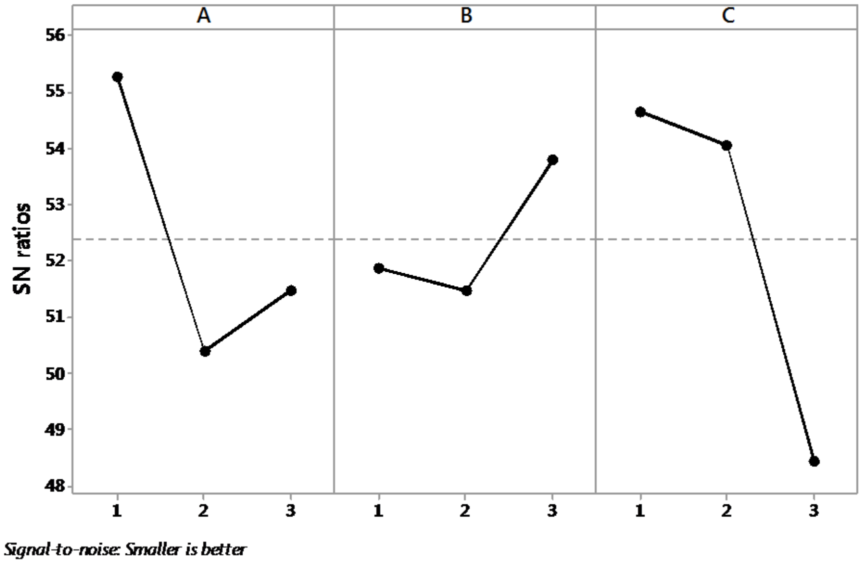

Figure 8. S/N Ratio for Vibration Amplitude

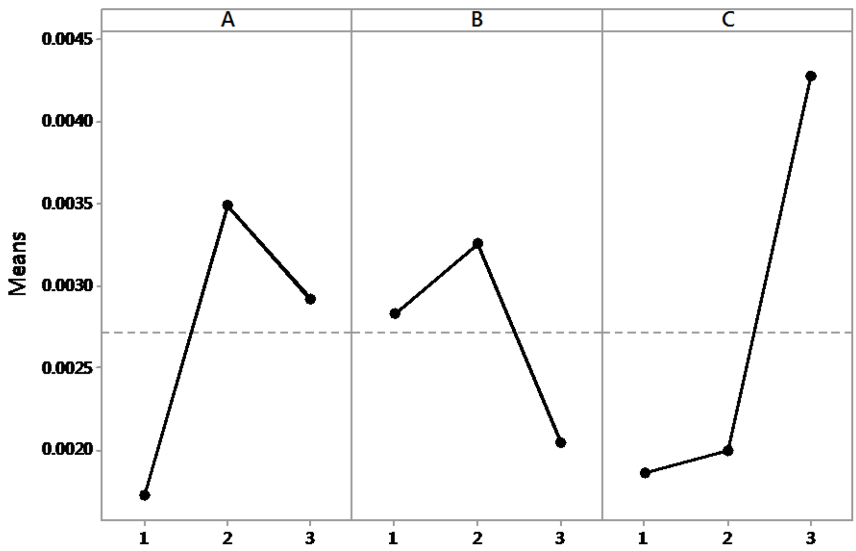

Figure 9. Main Effects for Vibration Amplitude

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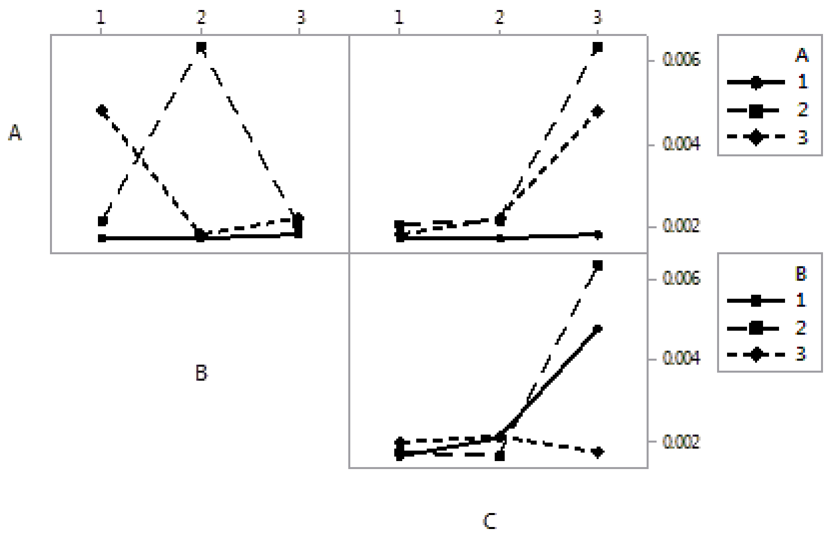

Figure 10. Interaction Plot for Vibration Amplitude

Contour Plot for Vibration Amplitude

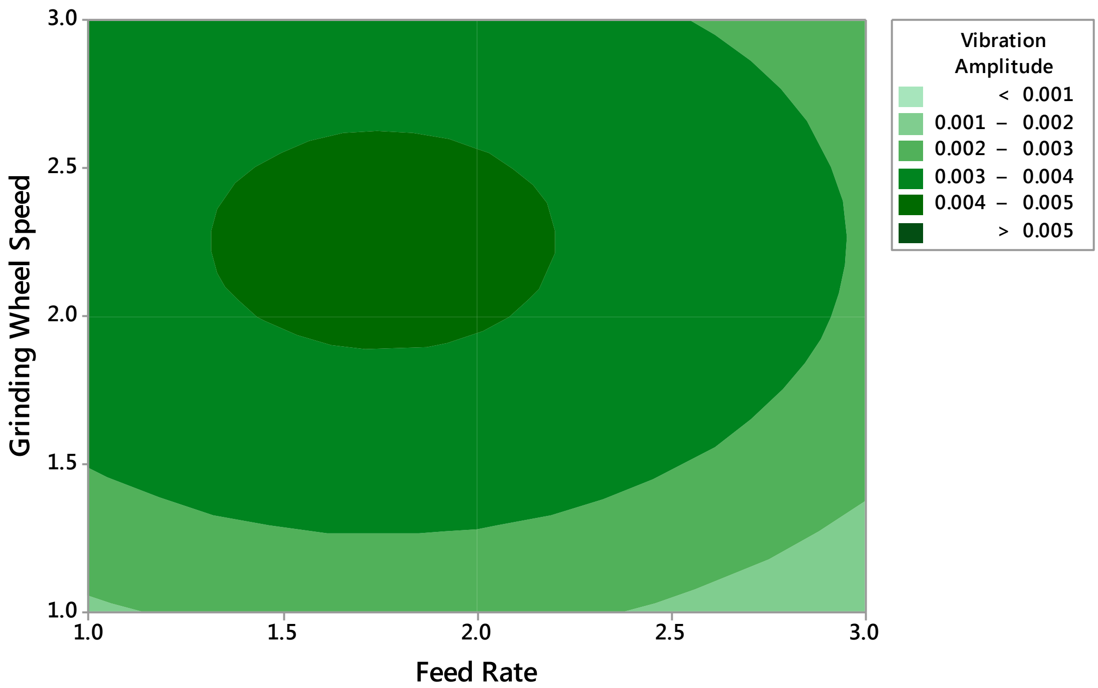

Figure 11. Grinding Wheel Speed Vs Feed Rate

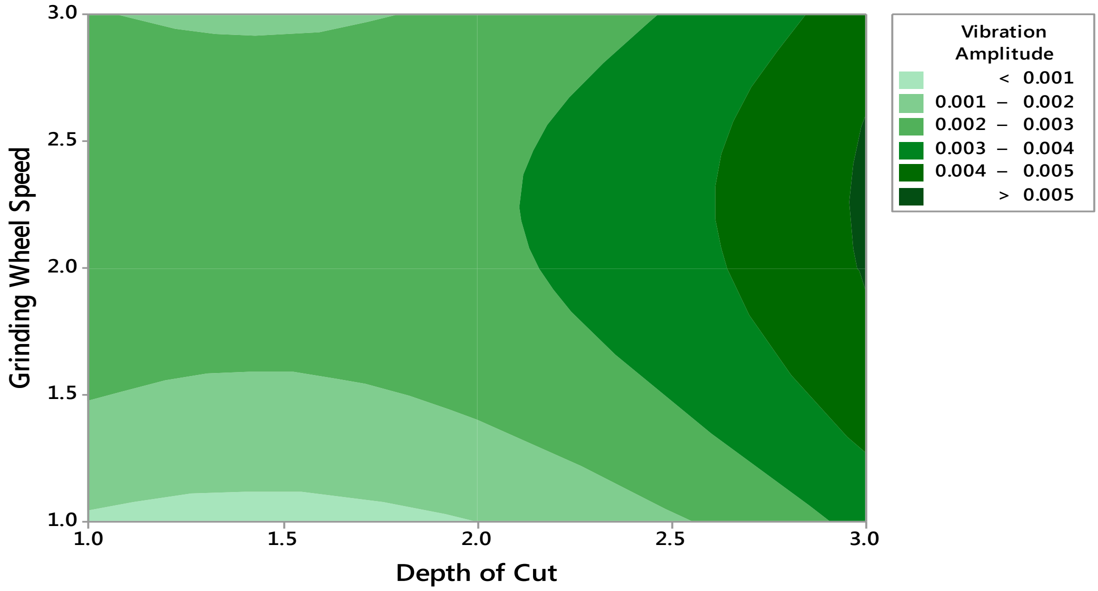

Figure 12. Grinding Wheel Speed Vs Depth of Cut

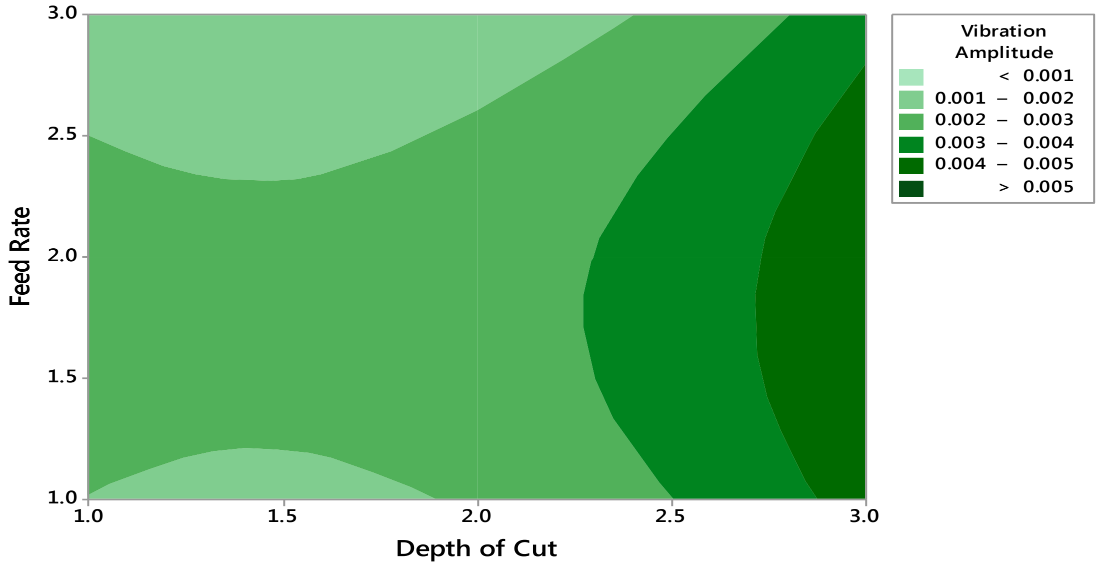

Figure 13 . Feed Rate Vs Depth of Cut

Surface Roughness (µm) = 5.151 - 0.0275 Grinding Wheel Speed - 0.8083 Feed Rate
+ 0.3825 Depth of Cut
R^2 = 84.93 **%**

Vibration Amplitude =-0.000122+ 0.000598 Grinding Wheel Speed - 0.000391 Feed Rate
+ 0.001210 Depth of Cut
R^2 = 74.98%

III. CONCLUSIONS

From the experimental results obtained and from the subsequent multi-objective analysis using GRA technique following conclusions are derived;

- It is observed that the process parameters are the key elements in the generation of self-excited vibrations.
- The Taguchi method helps to achieve the optimized combination of process parameters which will simultaneously reduce the level of vibration and enhance the response (surface finish).
- The Taguchi method found suitable for simultaneously optimizing the two response responses that is vibration level and surface finish.
- The contour plots for surface, vibration amplitude and gray relational grade gives fruitful information between the interaction of various parameters.
- The multiple linear regression analysis technique gives the equations for surface finish, vibration amplitude and overall grey relational grade. From this equations one can easily set the values for the process parameters such that the desired response can be obtained

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