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RESEARCH ARTICLE

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OPTIMIZATION OF SURFACE ROUGHNESS, MATERIAL REMOVAL RATE IN CAST IRON (FG-220) USING TAGUCHI APPROACH

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ABSTRACT

This paper reports on an optimization of MRR & surface roughness by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. FG-220 Cast Iron is used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate and Surface Roughness. Gear housing used are of length 312.0mm and height 258.0mm. There are three machining parameters i.e. Spindle speed, Feed rate, Depth of cut. Different experiments are done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Operating range is found by experimenting with top spindle speed and taking the lower levels of other parameters. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 15. In the first run nine experiments are performed and material removal rate (MRR) is calculated. When experiments are repeated in second run again MRR is calculated. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The metal removal rate was considered as the quality characteristic with the concept of "the larger-the-better". The S/N ratio for the larger-the-better . The S/N ratio values are calculated by taking into consideration with the help of software Minitab 15. The MRR values measured from the experiments and their optimum value for maximum material removal rate. Every day scientists are developing new materials and for each new material, we need economical and efficient machining. It is also predicted that Taguchi method is a good method for optimization of various machining parameters as it reduces the number of experiments. From the literature survey, it can be seen that there is no work done on FG-220 Cast Iron. So in this project the machining of FG-220 cast iron is done in order to optimize the machining process parameters for maximizing the material removal rate and surface roughness.

Keywords— Taguchi Method, Machining Parameters, FG-220 Cast Iron, Gear housing, Software Minitab15.

I. INTRODUCTION

Manufacturing process can be defined as the process of converting raw materials into products, including the product design, selection of raw materials and the sequence of the manufacturing procedure. In today's highly competitive market, the quality of manufactured products must be assured in all manufacturing stages. This has increased the demand for efficient manufacturing processes with optimum manufacturing cost, high quality and environmental sustainability considerations. There are two main concepts in modern manufacturing: Machining automation and advanced engineering materials.

Automation of manufacturing process could be the ideal solution to today's development revolution in terms of the new materials, cutting tools, and machining equipment. Automation will help in achieving an economical implementation of resources in the manufacturing process (materials, labor, energy, etc.) without compromising the high levels of quality and productivity. In addition, the change in market demands and product specification requires faster production rates and consistency and uniformity of the manufactured parts. Achieving these requires changing the tool just at the right time to get these benefits. The other main issue of modern manufacturing is the use of new advanced engineering materials. New industrial applications require materials with modified properties for products' particular requirements with reliable and economical manufacturing processes. Such advanced engineering materials are used in aerospace, electronics, medical applications and others industries. The modified properties will improve the quality of these materials and help meet certain mechanical, electrical, or chemical requirements. Typical properties of interest include: tensile strength, hardness, thermal, conductivity, and corrosion and wear resistance. Despite of all the advantage of advanced engineering materials. They are difficult to cut result in high cost of processing require high cost processing.

1.2 Turning Operation

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:

- With the work piece rotating
- With a single-point cutting tool
- With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.
- Taper turning is practically the same, except that the cutter path is at an angle to the work axis. Similarly, in contour turning, the distance of the cutter from the work axis is varied to produce the desired shape. Even though a single-point tool is specified, this does not exclude multiple-tool setups, which are often employed in turning. In such setups, each tool operates independently as a single-point cutter.

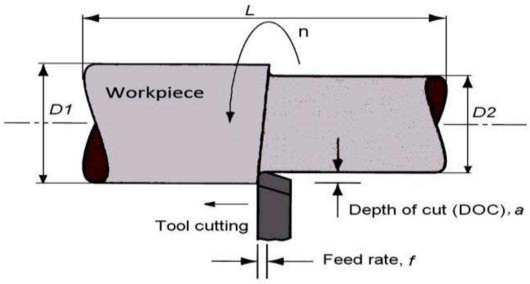

Figure 1.1 : Adjustable parameters in turning operation

1.3 ADJUSTABLE CUTTING FACTORS IN TURNING

The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

Speed: Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same.

$$v = \Pi\, DN/1000\text{m min}^{-1}$$

Here, *v* is the cutting speed in turning, *D* is the initial diameter of the work piece in mm, and *N* is the spindle speed in RPM.

Feed: Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$Fm = f\,.N\ mm.\text{min}^{-1}$$

Here, *Fm* is the feed in mm per minute, *f* is the feed in mm/rev and *N* is the spindle speed in RPM.

Depth of Cut: Depth of cut is practically self explanatory. It is the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

$$d\text{cut} = (D-d)mm / 2$$

Here, *D and d* represent initial and final diameter (in mm) of the job respectively.

1.4 ROUGHNESS MEASUREMENT

Roughness measurement has been done using a portable stylus-type profilometer, *Talysurf* (Taylor Hobson, Surtronic , UK) shown in Figure 3.2. The Talysurf instrument (Surtronic 3+) is a portable, self-contained instrument for the measurement of surface texture. The parameter evaluations are microprocessor based. The measurement results are displayed on an LCD screen and can be output to an optional printer or another computer for further evaluation. The instrument is powered by non-rechargeable alkaline battery (9V). It is equipped with a diamond stylus having a tip radius 5 µm. The measuring stroke always starts from the extreme outward position. At the end of the measurement the pickup returns to the position ready for the next measurement.The selection of cut-off length determines the traverse length. Usually as a default, the traverse length is five times the cut-off length though the magnification factor can be changed. The profilometer has been set to a cut-off length of 0.8 mm, filter 2CR, traverse speed 1 mm/sec and 4 mm traverse length. Roughness measurements, in the transverse direction, on the work pieces have been repeated four times and average of four measurements of surface roughness parameter values has been recorded. The measured profile has been digitized and processed through the dedicated advanced surface finish analysis software *Talyprofile* for evaluation of the roughness parameters. Surface roughness measurement with the help of stylus has been shown in Figure 2.3. Some typical surface roughness and waviness profile curves have been shown in Appendix.

Figure 1.2: Stylus-type profilometer

1.5 EXPERIMENTAL SET UP AND CUTTING CONDITIONS

The machining trials were carried out in dry condition without coolant on Machine CNC Kia model (fanuc series).The work piece material used was cast iron FG-220. The work piece was loaded on fixture w.r.t its faces parallel to each other. The hardness, tensile strength are 180 HBN, 22 Kg/mm2, respectively.

Figure 1.3: Experimental setup

1.6 WORKPIECE MATERIAL

Cast iron was widely used in automobile manufacturing company like clutch housing , oil sump ,cylinder block ,differential housing due to their high strength and high efficiency. FG-220 finds its application in buses, tractors, trucks, cars etc.

Table 1: Chemical composition of ductile cast iron (FG-220 grade)

Element Persentage [%]				
C	P	S	Mn	Si
3.2 to 3.5	Max 0.2	0.06 to 0.15	0.6 to 0.8	1.8 to 2.3

Table 1 shows the chemical composition of cast iron FG-220. CNMG 120408EN - TMR (insert) was used in this experiment. The surface roughness of the work piece was measured using a surface roughness tester model stylus type profilometer.

1.7 MACHINING TRIAL

Experiments were conducted using the design of experiments (DOE) technique with orthogonal L9 array of Taguchi methods, and then followed by optimization of the results using Analysis of Variance (ANOVA) to find the maximum MRR, minimum surface roughness, and maximum tool life. The nine of machining trials were as tabulated in Table 2. The ranges of machining conditions were based on the real industry practice for machining cast iron FG-220 grade. Each of experiment trials was started with a new cutting edge and machining was stopped at a certain interval of time to measure the surface roughness and MRR of the work piece material.

Table 2 : Process Parameters & their Levels

Speed (rpm)	Feed (mm/rev)	DOC (mm)	Time (sec)	Initial weight (g)	Final weight (g)	Diff of weight (g)	MRR
1500	15	0.1	21	24250	24093	157	7.48
1500	20	0.1	17	24200	24048	152	8.94
1500	25	0.3	34.8	24235	23763	472	13.56
1800	15	0.2	34.8	24280	23972	308	8.85
1800	20	0.3	43.5	24212	23772	440	10.11
1800	25	0.1	11.2	24250	24095	155	13.84
2100	15	0.3	54	24235	23828	407	7.54
2100	20	0.1	12.7	24230	24098	132	10.39
2100	25	0.2	19	24200	23960	240	12.63

1.8 RESULT AND ANYLYSIS

Introduction of Minitab: For the various analysis purposes Minitab statistical software is identified. Minitab ver. 15.1 is used because of its user friendliness. This software is available with Minitab worksheet which is similar to the Excel worksheet in tabulated form. It can save the data in worksheet, graph format and project form. It can create Taguchi design as per our level and factor selection. Once results are put up in the worksheet then analysis of Taguchi design can be performed. In this analysis signal to noise ratio is tabulated, factors are given rank based on delta value and main effects plots are extracted. This would be utilised for optimisation purpose. This software can predict the signal to noise ratio for comparison purpose. It also can perform regression analysis and analysis of variance.

Taguchi's analysis for MRR: Table 4 shows response table for signal to noise ratio for MRR. This response table represents the effects of various input factors on MRR. Higher the slope in the main effects plot corresponding values of delta is higher in the response table. The rank represents directly the level of effect of input based on the values of delta. Here according to ranks, the effects of various input factors on MRR in sequence of its effect are feed, speed, and depth of cut. That means feed affects the MRR at highest level and depth of cut at lowest level. However the effect of speed needed to be seen since the value of delta is nearer to the corresponding value of DOC Larger is better.

Table 4.1 Response Table for Signal to Noise Ratios for MRR

Level	Speed (rpm)	Feed	DOC
1	19.57	17.99	20.21
2	20.62	19.67	19.85
3	19.97	22.50	20.09
Delta	1.05	4.51	0.36
Rank	2	1	3

Table 4.2 Response Table for MEAN for MRR

LEVEL	SPEED	FEED	DOC
1	9.75	8.06	10.35
2	10.41	9.789	10.01
3	10.108	13.72	10.24
DELTA	0.66	5.7	.23
RANK	3	1	2

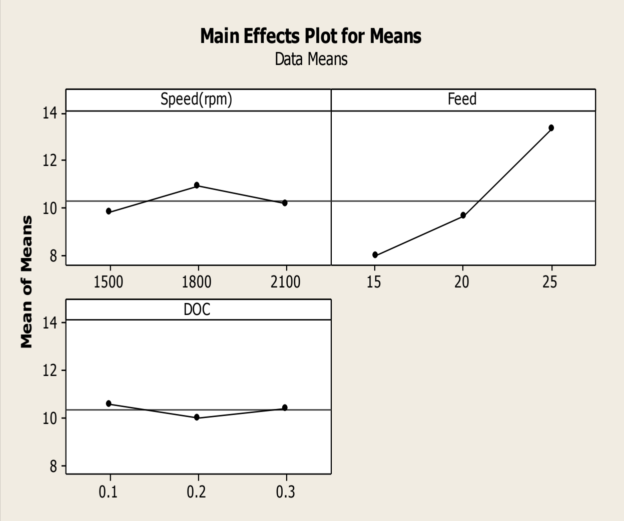

Fig 4.2 Main Effect Plot for Means of MRR

A main effects plot is a plot of the means at each level of a factor. One can use these plots to compare the magnitudes of the various main effects and compare the relative strength of the effects across factors. However it is important to be sure to evaluate significance by looking at the effects in the analysis of variable table.

Table 4.3: S/N ratio and mean for MRR

Speed(rpm)	Feed	DOC	MRR	SNRA1	MEAN
1500	15	0.1	7.476	17.47339	7.476
1500	20	0.2	8.494	18.58225	8.494
1500	25	0.3	13.56	22.64519	13.56
1800	15	0.1	8.851	18.93985	8.851
1800	20	0.2	10.11	20.09502	10.11
1800	25	0.3	13.84	22.82272	13.84
2100	15	0.1	7.537	17.54397	7.537
2100	20	0.2	10.39	20.33231	10.39
2100	25	0.3	12.63	22.02807	12.63

Table 4.3 shows the values of signal to noise ratio (SNRA) and mean for MRR. The representation of effects of various parameters on MRR and optimise condition is very much nearby. It is observed from the Table 4.1 and Table 4.2 that, the feed is the most responsible factor and depth of cut is the least responsible factor for the material removal rate. This is also seen in Figure 4.1 and Figure 4.2. From the Taguchi analysis it has been found that the feed is playing as a main parameter for material removal rate, where as depth of cut is having the least affect on the material removal rate.

4.3 Taguchi's analysis for SR

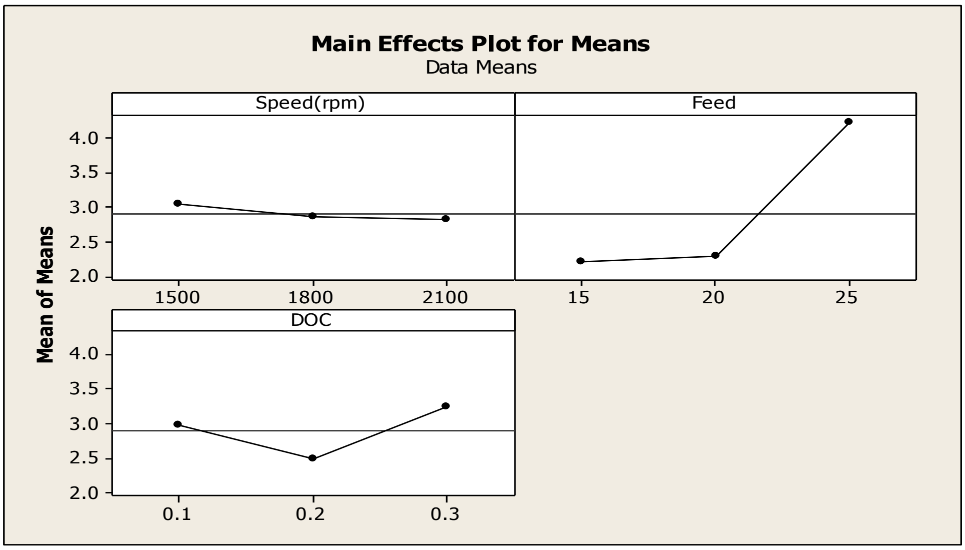

Fig. 4.3 Main Effect Plot for Means of Surface Roughness

Table 4.4 Response Table for MEAN for SR

LEVEL	SPEED	FEED	DOC
1	3.02	2.28	2.96
2	2.85	2.35	2.5
3	2.73	4.275	3.35
DELTA	.29	1.925	.85
RANK	3	1	2

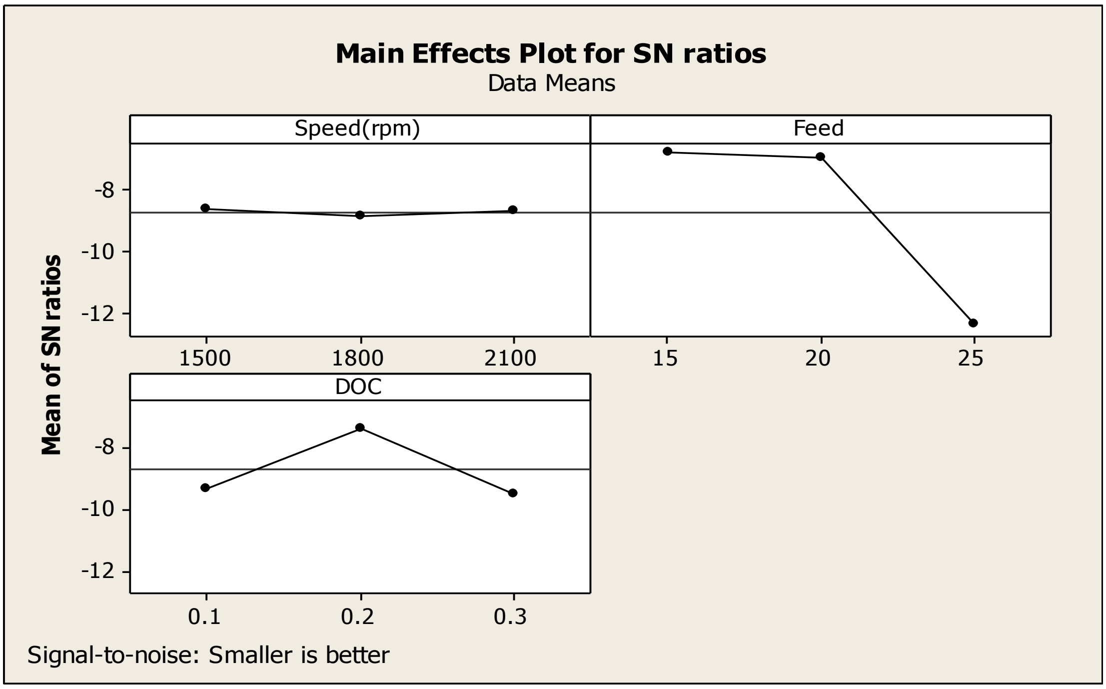

Fig. 4.4 Main Effect Plot for SN Ratios of Surface Roughness

Table 4.5 Response Table for S/N Ratios for SR

Level	Speed (rpm)	Feed	DOC
1	-8.624	-6.838	-9.310
2	-8.852	-6.973	-7.382
3	-8.718	-12.384	-9.503
Delta	0.228	5.546	2.121
Rank	3	1	2

It is observed from the Table 4.4 and Table 4.5 that, the feed is the most responsible factor and speed is the least responsible factor for the surface roughness. This is also seen in Figure 4.3 and Figure 4.4 Since it is always desirable to achieve the best surface finish smaller is better option is selected.

Table 4.6: S/N ratio and mean for SR

Speed(rpm)	Feed	DOC	SR	SNRA1	MEAN1
1500	15	0.1	2.42	-7.67631	2.42
1500	20	0.2	1.59	-4.02794	1.59
1500	25	0.3	5.11	-14.1684	5.11
1800	15	0.1	2.17	-6.72919	2.17
1800	20	0.2	2.58	-8.23239	2.58
1800	25	0.3	3.8	-11.5957	3.8
2100	15	0.1	2.02	-6.10703	2.02
2100	20	0.2	2.71	-8.65939	2.71
2100	25	0.3	3.71	-11.3875	3.71

Table 4.6 shows the values of signal to noise ratio (SNRA). The representation of effects of various parameters on SR and optimise condition is very much nearby. It is observed from the Table 4.4 and Table 4.5 that, the feed is the most responsible cutting speed is the least respons ible factor for the surface roughness. This is also seen in Figure 4.3 and Figure 4.4

CONCLUSION

Based on the experimental results presented and discussed, the following conclusions are drawn on the effect of cutting speed and feed & depth of cut on surface roughness and material removal rate during machining FG-220 cast iron using taguchi method. Feed is the most dominating factor & depth of cut is the least dominating factor for MRR. It was seen from Figure 1.5 that the MRR reduces at speed of 1500 m/min and after it starts increasing. Better material removal rate is observed at cutting speed of 1800 m/min, feed of 25 mm/rev and depth of cut 0.3 mm.

Feed is the most dominating factor & speed is the least dominating factor for MRR. It was seen from Figure 1.6 that the surface roughness achieved at speed 1800m/min after it starts increasing. So better surface finish is observed at cutting speed of 1500 m/min, feed of 20 mm/rev and depth of cut 0.2 mm.

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