Improvement Of Cutting Parameters in Lathe Turning Operation to Enhance Surface Finish

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Abstract- In this work, cutting parameters in a lathe turning operation were modelled to enhance surface finish quality of AISI1020 mild steel work-piece. The effect of cutting speed of the lathe turning operation on the rate of material removal and surface roughness of AISI1020 mild steel was analyzed. The amount of feed input on the material removal rate and surface roughness of AISI1020 mild steel was evaluated. Ultimately, an optimal matching cutting parameter for lathe turning operation that enhanced the surface finish quality of AISI1020 mild steel was generated. Employing the application of ANSYS, finite element and Johnson cook flow stress were utilized to get the near. The Taguchi's robust design was used for optimizing turning parameters on AISI1020 mild steel. Experiments were conducted using L9 orthogonal array and for each experiment, surface roughness was measured, recorded and analyzed using Taguchi S/N ratios. These ratios were calculated with consideration of performance characteristic: Lower-the- Better, as surface roughness is requested to be low. Result showed that surface roughness is mainly affected by depth of cut followed by cutting speed and feed rate respectively, therefore, it is crucial to consider the effects of interactions between other cutting parameters such as the cutting tool nose radius and rake angle and surface roughness in future research, for quality surface finish in lathe turning operations. Recommendations were made that finite element modelling could yield a reduction in overall machining costs and saves time as it predicts the optimal machining parameters for quality work-piece.

Indexed Terms- cutting Parameter, Lathe turning, enhance sirface finish

I. INTRODUCTION

Mechanical production processes can be classified into five principal types: shaping processes, property enhancing processes, surface processing operations, permanent joining processes, and mechanical fastening (Zouhar, & Piska, 2017). Shaping processes can be grouped into four categories: solidification processes, particulate processing, deformation processes, and material removal processes. Machining is the most important method of material removal processes as it offers excellent dimensional tolerances and the best surface quality. Machining can be defined as the process of removing excess material from an initial work-piece to produce the desired final geometry (Vikas *et al.,* 2013). The work-piece is cut from a larger piece, which is available in a variety of standard shapes such as round bars, rectangular bars, round tubes, and so on. This material removal process includes three principal categories: turning, drilling, and milling (Muhammad *et al.,* 2009; Zouhar, & Piska, 2017).

In turning operation, the tool is fed parallel to the axis of rotation. The work-piece is rotated at a particular speed (cutting speed), and the cutting tool is fed against the work-piece (feed rate) at a certain level of engagement (depth of cut). Turning process can be conducted either on conventional lathe or on computer numerically controlled (CNC) lathe. It can be done manually, in a traditional form of lathe, which requires continuous supervision by the operator or by using a computer controlled and automated lathe which does not requires constant supervision. Nowadays, the CNC lathe is widely used where machining operations are controlled by a program of instructions based on alphanumeric code. This machine tool provides more sophisticated and versatile means of control than mechanical devices. Metal cutting, which is the process of removing excess materials from a work piece, is one of the most important manufacturing processes and it is widely used in engineering industries.

In order to improve the quality of machined products' surface finish and reduce their production cost, material removal rate should be optimum (Amit & Kothiyal, 2012; Eckart. & Danny, 2020).

In this work, the cutting speed, depth of cut and feed rate cutting parameters of a lathe turning machine were considered and analyzed using Taguchi L9 orthogonal optimization technique to optimize removal rate the material of AISI1020 mild steel work-piece and to improve the quality of the steel product's surface finish. The modeling and simulation of the enumerated cutting parameters in the lathe turning operation was achieved with the use of ANSYS computer program while MATLAB computer software was used to analyze the work-piece data with ANOVA in orderto identify the effect of the machining parameters on individual responses of the work piece. This study evaluated the depth of cut, cutting speed, and feed rate cutting parameters of the lathe turning machine, on the cutting force, stress, material removal rate and surface roughness of the steel work-piece.

A. Objectives of the work

i. Determination of the effect of the cutting speed of the lathe turning operation on the rate of material removal and surface roughness of AISI1020 mild steel.
ii. To evaluate the influence of the amount of feed input on material removal rate and surface roughness of the AISI1020 mild steel.
iii. To determine the depth of cut in the AISI1020 mild steel work-piece on the material removal rate and surface roughness.
iv. To generate an optimal matching cutting parameter for the lathe turning operation that will enhance the surface finish quality of the AISI1020 mild steel.

This work evaluated the depth of cut, cutting speed, and feed rate cutting parameters of the lathe turning machine, on the cutting force, stress, material removal rate and surface roughness of the steel work-piece.

II. PAST REVIEW

Khalaf *et al.* (2018) analyzed finite element modeling and optimization of estimated cutting forces during machining of Inconel 718. In their study, the effect of different cutting parameters (cutting speed, feed rate, and depth of cut) on cutting force under dry hard turning of Inconel 718 was investigated.

According to Shrinivas *et al.* (2013) in optimization of cutting parameters in turning process to enhance tool life, modern manufacturers are seeking to remain competitive in the market by relying on their manufacturing engineers and production personnel to effectively set up manufacturing processes for new products.

Olodu (2018) performed an optimization and analysis of cutting tool geometrical parameters using Taguchi method. The study presented the finite element analysis of the influence of cutting tool geometrical parameters (nose radius, rake angle and clearance angle) on machining process evaluation indicators such as cutting force, temperature and thermal deformation of the tool using Taguchi method to statistically evaluate the signal-to-noise ratio.

Deepaganesh (2015) performed finite element simulation in orthogonal machining of Inconel 718 alloy. It was stated that knowing the stringent operating conditions to which super alloys are subjected to in automobile, aerospace and gas turbine industries, their efficient machining and generation of machined surface with integrity assumes a lot of importance. It was further stated that considerable attention has been given to the use of ceramic tools for improving productivity in the machining of heat resistant super alloy (HRSA) in recent years.

A. Conceptual Framework: Lathe Turning Operation; Cutting Parameters, Machining Characteristics and Taguchi Optimization Technique

Mathews and Nedheesh (2014) defined metal cutting as the removal of metal chips from a work piece in order to obtain a finish product with desired attributes of size, shape and surface roughness.

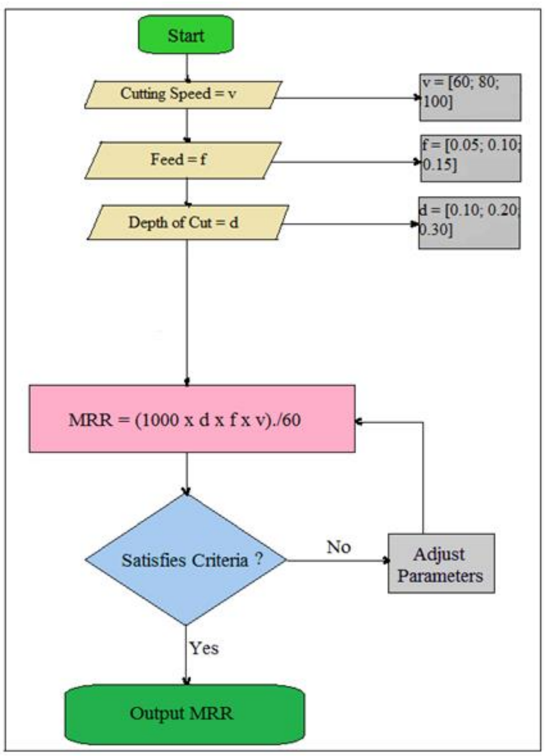
III. MATERIALS AND METHOD

The method of cutting parameters understand were cutting speed depth of cut and feed rate of the ASIS 1020 mild steed rod, was selected and a finite element computer aided design (CAD) and simulation software called ANSYS was employed for the analysis. Also, Taquchi method is performed by Utilizing MATLAB 17 to estimate the effect of the cutting parameter on (cutting force stress, material removal rate and surface roughness in operation.

Then analysis of variance (ANOVA) F-Test was performed to evaluate the influence of the cutting parameters (v.d, F) to generate optimal matching cutting force. It can be useful for determining any give input data parameter result.

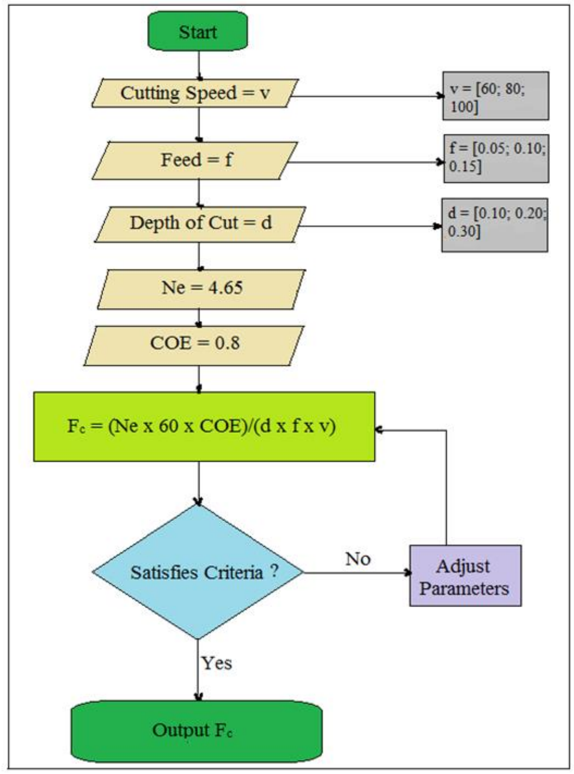
A. Flow chart for ANSYS Finite Element Modeling (FEM) of Material Removal Rate in Turning Operation

The flow chart for programming the material removal rate for quality and productivity of the work-piece is presented below:



B. Flow chart for ANSYS Finite Element Modeling (FEM) of Cutting Forces in Turning Operation

The flow chart for programming the cutting force for quality surface finish of the work-piece is presented below:



IV. RESULTS

The Taguchi L9 orthogonal array was selected to perform the simulation of cutting process. The machining controllable: cutting speed, feed rate, and depth of cut parameters were depended and their levels that were used during modeling are shown in Table 1. The L9 orthogonal array with three columns and nine rows was suitable for use in this research. In this work, analysis based on the Taguchi method is performed by utilizing the ANSYS and MATLAB software to estimate the significant factors of the lathe turning process parameters on cutting force, material removal rate, stress and surface roughness in the work-piece analysis of the obtained data from the simulations. Analysis of Variance (ANOVA) was performed to understand the percentage influence of all the cutting parameters.

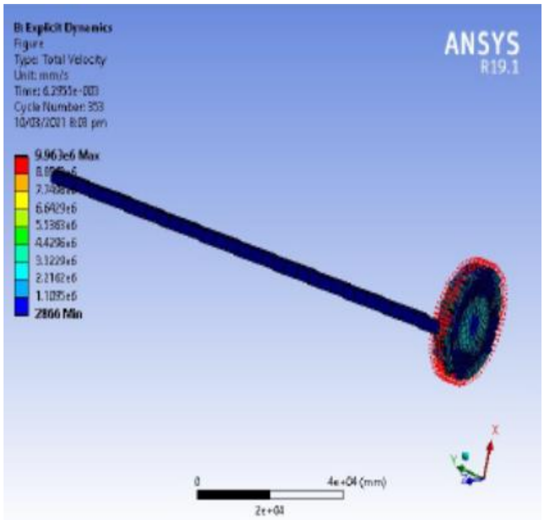


Figure 1 Simulation Results for Validation of Modeling

A. Simulation Results

In this model, the input cutting parameters data were cutting speed at 100 m/min, feed rate at 0.15 mm/rev, depth of cut at 0.3 mm and heating temperature at 30 ^{O}C. Fig. 4.1 shows the results of the model using ANSYS CAD finite element dynamic explicit simulation.

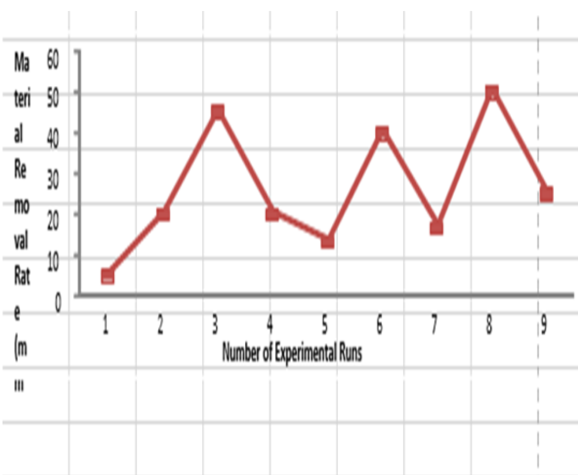


Figure 3: Material Removal Rate at different Experiment Runs

Figure 3 reveals the results of the stress on the work-piece for the nine (9) runs of experiments. The figure showed that the 5th experiment with cutting parameters (speed at 100m/min, feed at 0.10mm/rev. and depth at 0.10mm) on work piece produced the greatest stress while the 8th experiment (speed at 100m/min, feed at 0.10mm/rev. and depth at 0.30mm) produced the lowest stress.

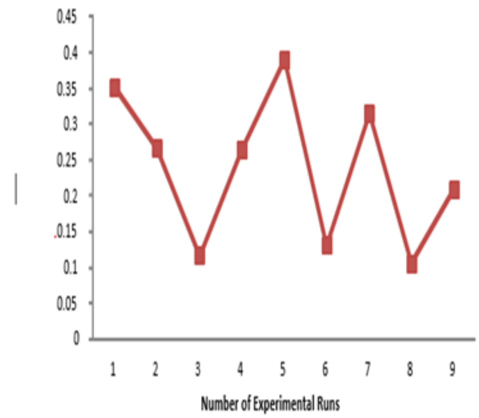


Fig. 4: Stress at different Experiment Runs

Figure .4 reveals the stress results of the materials removal rate of the work-piece for the nine (9) runs of experiments the figure showed that the 5th stress excrement (speed at 80m/min, feed 0.10min/rev, and depth at 0.10mn) produced the greatest materials removal rat while the 2nd run of experiment had the lowest material removal rate with cutting parameters (speed at 60m/min, feed at 0.10mm/rev. and depth at 0.20mm) on work-piece. The shear stress shows a lower maximum and a more uniform distribution across the surface.

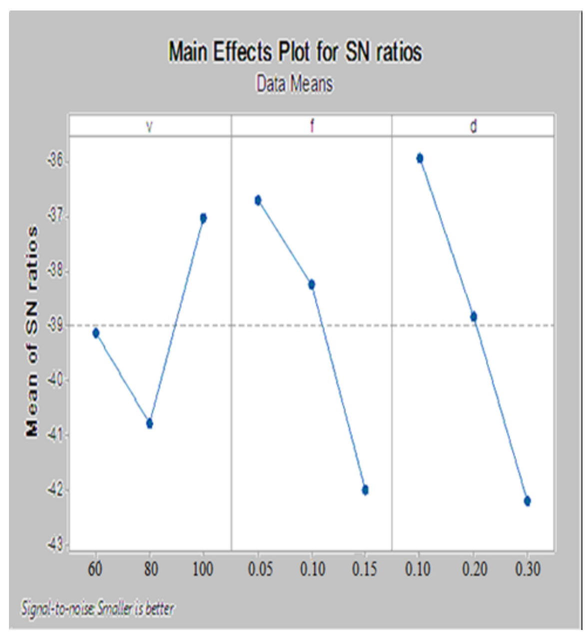


Figure 5: Main Effect Plot of Surface Roughness

Figure 5 depicts the main effect plot for S/N ratio on the surface roughness. Based on the results observed in Figure. 5 the optimal machining parameters that produce minimum value of surface roughness are A3B1C1 i.e. (cutting speed 100m/min, feed rate 0.05 mm/rev and depth of cut 0.10 mm). An increase in the depth of cut lead to increasing surface roughness and the energy (force) required. With the increase in depth of cut chip thickness become significant which causes more material to deform that requires more cutting force to cut the chip (4995.576mm^3/min). Further, if the feed rate increases the section of the sheared chip increases because the metal resists the rupture more and requires larger efforts for chip removal which subsequently increases the surface roughness.

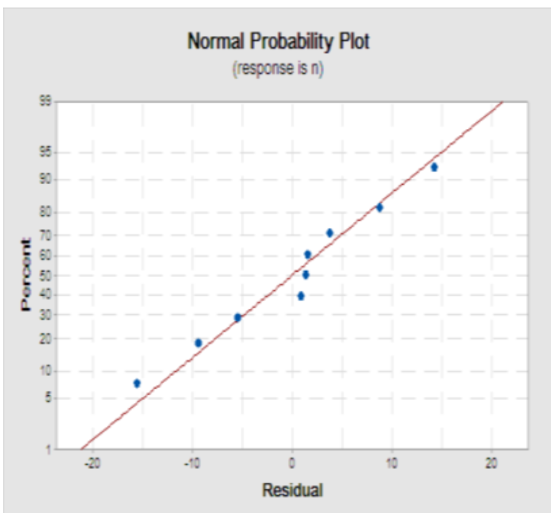


Figure 6 Normal Probability Plot of Cutting Force

Normal probability plot is represented in Figure. 4.6 was obtained to ensure that the data is normally fit distributed. It can be seen from Figure 4.6 that the data points fitted lie on the straight line or are closer to line which validates the normality distribution of the simulate data. The mean S/N ratio at each level of cutting parameters was computed by taking arithmetic mean average of S/N ratio at the selected level. Table 5 shows the mean S/N ratio for all nine models. Table.6 shows the ANOVA results for surface roughness and the contribution of each machining parameters.

Table 5 Response Table of Surface Roughness

Cutting Parameters	Level 1	Level 2	Level 3	Max-Min	Rank
V	248.0	233.7	209.0	39	2
F	221.5	236.5	241.7	20	3
D	210.0	225.3	256.3	46	1

B. Analysis of Variance (ANOVA) for Surface Roughness

The analysis was done using uncoded units, and the result shows that the factors were all significant, with probability factors less than 0.05, as shown in Table 4.6. The table shows the ANOVA results for surface roughness and the contribution of each machining parameters. It is clear from the results of Table 4.6 that the depth of cutis dominant factor affecting surface roughness where its contribution is (44%). The second factors effecting surface roughness is cutting speed where its contribution is (25%). While feed rate has least effect on temperature where its contribution (22%).

Table 6 ANOVA Results for Surface Roughness

Factors	SS	DF	MS	F	P	Contribution % (P)
V	1392	1	1392	15.84	0.015	25%
f	1324.7	1	1324.7	13.92	0.017	24%
d	2410.4	1	2410.4	26.4	0.002	44%
Error	365.6	5	365.6			7%
Total	5492.7	8				100%

CONCLUSION

In this research work, improvement of cutting parameters in lathe turning operation that influences the surface finish quality of an AISI1020 mild steel work piece were modelled and analyzed. The first objectives of this work which was to determine the effect of the cutting speed of the lathe turning operation on the rate of material removal and surface roughness of the AISI1020 mild steel was achieved from the ANSYS computer simulation as presented in Table 4. It revealed that increasing the cutting speed will increase the rate of material removal and surface roughness. For the second objective which was to evaluate the influence of the amount of feed input on the material removal rate and surface roughness of the AISI1020 mild steel was achieved from the ANSYS computer simulation as presented in Table 4. It revealed that increasing the feed rate of the work-piece on the lathe turning machine, will increase the rate of material removal and surface roughness. Similarly, the third objective which was to determine the effect of the depth of cut in the AISI1020 mild steel work-piece on the material removal rate and surface roughness was achieved from the ANSYS computer simulation as presented in Table 4. It revealed that increasing the depth of cut in the work-piece will consequently increase the rate of material removal and surface roughness.

REFERENCES

[1] Abhishek, K., & Ramandeep, S. (2013). Optimization of CNC Process Parameters on Inconel 625 Using Response Surface Methodology. *International Journal of Mechanical Engineering and Technology (IJMET),* 8(7), 1830-1836.

[2] Amit, J. P., & Kothiyal, R. P. (2012). Experimental Investigation of Machining Parameters of CNC Milling on MRR by Taguchi Method. *International Journal of Applied Engineering Research.* 3(11), 112-134.

[3] Deepaganesh, P. (2015) Finite Element Simulation in Orthogonal Machining of Inconel 718 Alloy. *International Journal of Mechanical and Research*, *5*(1), 49-54.

[4] Zouhar, J. & Piska, M. (2017). Modelling the Orthogonal Machining Process using Cutting Tools with Different Geometry. *MM Science Journal*, *5*(12), 48-52.

[5] Vikas, B., Magdum, V., & Naik, R. (2013). Evaluation and Optimization of Machining Parameter for Turning of EN 8 Steel, *International Journal of Engineering Trends and Technology (IJETT) 4*(5), 12-25.

[6] Muhammad, M., Nadeem A. M. & Hassan, I. (2009). Optimization of Surface Finish in Turning Operation by Considering the Machine Tool Vibration using Taguchi Method. *International Research Journal of Engineering and Technology (IRJET)*, *3*(8), 522-532.

[7] Eckart, U., & Danny, S. (2020). Process Behaviour of Micro-Textured CVD Diamond Thick Film Cutting Tools During Turning of Ti-6Al-4V. *International Research Journal of Engineering and Technology (IRJET),* 4(4), 474-483.

[8] Mathews, M., & Nedheesh, E. B. (2014). Modeling and Optimisation of Cutting and Feed Forces in Turning Inconel 718. *International Journal of Engineering Research & Technology (IJERT)*, *3*(10), 276-280.

[9] Khalaf, N., Suha, K., Shihab, A., & Mahmoud, K. (2018). Finite Element Modeling and Optimization of Estimated Cutting Forces during Machining of Inconel 718. *SSRG International Journal of Material Science and Engineering (IJMSE)*, *4*(3), 1-7.

[10] Shrinivas, D., Chilveri, M. E., & Suryavanshi, A. R. (2013). Optimization of Cutting Parameters in Turning Process to Enhance Tool life. *International Engineering Research Journal*, *14*(3), 1185-1189.

[11] Olodu, D. D. (2018). Optimization and Analysis of Cutting Tool Geometrical Parameters using Taguchi Method. *Journal of Applied Science and Environmental Management*, *22*(3), 346-349.