PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 29 (3) 1011-1013 Mar. 2025

Effect of Cutting Speed, Depth of Cut, and Feed Rate on Metal Removal Rate in the Machining of a Cylindrical Mild Steel Bar

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ABSTRACT: Metal cutting, plays a critical role in the manufacturing industry. To ensure sustainable growth in the quality of produced designed and manufactured, certain area of interest such as the cutting parameters, must be fully developed. Hence, the objective of this paper is to evaluate the effect of cutting speed, depth of cut, and feed rate on the metal removal rate in the machining of a cylindrical mild steel bar using appropriate standard method. From the study, a mean and standard deviation of 4.26 and 2.31 respectively is obtained. Data obtained shows that the metal removal rate obtained revealed sharp variation as a result of the influence of the cutting parameters. The feed rate revealed the most variation in its effect on the metal removal rate, as it was observed that the rate of removal increased greatly and progressively as the feed rate increased. However, a decline was observed, which is attributable to the wear of the cutting tool.

DOI: DOI: https://dx.doi.org/10.4314/jasem.v29i3.40

Cite this Article as: UCHEONWU, P. H. H; SADA, S. O; ENYI, L. C; SINEBE, J. E; EKPU, M (2025) Effect of Cutting Speed, Depth of Cut, and Feed Rate on Metal Removal Rate in the Machining of a Cylindrical Mild Steel Bar. *J. Appl. Sci. Environ. Manage.* 29 (3) 1011-1013

Dates: Received: 20 February 2025; Revised: 17 March 2025; Accepted: 24 March 2025; Published: 31 March 2025

Keywords: Mild Steel Bar; Machining; Metal Removal Rate; Cutting Speed; Depth of Cut

A strong manufacturing economy is driven by the quest to maintain the production of high quality and economically affordable products, with continuous improvement on the manufacturing processes (Gopalakannan and Senthilvelan, 2014). With approximately one third of engineering components and manufactured goods attributed to the industry (Gopalakannan and Senthilvelan, 2014), manufacturing processes must be accorded greater focus, as they account for the list of top technologies employed in manufacturing industries. Unfortunately, major challenges for the manufacturing processes are production of parts, with unsatisfactory surfaces quality (Kant and Sangwan, 2015). Among the several widely adopted manufacturing processes, the machining process commonly referred to as metal removal operation, are widely used in manufacturing operations, and have been critical in the development of the global economy through the application of the different machining processes, such as turning, drilling, grinding and milling (Sada, 2018).

With the increase in technologically driven machining processes, the desire to achieve machining accuracy has witnessed tremendous increase over the years, with manufacturers now desirous of applying the right cutting parameters with the most significant effect on the cutting processes (Onifade *et al.*, 2017). The selection of the appropriate machining parameters, along with their optimal values is necessary, to obtain certified standard products. As there are several variables that can be manipulated to

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affect the output of the process, hence it is considered as a multi-input, multi-output process.

Gupta and Kumar, (2015), proposes that the process parameters that affect the quality of the turned parts, can be identified by an Ishikawa cause effect diagram. It depicts that the following process parameters; Cutting parameters, Tool parameters, Environment parameters, and Work piece material, may affect the quality of the turned parts. However, Ojolo and Ogunkomaiya, (2014) reports that to understand the machining processes completely, an analysis of machining processes and the effect of the parameters must be studied to determine, how the machining output is influenced by various input parameters. Thus the objective of this paper is to evaluate the effect of cutting speed, depth of cut, and feed rate on the metal removal rate, in the machining of a cylindrical mild steel bar.

MATERIALS AND METHOD

The experiments were carried out using a lathe machine, along with a High Speed Steel (HSS) with 25° rake angle. Workpieces used were mild steel, of 50mm diameters and 200mm lengths. The lathe was set up for cylindrical turning with the high speed steel tool clamped to the tool post and the mild steel work piece fixed and held with the 3 jaw chuck. For machining cutting condition generally, a range of selected significant cutting parameters is selected from literature (Sada, 2020).

The cutting parameters range are; speed of spindle (120 - 220m/min), feed rate (0.10 - 0.24mm/rev), and depth of cut (1 - 2.5mm). The experiment is designed to be performed for the different experimental runs, using the soluble oil cutting fluid having 20% concentration in water, and 80 % Mineral oil. At the end of the experiment, the metal removal rate MMR is measured and recorded.

For each trial of the experiment, the various cutting speeds were inputted in RPM because the spindle speed selector of the lathe is rated in RPM. Equation 1 was used to convert the cutting speeds to RPM.

$$N = \frac{v \times 1000}{\pi \times D} \qquad (1)$$

Where N is the RPM, V is the cutting speed in m/min and D is the diameter of the workpiece in meters.

Metal Removal Rate (MRR): The metal removal rate measure the rate at which an amount of material is removed from the workpiece in a period of time, as the cutting processes progresses. It is measured cubic centimeters per minute (cm^3/min) and calculated using Equation 2.

$$MRR = \frac{Wb - Wa}{t * \rho} \qquad (2)$$

Where: Wb = Weight of the work piece before machining; Wa = Weight of the work piece after machining; t = Machining time; ρ = density of the work material (Kg/m^3)

RESULTS AND DISCUSSION

The results from experiment performed at the workshop and the corresponding analysis is presented in Table 1, for Cutting Speed (m/min), Depth of Cut (mm), and Feed Rate (mm/rev), Metal Removal Rate (cm^3/min) respectively. To evaluate the effects of the cutting parameters on the metal removal rate, a graph is plotted of each of the cutting parameters individually against the response as shown in Figure 1 – 3.

Table 1: Results of Machining Experiment using the Selected Cutting Tools

Exp. Run	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Metal Removal Rate (cm^3/min)
1	1150	0.3	2.0	5.41
2	900	0.2	0.4	4.31
3	900	0.4	1.6	3.34
4	750	0.3	1.0	3.31
5	1150	0.3	1.0	4.34
6	1400	0.3	1.0	4.36
7	900	0.4	1.6	5.21
8	1150	0.2	1.0	4.29
9	900	0.2	1.6	3.31
10	1150	0.3	1.0	3.31
11	1400	0.2	0.4	4.32
12	1150	0.3	1.0	3.31
13	1400	0.3	1.0	5.32
14	1150	0.3	1.0	4.33
15	1150	0.4	1.0	4.32
16	900	0.4	0.4	5.31
17	1150	0.3	1.6	3.32
18	1150	0.3	1.0	4.32
19	1400	0.4	0.4	4.32
20	1400	0.2	1.6	5.21
Mean				4.264
SD				2.31

SD = Standard deviation

The plot of the three cutting parameters all show effect of variations on the response as the parameter is altered with a set range of values. The level of their effect follows in the following order; feed rate, cutting speed, and lastly the depth of cut, which has the least effect on the response. The increase in the response, as witnessed in the plot of the feed rate against the response reflects how the rate of removal can increase with a deeper cut and can also begin to decline as the cutting tool begins to wear out (Sada, 2018). However, for the depth of cut, the variation is maintained at a controlled level to prevent heat generation, corresponding tool wear often experienced.

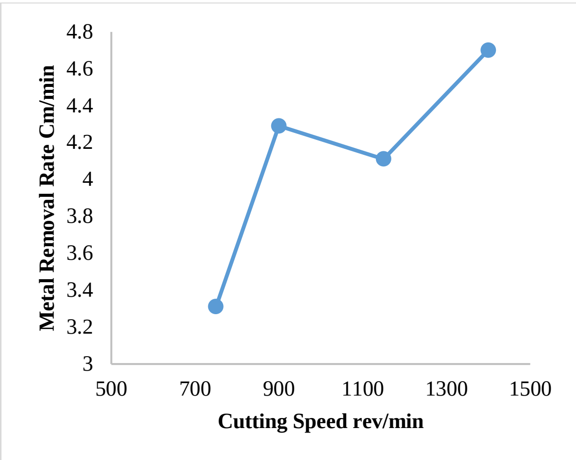

Fig 1: Plot of Cutting Speed versus Metal Removal Rate

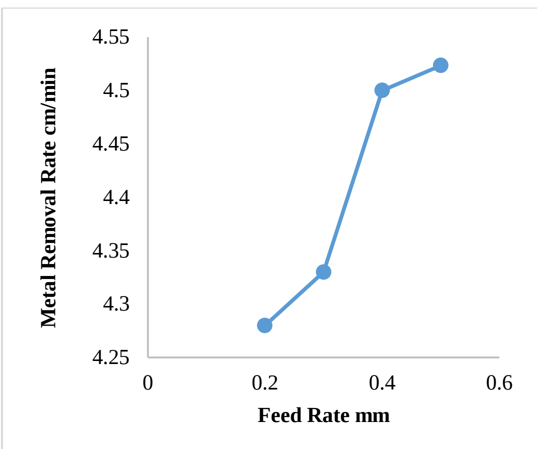

Fig 2: Plot of Feed Rate Speed versus Metal Removal Rate

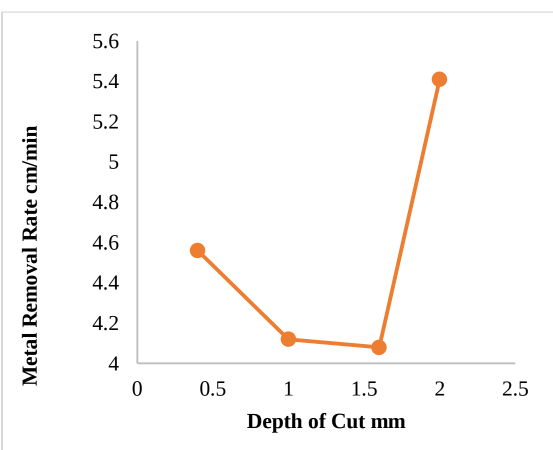

Fig 3: Plot of Depth of Cut versus Metal Removal Rate

Conclusion: The study of the effect of machining parameters on the metal removal rate was successfully carried using a mild steel cylindrical bar, with cutting speed, feed rate and depth of cut as input parameters. From the study, results of the metal removal rate obtained revealed sharp variation as a result of the influence of the cutting parameters. The feed rate revealed the most variation in its effect on the metal removal rate, as it was observed that the rate of removal increased greatly and progressively as the feed rate increased. However, a decline was observed, which is attributable to the wear of the cutting tool.

Declaration of Conflict of Interest: The authors declare no conflict of interest (if none).

Data Availability Statement: Data are available upon request from the first author or corresponding author or any of the other authors.

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