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Effect of Different Turning Parameters on Surface Roughness

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Abstract - *The surface roughness of a machined item plays an important part in the current production process due to the growing need for higher quality components. To satisfy the rising demands, manufacturers have been obliged to produce exceedingly fine surfaces as a result of recent developments in the manufacturing industry. The quality of the turned surface has a major impact on its performance, since a good quality turned surface increases several physical attributes such as fatigue strength, corrosion resistance, and creep life. Turning is a technique for achieving a desired surface that is utilized all over the world. Several criteria are taken into account in order to achieve the desired surface finish. This study investigates the effect of cutting factors in the turning process, such as feed rate, cutting tool nose radius, cutting speed, spindle speed, and depth of cut, on average surface roughness (Ra). In industries, average surface roughness (Ra) has long been employed as a reliable measure for determining a surface's functioning. Cutting settings have a substantial impact on surface quality, according to the research. The combined influence of these cutting settings on roughness is also discussed in the article. As the feed rate or depth of cut increases, the surface roughness increases, but as the cutting speed or spindle speed increases, the roughness decreases, resulting in a smooth surface finish.*

***Key Words*:** Surface roughness, feed rate, nose radius, machining parameter, Turning Process.

1. Introduction

Surface roughness, also known as roughness, is a measurable parameter that can be used to assess the machining process' quality. It's a useful tool for describing how a material will behave in the real world when interacting with the environment in which the component is housed, or the device operates. In the manufacturing and forming sectors, it serves as an acceptance criterion. The finish of a mechanical part's surface is considered a critical component in its performance and wear. Its relevance has grown significantly in recent years as manufacturing precision has improved. The frictional resistance, fatigue strength, and creep life of machined components are all influenced by surface roughness. As a result, a superior surface quality is essential since it lowers the need for further machining.

The machining used to develop the product determines the surface polish. Machining to a certain limit causes the cutting tools to shatter owing to the production of a built-up edge. This built-up edge or built-up layer formation also leads to deterioration of surface texture. Hence extensive study to find the optimized machining parameter is carried out. Roughness of a surface depends on many parameters such as the composition of the material, hardness of the material; machining parameters like the feed rate, cutting speed, tool geometry etc. which affect the surface roughness.

The most popular single point tool machining method for producing round components is turning. To generate complicated rotating forms, the tool is fed either linearly in a direction parallel or perpendicular to the work-axis piece's of rotation, or along a predetermined route. The rotation of the workpiece is the primary cutting action in turning, while the feed motion is the secondary cutting motion. Variations in these movements cause the workpiece's surface roughness to vary.

The purpose of this study is to see how major turning process variables like speed, feed, and depth of cut impact surface roughness for a certain material and tool combination under a specific set of machining conditions.

2. Literature review

Surface roughness has traditionally been one of the most essential factors in determining a surface's quality. Various studies have been conducted by a number of academics in attempt to develop an adequate approach for measuring and estimating surface roughness. In addition to these studies, numerous scholars have carried out a series of tests to determine the factors that influence surface roughness during machining. Shaw [1] emphasised the need of analysing cutting forces in turning operations. Ozel and Karpat [2] employed a Cubic Boron Nitride (CBN) tool for finish hard turning and observed that cutting factors such as feed rate, cutting speed, depth of cut, tool geometry, and tool material properties all had an impact on the machined component's surface quality. In a range of cutting conditions, they employed an artificial neural network to anticipate surface roughness and tool flank wear over time. Dhanlakshmi [3] investigated surface roughness as a function of speed (mm/min) and feed (mm/rev), determining that the surface finish of any given component may be quantified in terms of the average heights and depths of peaks and valleys on the work piece's surface. Feng and Wang [4] created an empirical model for predicting surface roughness in finish turning that included workpiece hardness (material), feed, cutting tool point angle, depth of cut, spindle speed, and cutting time. Additional testing validated the models' predictions of surface roughness levels, which were compared to those predicted by other representative models. Many experiments [5, 6, 7] were conducted to see how tool speed, feed rate, and depth of cut affected the steel surface. The influence of tool speed, depth of cut, and work-piece hardness on the surface roughness of plain carbon steel was examined by Bhattacharya et al. [8]. Miller et al. [9] studied the surface of cast iron alloy and the influence of speed, feed, tool condition, and cutting fluid. As a result, measuring surface roughness is difficult since it is impacted by a range of process factors such as tool speed, feed, and depth of cut for various tool and work material combinations.

According to the findings of the study, there is a paucity of empirical relationships between surface roughness and operational parameters such as speed, feed, and depth of cut.

3. Parametric Effect on Surface Roughness

Experimental data from the literature has been collated, evaluated, and efforts to establish a generalised correlation have been undertaken.

Montgomery identified a relationship between roughness and other machine parameters including feed rate, cutting speed, cut depth, and machining time in his study. He claimed that the following parameters may be used to mathematically define the roughness of a surface:

$$Ra = 2.374347 - 0.003339\ v + 16.07332\ f - 5.205469\ d - 0.02125\ t + 0.000000231481\ v^2 + 14.40972222\ f^2 + 3.430555556\ d^2 + 0.00128472\ t^2 - 0.01212963\ vf + 0.00277778\ vd + 0.00000694444\ vt - 14.4140625\ f\,d + 0.15625\ f\,t + 0.023958333\ d \quad (1)$$

where cutting speed(v) is measured in metres per min. feed rate(f) is measured in millimetres per revolution, depth of cut(d) is measured in millimetres, machining time(t) is measure d in minutes, and average surface roughness (Ra) is measured i n microns.

3.1 Effect of feed rate

The most essential aspect in the production of surface roughness is the feed rate. The roughness profile is influenced by the feed rate, as seen in Figure 1. The roughness increases as the feed rate rises. The feed markings on the roughness profile become more obvious as the feed rate increases. When the feed rate is sufficiently lowered, the roughness is no longer impacted and is solely reliant on the nose radius. As a result of the superimposed flaws over the grooves formed by chip removal, the micro roughness rises. When the feed rate is high and the nose radius is small, the surface roughness is determined by the feed rate rather than the nose radius. At low feed rates and with a greater height, plastic flow is in the opposite direction of the feed, which may result in increased roughness. Figure 1 shows how feed rate affects surface roughness and how ploughing motion creates many harmonics at lower feed rates. When the feed rate is increased, micro roughness decreases, and significant periodicity is observed with diminishing harmonics, eventually reducing to a single harmonic. This shows that at high feed rate the dominant mechanism is of chip removal.

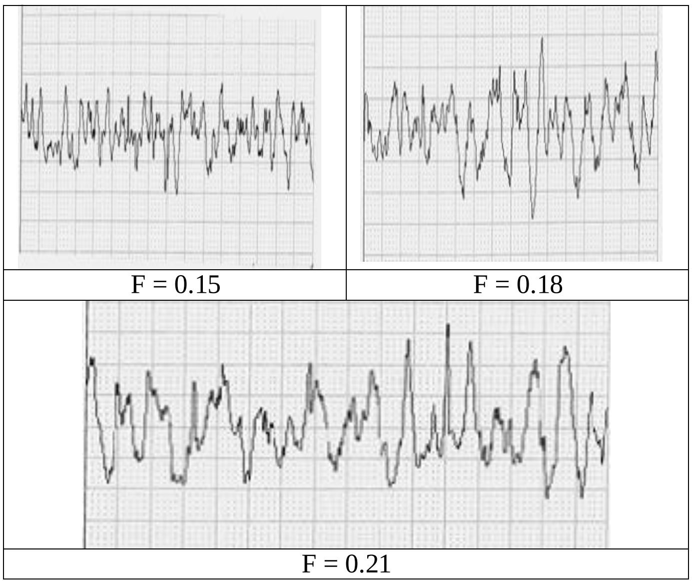

Figure 1 Typical roughness profile at different feed rate

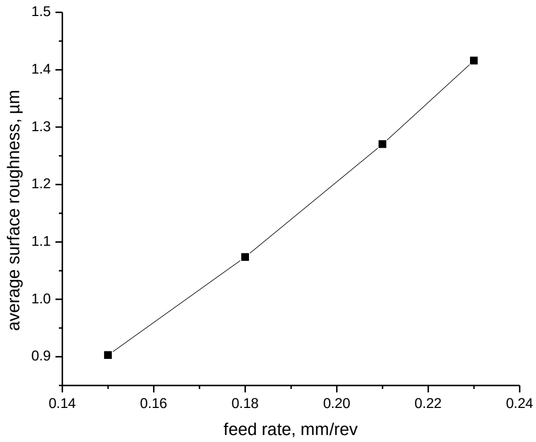

Figure 2. Variation between feed rate and surface roughness.

Figure 1 shows a graph of average roughness vs. feed rate. It shows that when the feed rate rises, the average surface roughness rises as well. Material is ploughed instead of moulded into chips at quicker feed rates, resulting in discontinuous chips deposited between the workpiece and the tool, resulting in a greater coefficient of friction and more interruption, resulting in poor surface quality.

3.2. Effect of tool nose radius

The tool's nose radius has a considerable impact on surface roughness. The average surface roughness reduces when the nose radius is raised, resulting in improved surface quality. The surface roughness rises when the nose radius is reduced. The influence of cutting tool shape and processing factors on the surface roughness of AISI 1030 steel was investigated by Hassan Gokkaya et al [14]. They investigated the impact of nose radius on surface roughness in this study. The tool with the biggest nose radius generated the best surface quality, whereas the tool with the smallest produced the lowest.

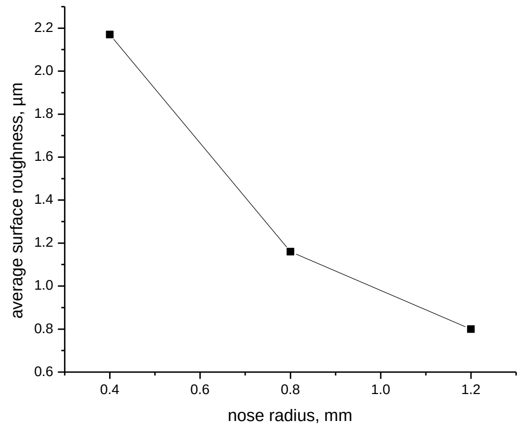

Figure 3. Variation of nose radius and average surface roughness at constant feed and depth of cut

The change in surface roughness as a function of nose radius is seen in Figure 3. It's obvious that the surface roughness diminishes as the nose radius increases. This is because a smaller tool nose radius results in a bigger uncut chip thickness, which requires more work to manufacture and leads to increased surface roughness.

3.3. Effect of cutting speed

The surface roughness decreases as the cutting speed is increased while the other parameters (feed rate and depth of cut) remain constant, implying that the surface quality improves as the cutting speed is increased. There have been numerous studies conducted to determine the effect of cutting speed on surface roughness. As a result, feed rate has a significant impact on surface roughness, whereas cutting speed has a negative impact, i.e. roughness decreases as cutting speed increases.

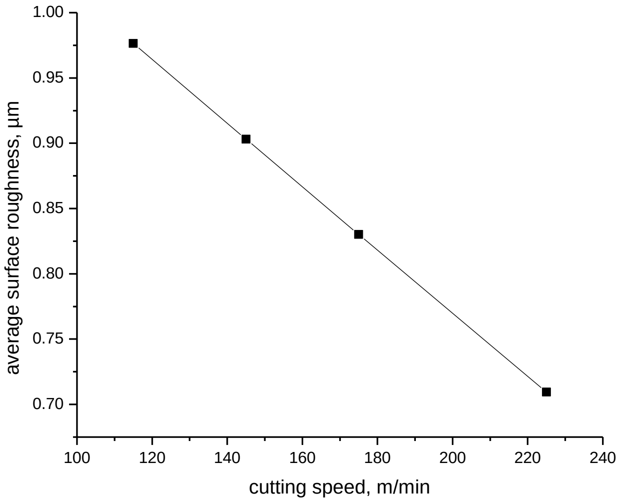

Figure 4. Variation in cutting speed with average surface roughness

3.4. Effect of spindle speed

The rotational speed of the work piece is referred to as spindle speed. The roughness of a surface is affected by the spindle speed. The surface roughness of the material is decreased when the spindle speed is raised. Because of the formation of discontinuous chips deposited at the workpiece and tool contact at low spindle speeds, friction between the workpiece and the cutting tool is high. Interruptions during cutting processes, needless effort in machining, additional energy, high temperature (heat), and poor surface quality are all caused by high friction at the tool-chip and workpiece-tool interfaces. As the spindle speed rises, the coefficient of friction between the workpiece and tool interface decreases, and chips continue to form, resulting in less contact between the workpiece and tool interface, resulting in a lower coefficient of friction and improved surface quality.

3.5. Effect of depth of cut

The surface roughness varies dramatically depending on the cut depth. The average surface roughness rises as the depth of cut increases. This is because uneven chips occur when the depth of cut is raised at a constant cutting speed and feed rate. Plowing the material instead of shaving it away produces irregular chips with a higher surface roughness grade. Furthermore, when the depth of cut grows, the system's vibrations increase, resulting in increased roughness.

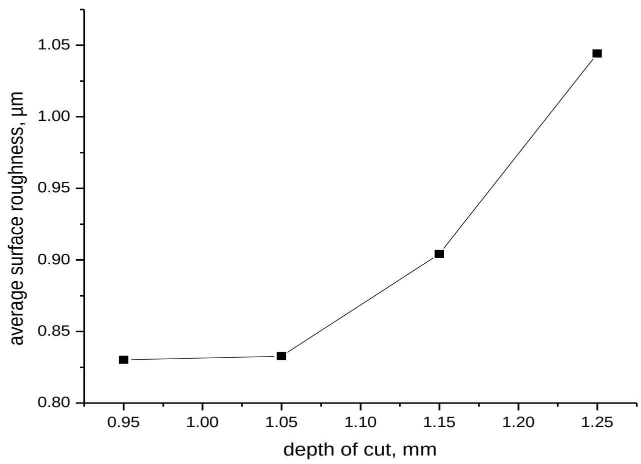

Figure 5. Variation of average surface roughness and depth of cut

Figure 4 indicates that the surface roughness rises as the depth of cut increases. Surface roughness is predicted to rise when the width of contact between the material and the cutting tool expands, producing friction between the workpiece and the tool and halting the cutting process. Cutting with more power and energy will result in a lower-quality surface.

4. The combined effect of the parameters

Figure 6 shows the combined influence of cutting speed and feed rate on surface roughness. The surface roughness rises as the cutting speed and feed rate increase. This is due to the fact that as the cutting speed and feed rise, wear from the workpiece to the tool propagates, resulting in a poor surface quality and increased roughness.

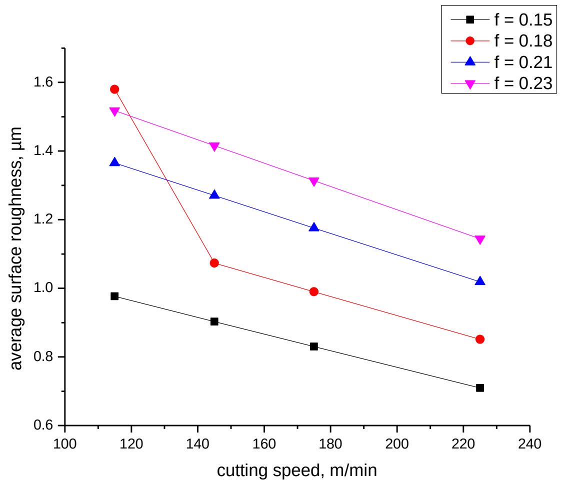

Figure 6. Variation of average surface roughness and cutting speed at constant depth of cut.

The average surface roughness increases as the depth of cut develops in lockstep with the cutting speed. Surface roughness changes extremely little with depth of cut, as seen in the graph, implying that a little change in depth of cut results in a very slight change in surface roughness.

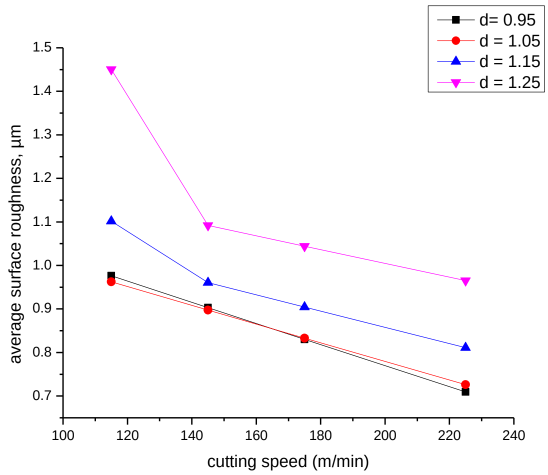

Figure 7. Variation of average surface roughness and cutting speed at constant feed rate

When feed rate and cut depth are combined, the result is completely different. Surface roughness increases as the depth of cut grows at a lower feed rate, but the surface smooths out and the roughness reduces as the feed rate and depth of cut increase.

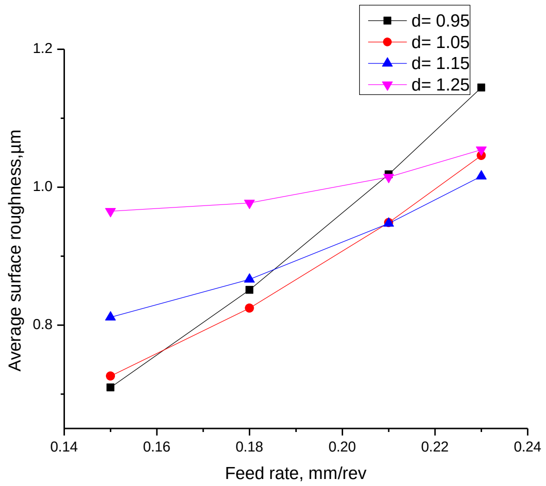

Figure 8 Variation of average surface roughness and feed rate at constant cutting speed of 225 m/min.

5. Conclusions

The following key findings may be taken from the current investigation based on the foregoing discussion:

- Surface roughness rises dramatically as the feed rate increases.
- A superior surface finish is produced by increasing the nose radius.
- Surface roughness is inversely related to cutting speed.
- As the spindle speed increases, the surface roughness lowers; as the depth of cut increases, the surface roughness increases.

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