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Investigation of Effects of Feed Rate and Cutting-Edge Angle Variation on Surface Roughness in External Cylindrical Turning Process of Ms58 Brass Material

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Abstract: The Ms58 brass material was machined dry by the lathe's external cylindrical surface turning method. Three different feeds (0.155, 0.088, and 0.028 mm/rev), 3 different cutting-edge angles (70°, 80°, and 90°), and three-spindle speeds (480, 630, and 1250 rpm) were used in machining experiments. The depth of the cut value was taken as a 0.5 mm constant. The effects of these different parameters on surface roughness values were investigated. For each surface roughness value measured from parts machined with other parameters, measurements were made five times, the largest and smallest values were discarded, and the average of the remaining 3 values was taken. This rigorous process of data collection ensured the reliability of the results. Graphs were prepared and examined with working parameters and surface roughness values. As a result, it was determined that the surface roughness value decreased with the decrease in feed and the increase in another parameter, the "cutting-edge angle" of the tool. When external cylindrical surface turning was performed with the experimental parameters of 480 rpm, a large cutting-edge angle of 90°, and a depth of cut of 0.5 mm within this study plan, the lowest average surface roughness was obtained as 1.228 µm.

Keywords: surface roughness; Ms58; brass; turning

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1. Introduction

Brass is a commonly used material for manufacturing various machine parts. These parts typically undergo a series of operations to become finished products, and the specific steps can vary significantly depending on the manufacturing method used. The choice of method can significantly influence the surface quality of the material.

A model predicts surface roughness by analyzing cutting speed, feed, and depth of cut. Research indicates that surface roughness (Ra), depth of cut, and feed parameters are positively influenced by an increase in corner radius (Işık & Çakır, 2001 [1]). Furthermore, CNC turning and cylindrical grinding processes were performed on AISI 4340 steel subjected to various heat treatments. The results indicated that surface quality deteriorated with specific feeds and depth of cut values. It is important to note that the study was limited to a specific range of feeds and depth of cut values, and further research is needed to explore the effects of a wider range of these parameters. It was also observed that surface roughness continued to increase with an increase in the number of revolutions (Çaydaş & Hasçalık, 2005 [2]). Another study aimed to achieve optimal surface roughness while machining AISI 304 austenitic stainless steel on a CNC lathe. This study adopted a comprehensive approach, ensuring that all relevant factors were considered, and concluded that while increasing cutting speed positively influenced surface roughness, raising the feed had a negative effect (Tekaslan et al., 2008 [3]). The effects of feed and cutting speed on surface roughness and cutting forces were examined experimentally while machining AISI 01 cold work tool steel. Experiments were conducted with a constant depth of cut of 1 mm, utilizing four different feeds (0.05, 0.1, 0.15, and 0.20 mm/rev) and 7 different cutting speeds (120, 160, 200, 240, 280, 320, and 360 m/min). The lowest surface roughness value was observed at 280 m/min cutting speed across all feeds (Zeyveli, Demir, 2009 [4]). The effects of feed and cutting speed on surface roughness in the machining of AISI 1040 steel were investigated. The experiments were carried out by dry turning at 2 mm cutting depth, different cutting speeds (46, 91, and 128 m/min), and feed values (0.16, 0.22, and 0.28 mm/rev). Uncoated carbide cutting tools were used in the machining. The findings of this research have practical implications, as it was observed that the surface quality deteriorated with the increase in feed and improved with the increase in cutting speed. As a result, it was seen that 2 mm cutting depth, 128 m/min cutting speed, and 0.16 mm/rev feed value were the most suitable values for surface roughness (Kavak, 2012 [5]). As a result of the analysis of the relationships between the material properties and forming limits of the M85 brass sheet, it was shown that the value of the homogeneity coefficients changed with increasing strain, and the value of the limit strains strictly depended on the values of the inhomogeneity coefficients and grain size (Stachowicz, 2016 [6]). In one study, the effects of tool coating and material on the machinability of low-lead brass alloys were investigated in an external surface turning operation. The tools were coated with carbides and polycrystalline diamond (PCD), and the workpiece materials were CuZn38As, CuZn42, and CuZn21Si3P. CuZn38As material showed the worst machinability regarding machining forces, chip formation, and workpiece quality. In tool life tests, PCD showed higher performance than coated carbide tools (Klocke et al., 2016 [7]). AISI D2 cold work steel was subjected to three different heat treatments and was machined on vertical CNC to investigate surface roughness and tool wear. The experiments were conducted by machining at different cutting speeds and feeds, with a constant cutting depth (0.5 mm) and dry-cutting conditions. The best and worst surface roughness values were measured (Şirin et al., 2012 [8]). GGG50 cast material was machined dry using four different cutting speeds (50, 75, 100, and 125 m/min), 4 different feed rates (0.1, 0.2, 0.3, and 0.4 m/min), and four different depths of cut (1, 1.5, 2, and 2.5 mm). The effects of these different parameters on surface roughness, vibration, and sound intensity were examined. It was determined that surface roughness, vibration, and sound intensity values increased with the feed value (Şahinoğlu et al., 2017 [9]). In a study, the parameters to minimize roughness in a brass workpiece are tool, depth of cut, cutting speed, and feed. The optimum parameters were investigated using response surface methodology (RSM). It was found that the process parameters can be obtained at a moderate level during the drilling process. (Mogaji & Famurewa, 2017 [10]). In one study, the processed material is Ms58 brass; the tool is cubic boron nitride (CBN), and the process is high-speed turning. In the study, the spindle speed, depth of cut, feed rate, and pressure are cold, dry-cutting Taguchi parameters. For optimum roughness in brass, the cutting conditions were determined as spindle speed 790 rpm, feed rate 0.0034 mm/min, depth of cut 1.5 mm, and pressure 50 Psi (Sugiarto, et al., 2018 [11]). In one study, dry cutting was performed using martensitic stainless steel. Factors such as fatigue, corrosion resistance, and wear performance were negatively affected by machining. For this reason, to minimize it, surface roughness was examined with different cutting speeds, feed values, and 0.6 mm constant cutting depth parameters, and the findings were compared (Güneşsu, Kaynak, 2019 [12]). The experiments were conducted using a [specific type of equipment] under controlled conditions. Cutting tool wear and surface roughness were investigated by milling GGG70 nodular cast iron material. Experiments were carried out using three different feed values (0.1, 0.15, and 0.2 mm/tooth) and 4 different cutting speeds (150, 200, 250, and 300 m/min) at a constant cutting depth (0.5 mm), and appropriate milling parameters were determined. As a result, the surface roughness increased with the increase in the feed value. The amount of wear on the cutting tool increased with the cutting speed (Kaçal et al., 2019 [13]). A study investigated the burnishing processes of holes drilled in Ms58 materials. It was determined that the surface roughness of the Ms58 material decreased by 89.6% after the process. A 20% increase in hardness was achieved with plastic deformation in the crushed region of the Ms58 material (Koçak, 2020 [14]). In addition, a comprehensive turning study was conducted on AISI 1050 steel, examining cutting parameters such as cutting speed, feed rate, and depth of cut at three different levels. Mathematical models and equations were developed to show the relationships between these parameters and surface roughness. The study also investigated the effect of cutting parameters on chip formation and geometry, providing a comprehensive understanding of the turning process (Yılmaz, Güllü, 2020 [15]). An Ms58 brass alloy was also studied using a C-axis lathe and end mill to produce hexagonal parts. The researchers demonstrated the precision of their work by developing distinct regression equations for surface roughness, cutting time, and dimensional deviation. By determining the optimum combination of processing parameters, they verified the accuracy and reliability of their results (Seçgin, 2021 [16]). This study investigated the drilling process of hot-forged, lead-free brass alloys with a form-cutting tool by artificial neural network modeling and genetic algorithm-based optimization methods. By obtaining optimum processing conditions, it was determined that the efficiency of the process could be increased by reducing production costs (Zohghipour et al., 2021 [17]). The study included constructing a water flow system to capture cavitation flow experimentally. Wear tests were conducted on red copper, brass, pure aluminum, and an aluminum alloy. The salient finding was that brass, with its high yield strength and good mechanical properties, exhibited the least cavitation wear. This discovery contributes to our understanding of material properties and inspires potential applications in industries where cavitation wear is a concern (He, Liu et al., 2022 [18]). In this study, CW724R lead-free brass material was machined using a carbide tip on a CNC lathe under dry conditions. The investigation of three different feeds, cutting speeds, and depths of cut to assess their impact on the surface roughness of the processed brass presents opportunities for optimization. The results indicated that the feed was crucial in determining surface roughness, with the lowest surface roughness value achieved at a cutting speed of 181 m/min, a depth of cut of 0.025 mm, and a feed of 0.08 mm/rev (Çakmak, Akyüz, 2022 [19]). The study investigated the practical implications of surface roughness of fine brass wire. After subjecting a wire with a diameter of 140–200 microns to two dieless drawing processes and incremental dieless drawing, it was found that the latter resulted in higher productivity and lower surface roughness. This finding informs our understanding of the wire drawing process and inspires potential improvements in wire production (Milenin, Wröbel, et al., 2022 [20]). In this study, Al 6061 aluminum alloy material was turned. In the experiment, a 0.2 mm/rev constant feed value, two cutting speeds (125 and 250 m/min), and 4 cutting depth values (0.4, 0.8, 1.6, and 2.4 mm) were the working parameters. As a result of the experiment, the lowest surface roughness value was determined as an Ra value of 0.5 µm at a 250 m/min cutting speed with a coded cutting tool. It was determined that the surface roughness values decreased with the decrease in cutting depth. The highest surface roughness value was 1.07 µm (0.4 mm cutting depth and 125 m/min cutting speed). When all cutting parameters and tools were compared, the highest surface roughness value was 7.22 µm at a 2.4 mm cutting depth with a TNMG-coded tool (Pul, Özerkan, 2022 [21]).

Research indicates that surface roughness measurements are commonly performed using materials such as steels, cast irons, aluminum alloys, and brass, considering various chip removal parameters as variables. The experimental designs employed in these studies suggest that optimal surface roughness can be achieved by determining the best chip removal conditions. Key parameters impacting chip removal typically include feed, feed rate, cutting speed, spindle speed, depth of cut, tool tip radius, and the amount of material removed. These studies reveal that the feed parameter significantly affects surface roughness, often showing that a decrease in feed leads to reduced surface roughness. Furthermore, increasing the cutting speed and decreasing the depth of the cut tends to improve surface roughness. However, only some studies focus specifically on Ms58 brass material, aside from those referenced as CW724R and CW509L.

The results of literature reviews and industrial applications indicate that the surface quality of brass materials, regardless of the production method used, is crucial in practice. This study experimentally investigates the surface quality of Ms58 brass material during the turning process of external cylindrical surfaces, focusing on variations in feed rate and cutting-edge angles. Given the limited research available on Ms58 material, the findings of this study will also add valuable contributions to the existing literature.

2. Materials and Methods

Brass is an alloy created by combining copper and zinc in different proportions. It is well-known for its strength and resistance to corrosion. The internal structure and mechanical properties of brass can vary depending on the ratio of zinc to copper. This versatile alloy is widely used in engineering and may contain additional alloying elements beyond copper and zinc. Elements such as nickel, manganese, iron, tin, or silicon can be added to enhance its mechanical properties. When these additional elements are incorporated, the resulting alloy is referred to as "unique brass," which exhibits high tensile strength. One of the critical advantages of brass is its ease of soldering, making it an efficient material for various applications. Its ability to be shaped using hot and cold processes further increases its usability, allowing for hot forging, pressing, and deep drawing. This versatility is a significant reason for its widespread application in shipbuilding, underwater metal detectors, various marine uses, and numerous industrial settings. A chemical analysis of Ms58 brass is provided in Table 1 below.

Table 1. Chemical analysis of Ms58 material (%).

Cu	Fe	Pb	Ni	Sn	Al	Zn
58	0.4–0.6	2.4–2.6	0.5–0.6	0.4–0.5	0.1–0.2	Remaining

The Emco-Maximat Mentor 10 turning-milling machine, the precision tool at the heart of this experimental study, is depicted in Figure 1. With its two-spindle speed stages, this machine operates with a three-phase electric motor. The first stage, running at 0.52 kW, 1.85 A, and 1300 rpm, is complemented by the second stage, which operates at 0.81 kW, 2.1 A, and 2700 rpm. It offers eight-spindle speed settings, with four spindle speeds in each stage, and supports 24 feeds, ensuring the utmost precision in our experiments. The experiments used freshly sharpened high-speed steel (HSS) tool material with square cross-sections (10 mm × 10 mm × 120 mm). The tool was prepared on the tool grinding machine. Their cutting-edge angle was 90°, with 12° of side cutting-edge angle, 3° of inclination angle, and 6° of clearance angle. The study employed the 'external cylindrical surface turning' method, a common machining technique under dry conditions. This method involves the rotation of a cylindrical workpiece while a cutting tool moves parallel to the axis of the workpiece, resulting in a cylindrical surface.

Figure 1. Emco-Maximat Mentor 10 turning-milling machine utilized in this study.

The lathe counter with the experiments has specific cycle settings. The feed numbers were selected from the values in the existing machine as the smallest feed value, followed by a medium and a large value; in total, there were three values with equal increments. The reason for selecting the smallest initial value is that, according to the literature information, surface roughness decreases at small feeds. Three distinct feeds (0.155, 0.28, and 0.88 mm/rev) and 3 cutting-edge angles (90°, 80°, and 70°) were applied while processing the prepared brass materials, as illustrated in Figure 2a–c. The cutting-edge angle of the tool in machining was adjusted by rotating the tool relative to the workpiece axis according to the angles in the experimental design. The recommended cutting speed values for machining were generally chosen as an average value (630 rpm) according to the tool and part material. The other two-spindle speeds were selected as smaller (480 rpm) and larger (1250 rpm) than the average spindle speed value. The increase between the spindle speed values was different.

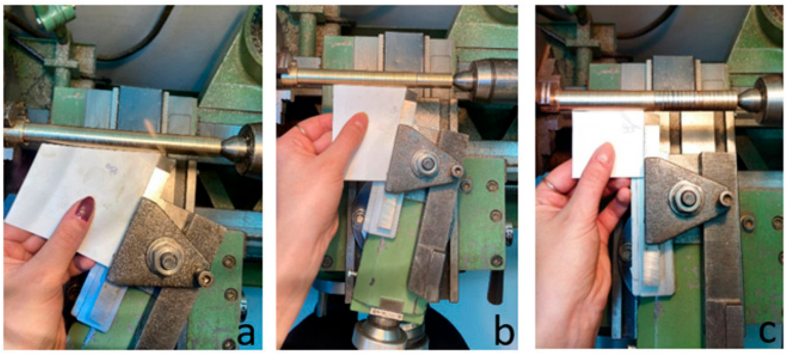

Figure 2. Cutting-edge angle values are (**a**) 70°, (**b**) 80°, and (**c**) 90°.

The test samples had a diameter of 14.75 mm and a length of 276.37 mm. Initially, the samples were machined to the desired diameter using a rough pass, followed by a lathe operation with a fixed depth of cut value of 0.5 mm (see Figure 3a) to prepare them for measuring surface roughness. Surface roughness, a key parameter in our study, was meticulously measured using a Mahr (Goettingen, Germany) brand MarSurf PS1 surface roughness measuring device, as shown in Figure 3b. To ensure the utmost accuracy, at least five measurements were taken for each sample, and outliers—specifically the highest and lowest values—were discarded. The average of the remaining three measurements was then calculated, ensuring the precision of our results. Graphs were created to depict the relationship between the working parameters and the measured surface roughness values. Finally, the effects of the processing parameters on surface roughness were analyzed and discussed based on the gathered data.

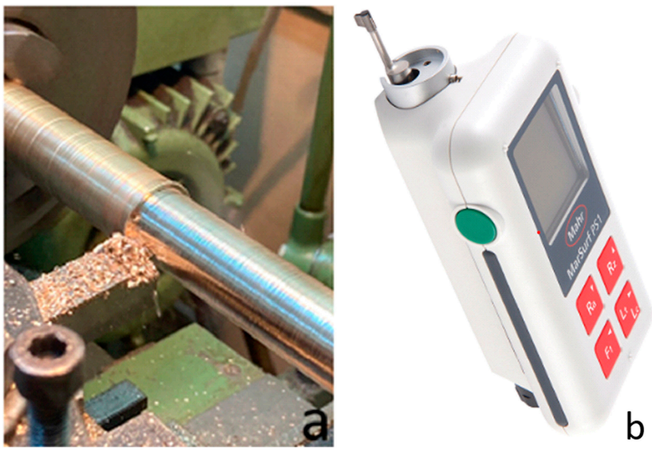

Figure 3. (**a**) Turning process of brass material; (**b**) Mahr-MarSurf PS1 device for measuring surface roughness.

3. Results and Discussion

Table 2 presents the measured surface roughness values of the test pieces machined using different parameters, including variable and constant factors. The surface roughness was measured using a surface roughness measuring device. Based on the data in the table, graphs were drawn. Upon examining the values in Table 2, it was observed that the surface roughness increased with an increase in the feed. This finding has practical implications for manufacturing processes, as it suggests that controlling the feed can help maintain surface quality. The surface roughness values decreased when the cutting-edge angle (CEA) of the cutting tools grew. The numbers given in the symbols in which the parameters are given in Table 2 (such as 1, 2, and 3, respectively) explain the experiments performed when they matched similar number parameters. When the surface roughness is examined according to the spindle speeds, it is seen that the surface roughness gets lower values with increasing spindle speed, with some exceptions.

Table 2. Average surface roughness variation in machining with feed, spindle speed, and cutting-edge angle variables.

Average Surface Roughness Values Ra (μm)									
Feed	**Spindle Speeds n1 = 480 rpm, n2 = 630 rpm, n3 = 1250 rpm**								
(mm/rev)	**n1**	**n2**	**n3**	**n1**	**n2**	**n3**	**n1**	**n2**	**n3**
0.028	2.513	2.282	2.711	2.336	2.101	1.785	1.228	1.639	1.784
0.088	3.363	3.108	3.357	2.530	2.180	1.810	1.868	1.667	1.757
0.155	3.573	3.558	4.745	2.956	2.888	2.680	2.457	2.214	2.057
CEA (°)	70°			80°			90°		

Surface roughness data obtained from experimental studies using different parameters must be reliable. When the data obtained from experimental studies are trustworthy, a correct evaluation can be made. For this purpose, since the number of variables in this study is high, the measured parameters were grouped according to a particular feed, cutting-edge angle, and spindle speed constants, as in Table 2. The average of the roughness values in each group and the deviations from the average were examined. This reliability examination showed that all data ranged from $-2\sigma < \mu < 2\sigma$ and below. Since the confidence interval of $-3\sigma < \mu < 3\sigma$, which is generally accepted for engineering studies, is sufficient, it is seen that all surface roughness values measured in this study are reliable in terms of making an evaluation.

Figure 4 shows the results for the sample, which was machined on a lathe. In Figure 4, the sample was machined on a lathe using a cutting-edge angle of 70° and a depth of cut of 0.5 mm. This study examined the effects of varying feed on surface roughness. The graph shows that the lowest average surface roughness recorded was 2.282 μm, achieved with a feed of 0.028 mm/rev at a spindle speed of 630 rpm. In contrast, the highest average surface roughness recorded was 4.745 μm, which occurred at a feed of 0.155 mm/rev and a spindle speed of 1250 rpm. In the graph, the average surface roughness measurement Ra1 corresponds to the value obtained at a spindle speed of n1 rpm. Ra2 and Ra3 represent similar measurements at different spindle speeds. To achieve optimal average surface roughness, the most suitable operating parameters with a 70° cutting-edge angle are identified as a spindle speed of 630 rpm and a feed of 0.028 mm/rev, resulting in a Ra value of 2.282 μm. The higher average surface roughness values observed at spindle speed n3, compared to n1 and n2, can be attributed to inappropriate processing parameters, which likely increased machine vibrations.

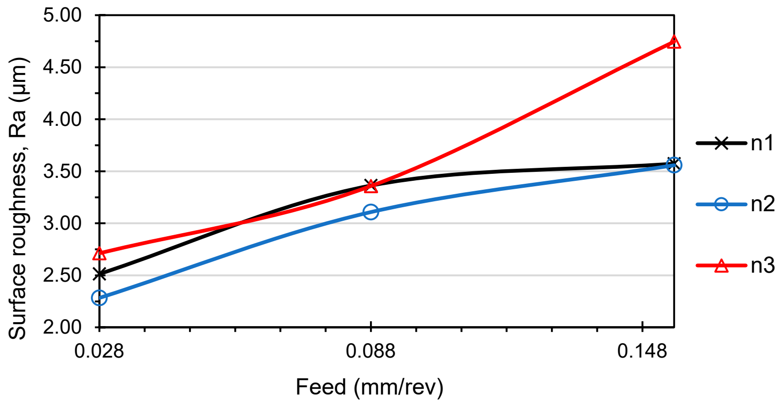

Figure 4. Surface roughness-feed graph. (Constants: CEA 70°, diameter 14.75 mm, depth of cut 0.5 mm. Variables: n1: 480 rpm, n2: 630 rpm, n3: 1250 rpm).

In Figure 5, the sample was machined on a lathe with the tool's cutting-edge angle set at 80° and a depth of cut of 0.5 mm. We specifically investigated how variations in feeds, a key machining parameter, affected surface roughness. The graph shows that the lowest average surface roughness value recorded was 1.769 µm, achieved at a feed of 0.028 mm/rev and a spindle speed of 1250 rpm. In contrast, the highest average surface roughness value was 2.956 µm, occurring at a feed of 0.155 mm/rev and a spindle speed of 480 rpm. In the figure, Ra1 represents the average surface roughness measurement obtained at spindle speed n1, while Ra2 and Ra3 correspond to similar measurements. The results indicate that the value associated with spindle speed n3 is more favorable for practical applications than n1 and n2, aligning with findings in the existing literature. This suggests that for a cutting-edge angle of 80°, the optimal working parameters were determined to be a spindle speed of 1250 rpm with a feed of 0.028 mm/rev, resulting in an average Ra value of 1.769 µm, which can be applied in real-world manufacturing scenarios. In Figure 5, while the increment between the feed values is equal, the increment between the spindle speed numbers increases from small to large, respectively. The increment amounts between the variable spindle speed numbers are variable. When the surface roughness curves obtained from the experiments carried out, in this case, are examined, the effect of the decreasing feed value and increasing spindle speed number on the surface roughness is positive.

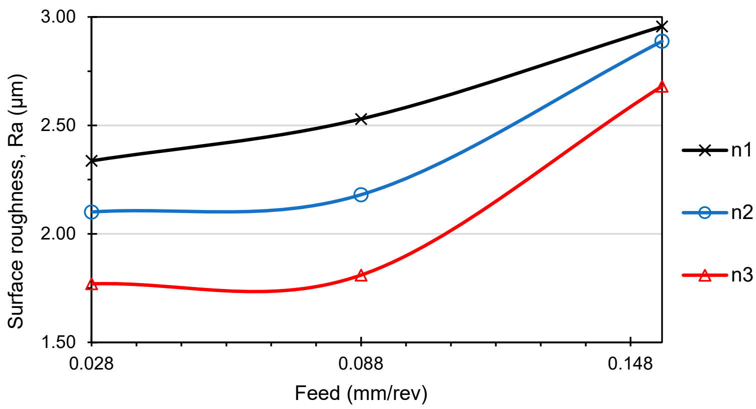

Figure 5. Surface roughness-feed graph. (Constants: CEA 80°, diameter 14.75 mm, depth of cut 0.5 mm. Variables: n1: 480 rpm, n2: 630 rpm, n3: 1250 rpm).

In Figure 6, the sample was machined on a lathe with the tool's cutting-edge angle set at 90° and a depth of cut of 0.5 mm. The investigation focused on how varying feeds affected surface roughness. The analysis revealed that the minor average surface roughness, measured at 1.228 µm, occurred at a feed of 0.028 mm/rev and a spindle speed of 480 rpm.

Conversely, the largest average surface roughness measured was 2.456 µm at a feed of 0.155 mm/rev while maintaining the same spindle speed of 480 rpm. In Figure 6, the average surface roughness values Ra1, Ra2, and Ra3 correspond to measurements taken at different operating spindle speeds, with Ra1 at n1 spindle speed being more suitable for practical applications than the others. For a cutting-edge angle of 90°, the optimal average surface roughness was observed at a spindle speed of 480 rpm and a feed of 0.028 mm/rev, resulting in a Ra value of 1.228 µm. Additionally, the graph indicates that at a feed of 0.155 mm/rev, surface roughness decreased as the spindle speed increased. However, this combination did not yield the lowest surface roughness value compared to the feed of 0.028 mm/rev, which is particularly noteworthy.

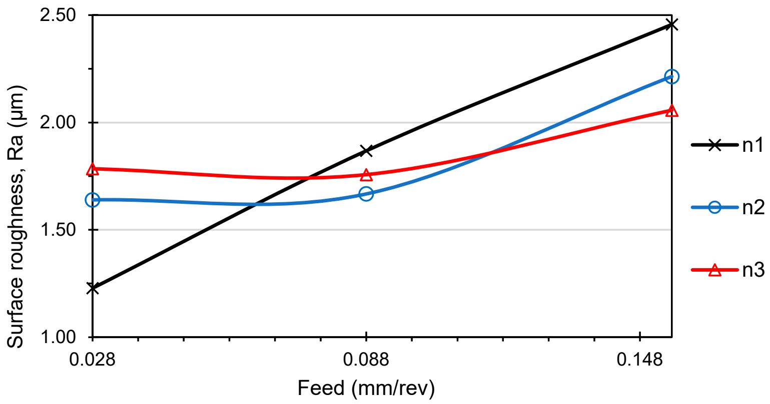

Figure 6. Surface roughness-feed graph. (Constants: CEA 90°, diameter 14.75 mm, depth of cut 0.5 mm. Variables: n1: 480 rpm, n2: 630 rpm, n3: 1250 rpm).

In Figure 7, the sample was machined on a lathe with a feed of 0.155 mm and a fixed depth of cut of 0.5 mm. This study focused on how cutting-edge angle variations affected surface roughness. The smallest recorded average surface roughness value was 2.056 µm, which occurred at a tool cutting-edge angle of 90° and a spindle speed of 1250 rpm. In contrast, the largest average surface roughness value was 4.745 µm, observed at a cutting-edge angle of 70° while maintaining the same spindle speed of 1250 rpm. In Figure 7, the average surface roughness measurements—Ra1, Ra2, and Ra3—correspond to the values obtained at spindle speeds n1, n2, and n3, respectively. It was noted that the value obtained at n3 is more suitable for practical applications than n2 and n1. With a feed of 0.155 mm/rev and a fixed pass of 0.5 mm, the most influential parameters for achieving the lowest average surface roughness were a spindle speed of 1250 rpm and a cutting-edge angle of 90°. Under these conditions, the Ra value recorded was 2.056 µm. The data presented in Figure 7 indicated that the average surface roughness decreased as the cutting-edge angle increased.

In Figure 8, the sample was machined on a lathe under conditions where the feed was 0.088 mm and the depth of cut was 0.5 mm. The effect of changes in the value of the cutting-edge angle on the surface roughness was investigated. The graph revealed that the smallest average surface roughness value was obtained at a significant cutting-edge angle of 90° and a spindle speed of 630 rpm. This practical result reassures us that these parameters are indeed the most suitable for achieving the best surface roughness. The largest average surface roughness value was obtained at a significant cutting-edge angle of 70° and a spindle speed of 480 rpm. The average surface roughness measurement value Ra1 corresponds to the value obtained when operating at n1 spindle speed. Ra2 and Ra3 are similar, respectively. It was observed that the value obtained with n2 in the figure is a more suitable working value in practice than n1 and n3, respectively. For feed of 0.088 mm/rev and 0.5 mm fixed pass values, the working parameters for the most suitable average surface roughness value are 630 rpm spindle speed and a large cutting-edge angle of 90°. Ra value was obtained as 1.667 µm. In Figure 8, the average surface roughness decreased with increasing values of large cutting-edge angles.

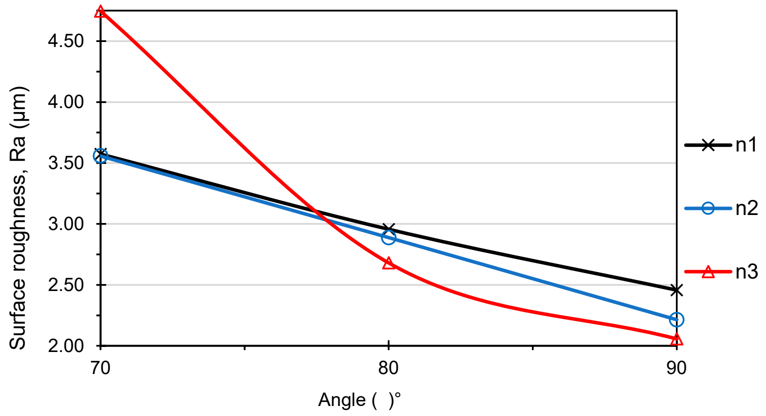

Figure 7. Surface roughness-cutting-edge angle graph. (Constants; feed 0.155 mm/rev, depth of cut 0.5 mm, diameter 14.75 mm. Variables: n1: 480 rpm, n2: 630 rpm, n3: 1250 rpm).

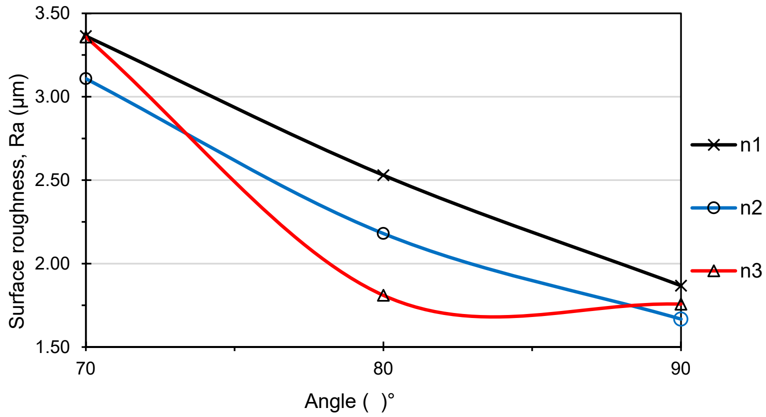

Figure 8. Surface roughness-cutting-edge angle graph. (Constants; feed 0.088 mm/rev, depth of cut 0.5 mm, diameter 14.75 mm. Variables: n1: 480 rpm, n2: 630 rpm, n3: 1250 rpm).

In Figure 9, the sample was machined on a lathe with a feed of 0.028 mm per revolution and a fixed depth of cut of 0.5 mm. This study explored the impact of varying the cutting-edge angle on surface roughness. The results from rigorous research revealed that the lowest average surface roughness recorded was 1.228 µm. This was achieved at a cutting-edge angle of 90° and a spindle speed of 480 rpm. In contrast, the highest average surface roughness measured was 2.711 µm, which occurred at a cutting-edge angle of 70° and a spindle speed of 1250 rpm. These findings significantly advance our understanding of machining parameters and their effects on surface roughness. In Figure 9, average surface roughness measurements are labeled as Ra1 for the spindle speed n1, while Ra2 and Ra3 correspond to measurements for the other spindle speeds. It was noted that the value obtained at n1 is more suitable for practical applications than those at n2 and n3. For a feed of 0.028 mm/rev and a fixed pass depth of 0.5 mm, the optimal operating parameters to achieve the best average surface roughness are a spindle speed of 480 rpm and a cutting-edge angle of 90°. Under these conditions, the achieved Ra value was 1.228 µm. The graph indicates a general trend of decreasing average surface roughness as the cutting-edge angle increases, reinforcing the practicality of this research and its implications for the industry by providing a clear roadmap to achieve optimal surface roughness.

Figure 10 shows the change in surface roughness depending on the change in spindle speed. This study has some constants: the cutting-edge angle is 70°, the workpiece diameter is 14.75 mm, and the cutting depth is 0.5 mm. For different spindle speeds, one of the three feed values corresponds to a certain one (f1: 0.028 mm/rev, f2: 0.088 mm/rev, and f3: 0.155 mm/rev). Figure 10 shows that the surface roughness value increases with the increase in feed value. This change is consistent with the literature. Figure 10 measured the largest surface roughness (1250 rpm–0.155 mm/rev) as 4.745 µm. Figure 10 measured the most minor surface roughness (630 rpm–0.028 mm/rev) as 2.282 µm. The selected operating parameters here show that the machine operating parameters that can cause the lowest surface roughness are 630 rpm and 0.028 mm/rev. The increment between the first two revolutions is low, while the increment between the second and third revolutions is more than four times the first increment. In this case, in the experimental design, it is seen that the roughness value increases even more with growing high revolutions, especially if large feeds are preferred. Of course, tool-part materials are essential when determining the material removal parameters. However, together with the machining methods that give movement to the tool and the part and are formed according to these movements, it is also essential to know the machine's usable revolutions and feed values. In addition, the rigidity of the machine is also significant for obtaining good surface quality.

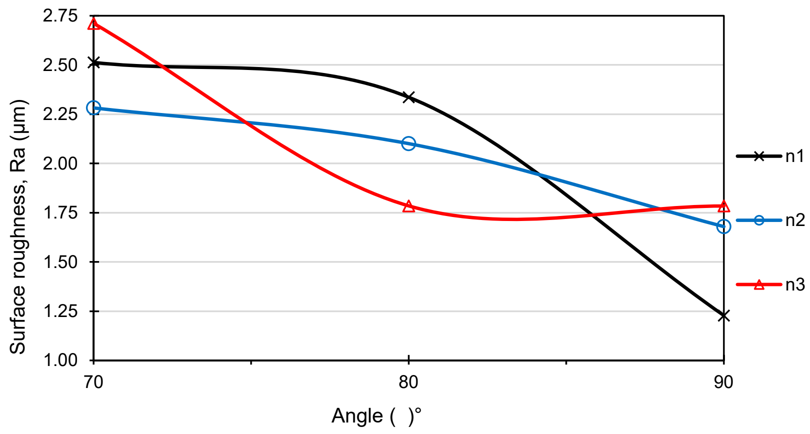

Figure 9. Surface roughness-cutting-edge angle graph. (Constants; feed 0.028 mm/rev, depth of cut 0.5 mm, diameter 14.75 mm. Variables: n1: 480 rpm, n2: 630 rpm, n3: 1250 rpm).

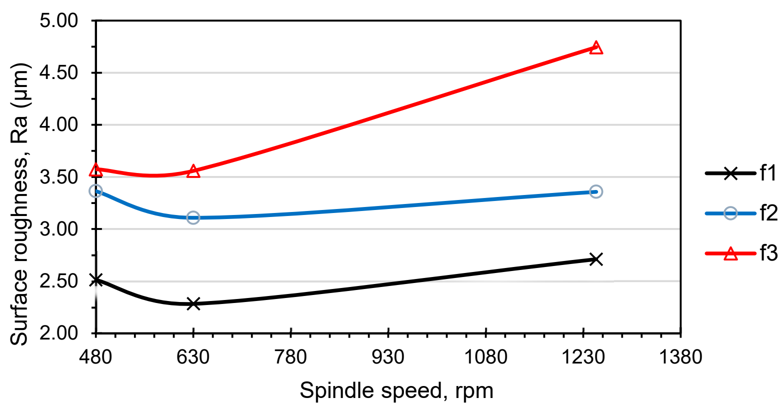

Figure 10. Surface roughness-rpm graph. (Constants; CEA 70°, depth of cut 0.5 mm, diameter 14.75 mm. Variables: f1: 0.028 mm/rev, f2: 0.088 mm/rev, f3: 0.155 mm/rev).

Figure 11 shows the spindle speed-surface roughness change. The fixed parameters used in the experiments are a cutting-edge angle of 80°, a diameter of 14.75 mm, and a cutting depth of 0.5 mm. In these experiments, for each spindle speed, three different feed values (f1: 0.028 mm/rev, f2: 0.088 mm/rev, and f3: 0.155 mm/rev) correspond. In other words, for each feed, experiments were carried out with three-spindle speed changes (n1: 480 rpm, n2: 630 rpm, and n3: 1250 rpm), and graphs were drawn. In Figure 11, the surface roughness also increased when the spindle speed increased at the feed value of 0.155 mm/rev. This situation confirms the literature that when the feed value remains constant, the spindle speed increase positively affects surface roughness. This experimental study also observed that the surface roughness decreases with the increase in spindle speed obtained for the other two feed values. With the experimental study parameters, the largest surface roughness (480 rpm, 0.155 mm/rev) was obtained as 2.956 µm, and the smallest surface roughness (1250 rpm, 0.028 mm/rev) was obtained as 1.181 µm.

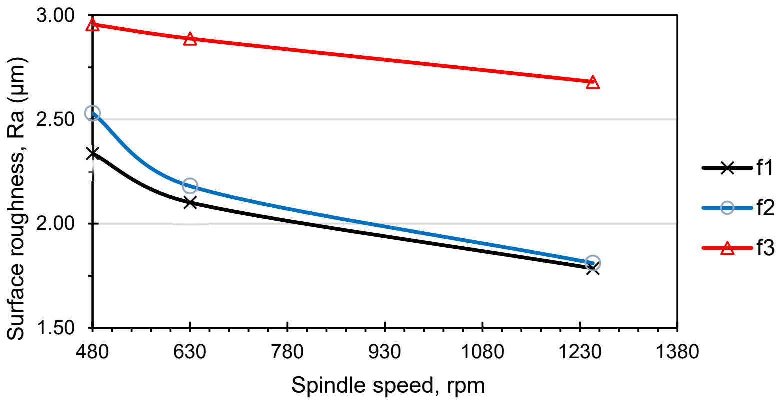

Figure 11. Surface roughness-rpm graph. (Constants; CEA 80°, depth of cut 0.5 mm, diameter 14.75 mm. Variables: f1: 0.028 mm/rev, f2: 0.088 mm/rev, f3: 0.155 mm/rev).

Figure 12 shows the variation in surface roughness with spindle speed when the cutting-edge angle is 90°. Figure 12 shows the measured surface roughness for each spindle speed parameter, corresponding to three feeds (f1: 0.028 mm/rev, f2: 0.088 mm/rev, and f3: 0.155 mm/rev). Figure 12 shows that the largest surface roughness (480 rpm, 0.155 mm/rev) is 2.457 µm, and the minor surface roughness (480 rpm, 0.028 fee/rev) is 1.228 µm. The surface roughness decreased with the increasing spindle speed value (in the machining with the 0.155 mm/rev parameter). The curve given by the values measured in the machining performed with feed f1: 0.028 mm/rev showed the opposite of the previous situation. In this case, the increasing spindle speed increased the surface roughness. In the machining performed with feed f2: 0.088 mm/rev, the growing spindle speed (from 480 rpm to 630 rpm) primarily caused a decrease in the surface roughness. When the spindle speed increased from 630 rpm to 1250 rpm, the surface roughness increased. In the machining, after the feed and spindle speed parameters are adjusted on the machine, when the depth of cut between the tool and the part and other processing factors are also considered, it can be said that a specific optimization is required for a particular manufacturing method on the machine. It cannot be worked on by selecting random parameters.

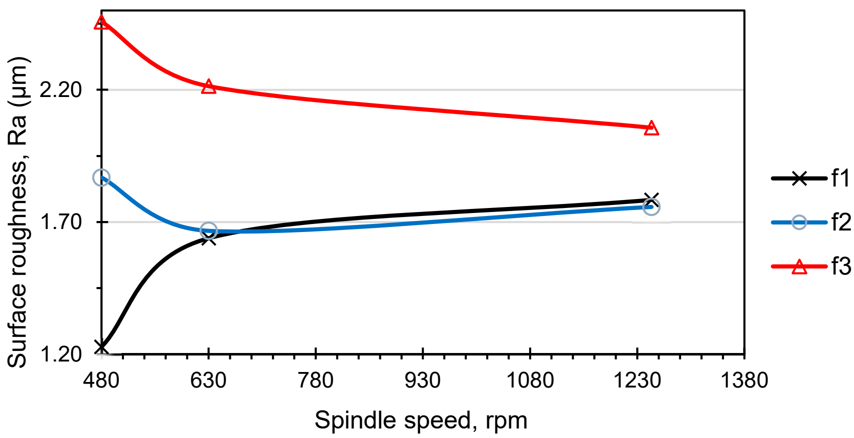

Figure 12. Surface roughness-rpm graph. (Constants; CEA 90°, depth of cut 0.5 mm, diameter 14.75 mm. Variables: f1: 0.028 mm/rev, f2: 0.088 mm/rev, f3: 0.155 mm/rev).

4. Conclusions

- Upon reviewing the graphs generated from this study's experimental plan, it was observed that an increase in the feed led to higher surface roughness values, which negatively impacted surface quality. Conversely, increasing the tool's cutting-edge angle resulted in lower surface roughness values, improving surface quality. In the experiments, it was observed that there was an improvement in surface roughness that was in line with the general trend with the increase in spindle speed. It was also determined that surface roughness values that did not comply with the general trend increased by combining some processing parameters. In addition to the harmony of the tool-part-machine tool trio in processing operations, the correct determination of the chip removal method is necessary. Therefore, each of the processing parameters is important. Lower surface roughness can be obtained by optimizing processing parameters. This way, the lowest surface quality can be obtained quickly with low power consumption. For these reasons, it can also be said that some of the processing parameters in this study are not the most accurate working parameters for the tool-part-machine tool trio. As a result, it was determined that when the correct processing parameters were selected, the final demand and the best surface roughness value could be obtained.
- When examining Figures 4–6, which used a constant depth of cut of 0.5 mm, the average surface roughness values based on cutting-edge angles of 70°, 80°, and 90° were measured to be 2.282 µm, 1.769 µm, and 1.228 µm, respectively. Similarly, Figures 7–9 were analyzed under the same depth of cut of 0.5 mm but with varying feeds of 0.155, 0.088, and 0.028 mm/rev. The corresponding average surface roughness values were 2.056 µm in Figure 7, 1.667 µm in Figure 8, and 1.228 µm in Figure 9. When Figures 10–12 are examined, the lowest surface roughness values are measured as 2.282 µm (CEA 70°, 630 rpm, 0.028 mm/rev), 1.785 µm (CEA 80°, 1250 rpm, 0.028 mm/rev), and 1.228 µm (CEA 90°, 480 rpm, 0.028 mm/rev), respectively. These data show that the lowest surface roughness value is measured as 1.228 µm in Figure 12 due to the experimental studies conducted on the constant spindle speed-surface roughness relationship and other variables. These experimental parameters also confirm the general approach that the lowest spindle speed, lowest feed, and cutting tool angle are 90° and that the lowest feed value among these values will give lower surface roughness when some machining parameters are selected, as in Figure 11 (1250 rpm, 0.155 mm/rev, 2.680 µm) and Figure 12 (1250 rpm, 0.155 mm/rev, 2.057 µm), increasing the spindle speed can lower surface roughness for a fixed feed value. The difference between the surface roughness values in the last two figures and the lowest surface roughness values in Figure 10 is slight. Therefore, this selection can be helpful when machining at high operating spindle speeds is required.
- In conclusion, the optimal parameters for achieving the lowest average surface roughness (1.228 µm) in these nine experimental setups were a depth of cut of 0.5 mm, a cutting-edge angle of 90°, a spindle speed of 480 rpm, and a feed of 0.028 mm/rev.
- In the article, only HSS was used as the tool material for processing. Different tools were not added to this study. For this reason, an explanation about this subject was added to the Conclusion Section. As a future study, a more meaningful evaluation can be made about the surface roughness of Ms58 brass material by using the parameters in this study, working experimentally with different tool materials, and evaluating the results obtained together with all the study results.
- The article's authors preferred turning the outer cylindrical surface as a machining process since the processed part is cylindrical. Only the process results for the cylindrical surface were examined in this study. In the future, the article can be made with more comprehensive machining methods such as cutting, channel opening, inner cylindrical surface machining, drilling, and similar studies by changing the work material. In this way, the results can be evaluated in a broader range.

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