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Analysis Of The Effect Of Carbide Cutting Angle On The Surface Roughness Of Aisi 4337 Steel In Turning Axle Rail Shafts Without Cutting Fluid

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Abstract

Varying cutting angles are applied to understand the relationship between cutting angles and machining result characteristics, such as surface roughness (Ra). Surface roughness as a dependent variable is influenced by machining parameters, namely depth of feed. Cutting angle, cutting speed and feed speed as independent variables. The aim of the research activity is to analyze the effect of variations in the cutting angle of carbide tools and identify the optimum cutting angle on the surface quality of the axle rail shaft from AISI 4337 steel processed using the dry turning method. The research was carried out experimentally, which had 9 specimens as test material to obtain surface roughness values with variations in cutting angles using a CNC lathe without cutting fluid and a surface test tool. Test data is provided with machine spindle rotation speeds, namely 1200 rpm, 1400 rpm and 1600 rpm. Variations in cutting angles of 25o, 55o, 85o and feeds of 0.1 mm/r, 0.15 mm/r, 0.2 mm/r and a constant cutting depth of 1 mm are used for the dry turning process which is commonly used in industry to reduce the environmental impact . The average surface roughness (Ra-avg) values of 3.05 µm, 2.35 µm, 1.64 µm obtained as a function of cutting angle are part of the optimum cutting conditions on HP9. From the analysis, it was found that the most optimum cutting angle (Kr) was an angle of 85o with an average surface roughness value (Ra-avg) of 1.64 µm as shown in figure 4.3. The results show that larger cutting angles tend to produce surfaces with lower roughness, while smaller angles can increase the tool wear rate. Factors such as cutting speed, depth of cut, and feed rate also influence the results significantly. This research provides important insights for the optimization of machining processes in industrial applications.

Keywords : Dry Turning, Cutting Angle, Carbide Tool, Surface Roughness, Aisi 4337 Steel

INTRODUCTION

Machining processes, especially turning, are manufacturing techniques that are widely used to shape materials into components with precise geometries. In turning the axle rail shaft after machining, the quality of the machining results, such as surface roughness, is greatly influenced by various factors, including cutting parameters, tool geometry, and machining conditions. One important parameter is the cutting angle of the tool, which can influence the cutting force, heat generated, and surface characteristics of the workpiece.

In the lathe machining process, all cutting energy is converted into heat through the process of friction between the tool and the tool and between the tool and the workpiece, as well as the process of destroying molecular or atomic bonds in the sliding plane. This heat is mostly carried by the gram, some of it propagates through the tool and the rest flows through the workpiece to its surroundings. The temperature that arises is quite large and because the contact area is relatively small, the temperature of the tool, especially the gram area and the main area, will be very high, because the high pressure due to the cutting force and the high temperature cause the active surface of the tool to experience wear. In dry machining processes, the use of cutting fluids is eliminated to reduce environmental impact, increase sustainability and reduce operating costs. However, a challenge with dry machining, especially when processing strong materials such as AISI 4337 steel, is increased heat and tool wear, which can impact surface quality and process efficiency.

AISI 4337 steel is a low alloy steel with chromium and nickel content that is used in heavy engineering applications due to its high tensile strength and resistance to wear. In machining this material, carbide tools are widely used because they have resistance to high temperatures and wear. Therefore, this research focuses on the influence of the cutting angle of carbide tools under dry machining conditions on the surface quality of AISI 4337 steel. Understanding the relationship between cutting angle, surface quality and material behavior can provide important insights for optimizing machining processes with high efficiency and impact. minimal environment.

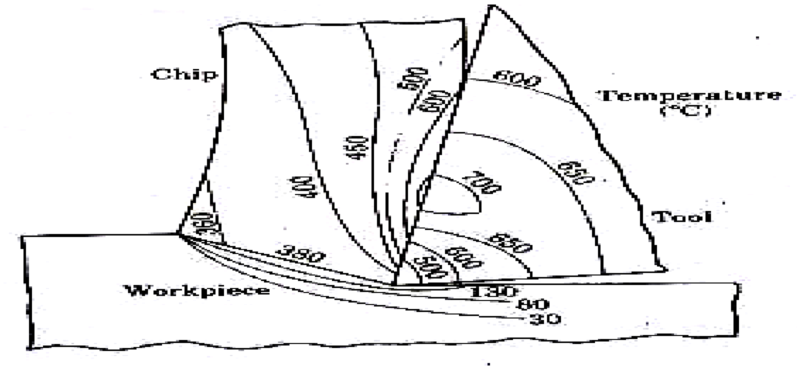

Figure-1. The relationship between tool temperature, gram and workpiece in the process CNC lathe machining

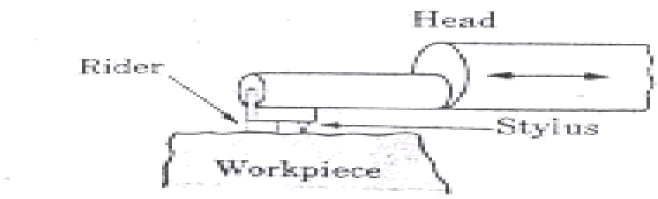

Figure-2. Stylus on the workpiece surface

To obtain the surface roughness value of the machining results, the equation is used :

$$Ra = (a + b + c + d + ...)/n \qquad ....(1)$$

So the formula above, such as, a, b, c, d and so on is the value of the ordinate point on the surface profile as measured from the center line according to the profile.

The correlation between surface roughness, nose radius and ingestion is given by the following empirical formula:

$$Ra = \frac{0{,}0321.f^2}{rc} \quad (\mu\ m) \qquad ....(2)$$

Based on equation (2) where f is feed and is the corner radius of the tool with a constant of 0.8.

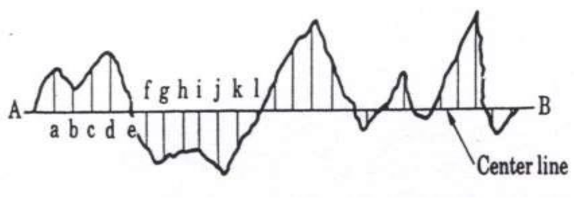

Figure-3. Use of coordinate points in surface roughness Measurement

RESEARCH METHODS

Materials, tools and methods for treatment in carrying out tests are:

Figure-4.Axle rail shafts material of AISI 4337 Steel
Standard Conditions of workpieces with a length / diameter ratio greater than 10 are not recommended (ISO 3685).

Table.1. Chemical composition of workpiece material (in%)

C	Si	Mn	P	S	Cr	Mo	Ni
0,30-0,38	0,15-0,40	0,40-0,70	≤ 0,035	≤ 0,035	1,40-1,70	0,15-0,30	1,40-1,70

Table.2. Mechanical properties

Yield strength (N/mm^2 min)	Tensile Strength (N/mm^2)	Elongation (%)	Reduksi (%)	Strength impact (Joule)	Hardness (HV)
785	980-1180	11	50	48	300-360

Fiture-5. CNC Machine

Figure-6. Surface Test

Figure-7. Tool holder and insert are integrated as a tool

Testing of specimens as test objects was carried out experimentally. The cutting process is carried out with a CNC lathe without cutting fluid on the surface of a cylindrical rod-shaped workpiece made of AISI 4337 steel. The workpiece is cut using variations in cutting angle, machine rotation speed and feed with a constant cutting depth. Testing of 9 specimens resulting from machining was to measure the average surface roughness (Ra-avg) using a surface test tool carried out 3 times on the surface of the specified part of the test object. The data obtained from the test results were observed and analyzed and then discussed to obtain an optimum cutting condition as a reference for determining the quality of machining results related to surface roughness.

RESULTS AND DISCUSSION

From the test results data, the average surface roughness Ra-avg) was obtained for 9 test results with machine rotation speed, cutting angle, feed as attached in table 1 below.

Table.1. Test result data

HP	n (rpm)	Kr (o)	a(mm)	f (mm/r	Ra-avg(μm)
HP1	1200	25	1	0,1	3,54
HP2	1200	55	1	0,15	3,25
HP3	1200	85	1	0,2	3,05
HP4	1400	25	1	0,2	2,75
HP5	1400	55	1	0,1	2,54
HP6	1400	85	1	0,15	2,35
HP7	1600	25	1	0,15	1,92
HP8	1600	55	1	0,2	1,75
HP9	1600	85	1	0,1	1,64

Table 2. was obtained based on the application of the L9 (34) orthogonal array standard to obtain the test design in table form below.

No	Coulumn number/ Factor			
Trial	n(rpm)	Kr(°)	a (mm)	f (mm/r)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Source : Phillip J.Ross, 1996

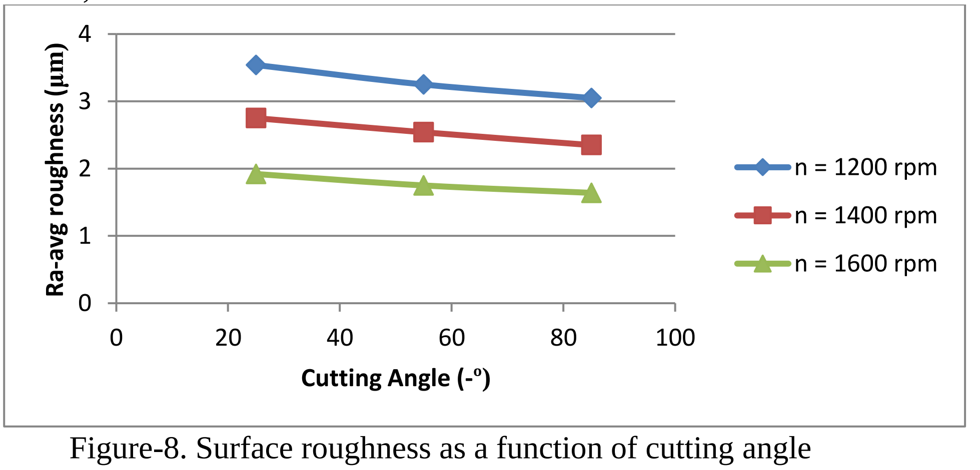

Figure-8. Surface roughness as a function of cutting angle

Figure-8. shows 3 relatively linear and parallel line graphs where the independent variable is the cutting angle and the dependent variable is the surface roughness. For feed f = 0.1 mm/r, the average roughness value is 3.54 µm, 3.25 µm, 3.05 µm at cutting angles (Kr) = 25o, 55o, 85o. Furthermore, with feed f = 0.15 mm/r, Ra-avg values were obtained at 2.75 µm, 2.54 µm, 2.35 µm. Meanwhile, ingestion f = 0.2 mm/r is Ra-avg with Ra-avg data namely 1.92 µm, 1.75 µm, and 1.64 µm. The three graphs have the property that the greater the cutting angle Kr from 25o, 55o to 85o, the decrease in surface roughness (Ra-avg) will be obtained. A decrease in surface roughness occurs due to an increase in the cutting angle Kr and the machine spindle rotation speed.

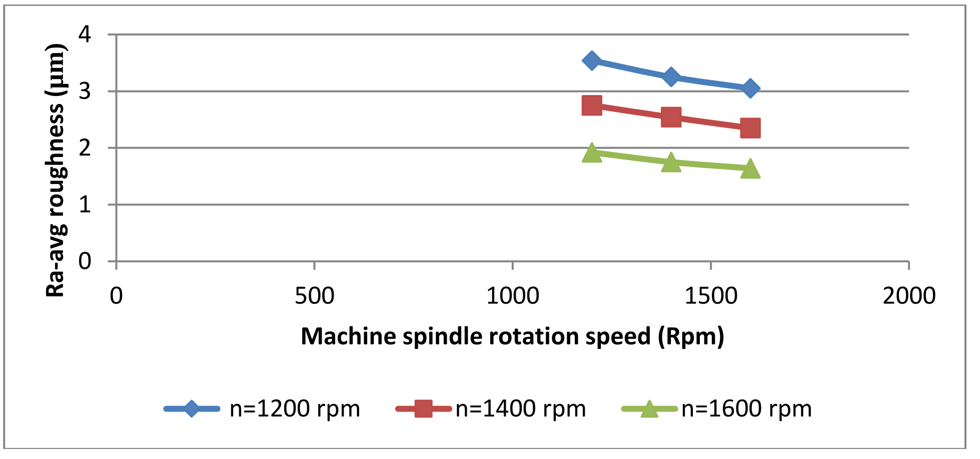

Figure-9. Surface roughness as a function of engine rotation speed

Figure-9 shows a graph with the relative characteristics of straight and parallel lines. Forn = 1200 rpm obtained Ra-avg values of 3.54 µm, 3.25 µm, 3.05 µm respectively. Speed value engine speed(n) = 1400 rpm is 2.75 µm, 2.54 µm, 2.35 µm, then with n = 1600 rpm. The Ra-avg roughness values obtained were 1.92 µm, 1.75 µm, and 1.64 µm. Straight line/linear graphmThe one closest to the x axis is the engine rotation speed which is 1600 rpm while the away from the x axis is for engine rotation speed (n) = 1400 rpm and so on which is further from the x axis at n = 1200 rpm. So the properties of the three line graphs above mean The greater the cutting angle of the tool, the lower the surface roughness.

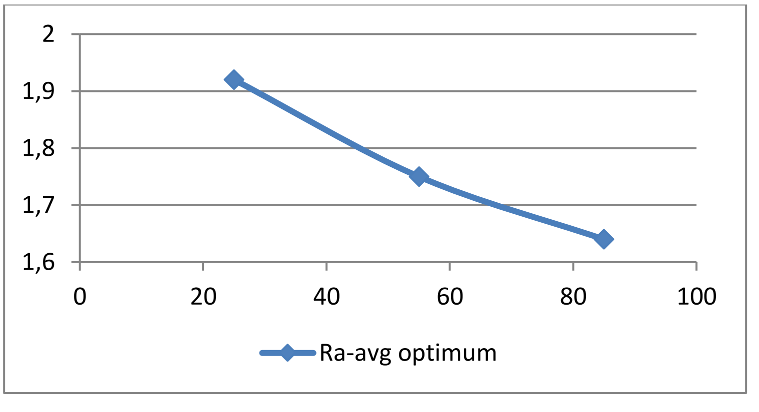

Figure-10. The relationship between cutting angle and optimum surface roughness

Figure-10 shows an optimum linear graph related to surface roughness with a constant depth of cut (a) = 1 mm where the roughness Ra-avg is a function of the cutting angle. The Ra-avg roughness at rotation (n) = 1600 rpm with a cutting angle of 25o, f = 0.15 mm/r obtained a Ra-avg value of 1.92 µm while the cutting angle was 55o, f = 0.2 mm/r obtained Ra-avg = 1.75 µm. Furthermore, with a cutting angle of 85o for f = 0.1 mm/r it is 1.64 µm. Increasing the cutting angle from 25o, 55o to 85o results in a smaller Ra-avg roughness value, namely from 1.92 µm, 1.75 µm, to 1.64 µm which is due to the small f feed value (0.1 mm/r). From the observations made, it turns out that the optimum surface roughness value is 1.64 µm at n = 1600 rpm with a cutting angle of 85o, f = 0.1 mm/r.

CONCLUSION

1. The cutting angle can affect the surface quality of the machining results, which of the three line graphs has a linear nature, with the greater the cutting angle Kr, the lower the Ra-avg surface roughness value. Cutting angles can reduce cutting forces and produce good surface quality, but have the potential to cause tool wear more quickly. Therefore, carbide chisels were chosen with properties of high hardness, wear resistance and thermal stability, which makes it ideal for machining hard materials such as AISI 4337 steel.
2. Increasing the machine rotation speed from n = 1200 rpm, 1400 rpm to n = 1600 rpm to cut AISI 4337 steel specimens without cutting water results in a lower Ra-avg surface roughness.
3. From the observations made it turns out that a cutting angle of 85o, n = 1600 rpm, f = 0.1 mm/r gives a Ra-avg surface roughness value of 1.64 µm. This means that HP9 machining results are obtained at optimum cutting conditions.
4. Inappropriate cutting angles or rotation speeds that are too low can cause an increase in surface roughness due to the generation of rough chips and machine vibration. With the right cutting angle and relatively high rotation speed applied, the surface roughness will decrease according to table 1.

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