Effect of the Machined Surfaces of AISI 4337 Steel to Cutting Conditions on Dry Machining Lathe

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Abstract. The objective of the research is to obtain a cutting condition which has a good chance of realizing dry machining concept on AISI 4337 steel material by studying surface roughness, microstructure and hardness of machining surface. The data generated from the experiment were then processed and analyzed using the standard Taguchi method L9 (3⁴) orthogonal array. Testing of dry and wet machining used surface test and microhardness test for each of 27 test specimens. The machining results of the experiments showed that average surface roughness (Raavg) was obtained at optimum cutting conditions when VB 0.1 mm, 0.3 mm and 0.6 mm respectively 1.467 μm, 2.133 μm and 2,800 μm for dry machining while which was carried out by wet machining the results obtained were 1,833 μm, 2,667 μm and 3,000 μm. It can be concluded that dry machining provides better surface quality of machinery results than wet machining. Therefore, dry machining is a good choice that may be realized in the manufacturing and automotive industries.

1. Introduction

Today's wet machining applications are still done in metal cutting industry for cutting steel [1]. This 16% cost is converted to the total cost of production from the automotive industry in America to 48 billion dollars, 1 billion mark in Germany and 78 billion yen in Japan [2]. Based on the above values, the recommended cutting fluid is eliminated then it can be imagined how much value can be saved so that the selling value of the product can be reduced. The impact of a fluid intake on wet machinery is not only a matter of cost but also on health and the environment. To solve the problem of this cutting fluid, the machining experts finally recommend dry machining [3]. Viewed from the ecological aspect that the green machining can also be referred to as dry machining.

Che Haroen and Ginting[4] reported that the tendency of dry machining is better than wet machining to lathe tool steel using a TIN-coated carbide tool. Surface integrity is affected by cutting depth (a), feeding (f), corner radius (r) and cutting fluids [5]. The cost advantages of dry machining
include without cooling, no cooling pump, no filter and no sales of chips cleaners [6]. Without the use of cutting fluid in dry machining cutting will certainly lead to high cutting temperatures and greater frictional force occurring in the cutting area because temperature and friction will result in disruption to tool life and surface smoothness.

Canter [7] reports that without cutting fluid, excessive tool wear and worse surface packaging during machining, these two factors will increase the cost of fabrication and reduce productivity. If dry machining is implemented in AISI 4337 steel, then what may be encountered are:

a. AISI 4337 alloy steel is a ductile material, the absence of cutting fluid will cause friction and high heat.

b. Decrease in cutting speed and attachment of chip on surface will be obtained by chip / continuous chip with properties of workpiece AISI 4337 ductile.

c. Applications for dry machining will cause the machining surface hardness to be higher than wet machining. Dry machining performed on machining of several metal materials such as cast iron, carbon steel, titanium alloys

To overcome these problems it is necessary to change the machining method from wet machining to dry machining method, thereby reducing production costs and avoiding environmental pollution. From the above exposure it is deemed necessary to analyze the problem of surface roughness, surface hardness and surface microstructure machined as an ingredient for fabricating machine components. This study aims to obtain cutting conditions that have a good chance for the realization of dry machining concept on AISI 4337 steel material.

2. Material and Method

AISI 4337 steel cylindrical rod is machined using CNC machine (length = 200 mm and diameter 50 mm) using CNC machine. The standard condition of the workpiece with a ratio of length and diameter of more than 10 is not recommended on metal cutting [8]. In analyzing surface roughness and surface hardness was carried out with variations of VB wear, cutting variation and different tool geometric, see table 1 below. The result of machining lathe has 9 different cutting forms when performed on wet machining as well as dry machining.

By three variations of VB wear, ie 0.1 mm, 0.3 mm and 0.6 mm of 9 cutting forms, one optimum cutting method was chosen to obtain 3 optimum cutting forms for wet and dry machining. Thus can be compared wet and dry machinery results. Measurement of surface hardness of machining result used Micro hardness test equipment while surface roughness with surface test.

Table 1. Plan for Variations VB = 0.1 mm; 0.3 mm and VB = 0.6 mm with wet machining and dry machining.

| Number of Experiments | V(mm/min) | a (mm) | F(mm/r) | Gp(°) |
|-----------------------|-----------|--------|---------|-------|
| HPB1;HPK1             | 200       | 1.0    | 0.15    | 6     |
| HPB2;HPK2             | 200       | 1.5    | 0.20    | 12    |
| HPB3;HPK3             | 200       | 2.0    | 0.25    | 18    |
| HPB4;HPK4             | 250       | 1.0    | 0.20    | 18    |
| HPB5;HPK5             | 250       | 1.5    | 0.25    | 6     |
| HPB6;HPK6             | 250       | 2.0    | 0.15    | 12    |
| HPB7;HPK7             | 300       | 1.0    | 0.25    | 12    |
| HPB8;HPK8             | 300       | 1.5    | 0.15    | 18    |
| HPB9;HPK9             | 300       | 2.0    | 0.20    | 6     |

Characteristics of the S / N ratio can be divided into three categories:

a. Nominal best characteristic:
Data collected, processed and then analyzed using Taguchi method. The experimental design was carried out with the standard L9 (3^4) orthogonal array. Standard L9 (3^4) orthogonal array has nine lines, three levels and four factors [9].

3. Results and Discussion
VB wear and tear connection with surface roughness at optimum cutting conditions for dry and wet machining with the meaning of a larger wear curve followed by increased roughness. The ratio of Ra values to dry and wet machining is not significant where dry machining has better curve characteristics because the Ra value is lower for the same cutting condition, see figure 1 below:

![Figure 1: VB wear relationship with Surface roughness of HPK and HPB for optimum cutting conditions.](image)

In other words, optimum dry machining cutting conditions (HPK8.0.6 dry machining = 2.8 μm) has a finer surface than wet machining (HPK8.0.6 dry machining = 3 μm)
Figure 2. Relation of experimental amount with Ra exp on VB 0.1; 0.3 and 0.6 mm.

Figure 3. Relation of experimental amount with Ra Rasio S/N pada VB 0.1; 0.3 dan 0.6 mm.

Table 2. Two Ways for Surface Roughness, C1D3 Maximum Cutting Condition.

| Added with Level Factor | C1   | C2     | C3      | Total |
|-------------------------|------|--------|---------|-------|
| D1                      | 0.322| 1.112  | 1.159   | 2.593 |
| D2                      | 0.697| 0.973  | 1.872   | 3.542 |
| D3                      | 0.425| 0.657  | 0.894   | 1.976 |
| Total                   | 8.111| 12.566 |         | 15.942|

Table 3. ANOVA Pareto Analysis for Surface Roughness.

| Added with Level Factor | Factors and Interactions |
|-------------------------|--------------------------|
|                         | C x D | A       | B      | C      | D      |
| 1                       | 11.842| 11.842  | 12.031 | 8.111  | 12.414 |
| 2                       | 12.177| 12.177  | 11.476 | 12.566 | 13.845 |
| 3                       | 12.600| 12.600  | 13.112 | 15.942 | 10.360 |
| The sum of squares of the| 0.865 | 0.865   | 4.408  | 92.568 | 15.269 |
| difference (S) | Contribution Rate (%) |
|---------------|------------------------|
| 8,140         | 8,163                  |
| 70,154        | 5,509                  |
| 7,628         |                        |

For the geometry of tool $12^\circ$ indicates a change of sub-surface structure which the heat on the workpiece is high enough that the outer layer hardened by consequence the formation of a crater-like hole seen in figure 4 below.

![Figure 4. Micro Structure with HPK2,0.6.](image)

With tool geometric $6^\circ$ providing a softer outer surface layer, the phenomenon occurring in the outer surface layer is a white base structure enclosing a surface layer of ferrite like Figure 5 and Figure 6.

![Figure 5. Micro structure with HPK5,0.6 for tool flank wear of VB in dry machining.](image)

Figure 5 and figure 6 shows the wear of VB proportional to the surface hardness in which the above two graphs are the result of dry machining (HPK) and also the result wet machining (HPB) gives a difference in HV hardness. Wet machining hardness value of HV is lower due to low temperature factor on machining surfaces with the same VB wear. In the dry machining process the friction and heat that occurs will be very high where the tool will experience wear on the edge (VB) that is directly related to the workpiece surface. Flank wear will occur with variations of VB = 0.1 mm, 0.3 mm and 0.6 mm. Wear VB is higher then the workpiece surface will experience the friction and higher heat because end cutting edge of the tool with the consequence of the work surface of machining results will be harder. So the wear of VB greatly influences the hardness, the greater the wear of VB then the HV hardness increases. From the graph it can be seen that the hardness of HV is the dependent variable which is hardness as a function of VB wear. From the observations presented in Figures 6 and 7, fluctuations of Ra change in VB 0.1; 0.3 and 0.6 mm with 9 cutting conditions which in figure 6 the value of Ra change of the variation of VB data is processed through the S / N ratio equation as shown in Fig. 7. Figure 7 shows a change in Ra of a fluctuating S / N ratio. The average occurrence of a decrease is due to the change in the rate of small Ra while the rate of change Ra is large (from 1,467 $\mu$m to 3.6$\mu$m) on HPK1 machining results. The change of Ra in VB (0.3-0.6) mm is relatively higher, this is due to the higher rate of Ra change as in HPK2 from 3,767 $\mu$m up to 13,567 $\mu$m and
HPK7 from 9.3 μm up to 21,067 μm. Of the three Ra changes to the VB wear variation, the resulting Ra value is low with 0.15 mm / r feed for the same so for the 9 cutting conditions with the same cutting depth resulted in Ra fluctuating as a result of significant influence of the feed in determining the value Ra. Based on Table 6 it turns out that C1D3 is the 8th cutting condition providing optimum cutting conditions in the form of surface roughness Ra. So with optimum cutting condition in C1D3 it can be said that Ra surface roughness (1.976 μm) is expected which according to dry machining criteria. From Figure 8 it is shown that wear VB = 0.6 mm has a mean S / N ratio higher than VB = 0.1 mm and 0.3 mm for each factor and the same interaction because the average Ra value or ratio value S / N is bigger. Based on Table 7 ANOVA analysis, there is a correlation between factor and interaction with contribution ratio as in Fig 9 where cutting condition B = (feeding f), A = (cutting speed V), C = (cut a depth), D = (tool geometric of GP) and interaction of CxD = (interaction of cutting depth and tool geometric) shows significant differences between B (feeding f) with A, CxD, D and C. The significant factors and interactions selected from the left side cumulatively contribute 70.154% B (feeding f) has a dominant effect in the machining process.

4. Conclusion
From the experiment can be taken several conclusions as follows:

a. Testing data Roughness and hardness of AISI 4337 alloy steel surface surfaces that machining surfaces that dry machining is better than wet machining where no significant difference is seen in Figures 5 and 12.

b. In the 3 optimum cutting conditions consisting of HPK1.0.1; HPK8.0.3 and HPK8.0.6 that the variation of VB HPK8.0.6 provides a more optimum cutting condition due to Ra surface roughness and hardness of HV is more ideal than wet machining through quality aspects of machining results and in accordance with ISO 3685 which is more cutting time 5 minutes.

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