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An investigation of cutting speed effects on geometric tolerances in turning of AA 7075 aluminum alloy

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Abstract. The main purpose is to produce the machine parts within the defined geometric limits for performing their functions where they are assembled. Production between the tolerance values stated in the technical drawing is very important for rapid assembling of the shaft-hub connections working with the longevity of the moving mechanisms accurately. Because, production of machine parts at geometric tolerances is required in order to minimize the error-free assembly and undesirable conditions (heating, vibration, wear etc.). For this purpose, AA 7075 T651 aluminum alloy, which is frequently used in aviation, defense, automotive industry where desired geometric tolerance values are so important, is used as workpiece. It was machined by four different coating speeds (100, 200, 300 and 400 m/min), 0.1 mm / 0.5, 1.5 and 3 mm cut depths. The effects of cutting speed on geometric tolerances (cylindricality, circularity, linearity) after processing were investigated. It was observed that the increase of cutting speed is an effective parameter for increasing or decreasing the geometric tolerance values obtained. Increasing cutting speed was resulted in increase of tool vibration, and so increased vibration led to an increase in geometric tolerance values.

1. Introduction

While machine systems are being built, the design involves manufacturing and assembly stages. The parts are required to be produced in desired geometries, measurements, surface qualities and tolerances specified in the technical drawing for the rapid and accurate assembly. Geometry and tolerances are quite important in the manufacturing of system components that are handled particularly mobile and sensitive. Production with desired dimensions and geometric tolerances is inevitable for long-lasting and efficient operation of co-operating moving systems, such as hole-shaft and slides. Manufacturing at desired geometric tolerance values reduces the problems like misassembly, vibration, friction and high temperature. These machine parts are manufactured via many manufacturing methods. However, geometric shapes and dimensions whose manufacturing is difficult, the parts required high surface quality and special geometric details can be produced via other methods like machining. Turning is the most preferred manufacturing method for producing cylindrical and circular geometries.

Cutting parameters in the turning process are important factors in determining the geometric, dimensional and surface quality of the product. Therefore, cutting parameters are common issue for
many researchers. In earlier studies, it is seen that the cutting parameters are upon particular topics such as machinability, surface integrity and machine tool vibration. It is desired that cutting force values should remain stable without changing during turning. However, the change in cutting forces causes to vibration on the cutting tool [1]. The vibrations in the turning operation are occurred due to the structure of the machine tool, the gaps and abrasion in the bearings, the attachment type of the part, the geometrical structure of the cutting tool, the applied cutting parameters and the environmental effects [2].

The formation of BUE (Built-up edge) on the cutting tool makes the surface quality worse and causes vibrations by increasing the dynamic forces acting on the cutting insert. Control of vibrations occurring on machine tools can be done by selecting the appropriate cutting parameters [3-5]. The vibration values generated during turning are an important factor in determining surface roughness, dimensional and geometrical deviations [6]. It is known that the higher cutting speed, among the cutting parameters, means better surface roughness [7,8].

Although it is generally known that the increase in cutting speed improves the surface roughness, it has been found that the surface roughness gets worse with increasing cutting speed and vibration after a certain value [9,10]. It is generally understood from the literature that the increase in cutting speed has a positive effect on the surface roughness, but the effect on size and geometric tolerances has not yet investigated. For this purpose, in this study, the effect of cutting speed during turning of AA 7075 T651 aluminum alloy, widely used in many industries, on geometric tolerances (cylindricality, circularity, linearity) was investigated.

2. Material and method
AA7075-T651 aluminum alloy having diameter of 50mm and according to ASTM B221M-12 Standard is used in the work. The hardness of the part was measured via Burton GOKO SEIKI manual hardness tester, which is located in TUBITAK SAGE dimensional and quality control laboratory, by applying HRB type 1/16 "ball tip and 100 kg load. The physical properties and chemical composition of the workpiece are shown in Table 1. The samples having diameter of 48 mm and length of 45 mm were turned on the face of the samples and a centre hole was opened from one side. In the experiments, VCGT 160404-AS coded insert and SVJCR 2020K 16 coded tool holder were used in according to the ISO 3685 standard recommended for aluminum materials in the catalog of ISKAR.

Cutting parameters were selected with four different cutting speeds (100, 200, 300 and 400m/min), three different depth of cut (0.5, 1.5 and 3 mm) and 0.1 mm/rev feed rate recommended by the tool manufacturer. The properties of insert are given in Figure 1. Machining experiments were carried out on The SPINNER-TC65 CNC tuning lathe. CIMCOOL Cimperial 806 semi-synthetic emulsion (5%) was used as cutting fluid in the experiments. The new inserts were used for each test, and the cylindricality, circularity, linearity measurements of the parts after experiments were performed on the CMM device (Figure 2).

Table 1. The physical properties and chemical composition of the workpiece.

| The chemical composition | Cr | Cu | Fe | Mg | Mn | Si | Ti | Zn | Al |
|--------------------------|----|----|----|----|----|----|----|----|----|
| Density (g/cm³)          | 2.81 | 99.5 | 572 | 503 | 11 | 71.7 | 0.33 | 635 | 130 |

2.81 99.5 572 503 11 71.7 0.33 635 130
3. Result and discussion

After the experimental studies; cylindricity, circularity and linearity measurements were performed on the CMM device and converted into graphs in Figure 3.a-c. Examining the Figure 3, the increasing depth of cut lead to increase in deviation values of cylindricity, circularity and linearity. This situation can be interpreted as increasing cutting forces by increased chip load with increasing depth of cut. Increasing cutting forces lead to increase the deviation values of geometric tolerance by increasing the vibration amplitude of the machine tool-insert [3-5].

When the graphs are examined in terms of cutting speed, at the depth of cut of 0.5 mm, the higher cutting speed means the higher deviation values of cylindricity, circularity and linearity and they reach the highest level at cutting speed of 400 m/min. This can be attributed to that increasing cutting speed causes increase in the vibration of the machine tool-insert. However, cylindricity, circularity and linearity deviation values were the highest values at a cutting speed of 100 m/min while it decreased to the lowest values at a cutting speed of 200 m/min. in the combination with cutting speed and depth of cut of 1.5 and 3 mm. It is believed that this situation is originated from increasing machine tool-insert vibration by the BUE formation in the cutting tool at low cutting speeds and problems experienced in removing chip. The BUE formation on the insert (see Figure 4) causes fluctuations of the cutting forces, and accordingly the vibration amplitude of the insert increases [1-6].

The increasing vibration amplitude led to an increase in the deviation values. Cylindricity, circularity and linearity deviation values increased at a cutting speed of 300m / min and the maximum deviation values were measured at a cutting speed of 400 m / min. This can be attributed to an increase in cylindricity, circularity and linearity deviation values in the results of increase in machine tool-insert vibration by increasing cutting speed [10]. Therefore, the lowest cylindricity, circularity, and linearity deviation values were obtained in the combination between depths of cut of 1.5 mm and 3 mm and cutting speed of 200 m/min. The combination of these machining values, breaking and removing the chip appropriately and reducing the vibration amplitude can be considered to be effective in keeping these geometric tolerance values low.
Figure 3. Geometric tolerance values.
4. Conclusion
In this study, the effect of cutting speed on geometric tolerances (cylindricality, circularity, linearity) was investigated in turning of AA 7075 T651 aluminum alloy. As a result:

- Cylindricality, circularity and linearity deviation values at combinations of cutting speed and depth of cut of 0.5 mm increase with increasing cutting speed.
- The lowest geometric tolerance deviation values were achieved in the combinations of cutting speeds of 200 m/min and depth of cut of 1.5 and 3 mm.
- The depth of cut, BUE formation, fluctuations on cutting forces, machine tool-insert vibration caused by increase in cutting speed are very important factors in the increase in geometric tolerance deviation values.

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