Special Issue of the 6th International Congress & Exhibition (APMAS2016), Maslak, Istanbul, Turkey, June 1–3, 2016

Effect of Copper Addition to Aluminium Alloys on Surface Roughness in Terms of Turning Operation

F. Özen[a,*], F. Fiçici[a], M. Dündar[b] and M. Çolak[c]

[a]Sakarya University, Faculty of Technology, 54187, Sakarya, Turkey

[b]Çanakkale 18 Mart University, Biga Vocational School, 17200, Çanakkale, Turkey

[c]Bayburt University, Faculty of Engineering, Materials Science and Nanotechnology, 69000, Bayburt, Turkey

Aluminium alloys have found usage in numerous industries due to some superior properties, such as high strength-to-weight ratios and high oxidation resistance. Aluminum alloys can be strengthened by some techniques. One of them, the most practical one, is precipitation hardening in aluminum alloys. By adding Cu, aluminum gains strength and hardness. In this work the machinability of unalloyed aluminum and aluminum alloyed with 4% and 8% of Cu have been investigated. Machinability assessment was executed in terms of surface roughness during turning operation. Specimens were manufactured by sand casting method, which is a commonly utilized casting operation. In machinability experiments, three different cutting tool materials were employed. Three different cutting speeds and three different feed rates have been used. Effect of these feeds, speeds and cutting tool materials on surface roughness has been studied. In addition, effect of Cu addition to aluminum alloys on surface roughness has been examined.

DOI: 10.12693/APhysPolA.131.467

PACS/topics: 81.05.–t

1. Introduction

Surface roughness is an important parameter which affects fatigue life, corrosion resistance and tribological properties [1]. Namely, it is an indication of quality of machined parts and implies the tool wear condition [2]. Surface roughness is affected due to various reasons, such as cutting parameters, tool type, tool condition (wear, build-up edge), work material machinability, vibration etc. [3].

Cutting fluid is essential while cutting metals because of cutting resistance. It provides lubrication and cooling, which diminish machining temperature, cutting forces, changes wear type and reduces wear and tribological properties of both tool-chip and tool-workpiece interfaces [4]. Thus, a longer tool life is achieved. However, considering the expenditures of cutting fluids, the cost of cutting fluids is 7–17% of all machining process costs [5]. These lubricants are also pollutant or are potentially harmful for the environment [6]. Excessive contact with these fluids may cause diseases like asthma, cancer etc. [6]. These problems, which are listed above, are questioning whether using of cutting fluids can be minimized or completely stopped. To fill this gap, Minimum Quantity Lubrication (MQL) system has been developed. In this system, compressed air is mixed with a small amount of lubricants and is then sprayed into the machining zone [7]. This technique is close to dry machining. It uses approximately 10 to 100 ml/h of lubricant oil. With this utilization level, it meets economical, ecological and medicine concerns in a large degree. From the machining view, good results have also been obtained. MQL system brings out better performance than dry and conventional wet machining, achieves longer tool life, higher surface qualities, lower tool wear and lower cutting temperatures [8]. Machining of aluminium, despite being a soft material, is not easy. Because aluminium materials tend to built up edge (BUE) formation, which can be defined as accumulation of machined material on the tool tip [9]. The accumulated material distorts tool faces and results in some critical consequences, such as poor surface quality and tool failure.

In this work, the effect of different composition of Cu addition to Al on the surface roughness is investigated. Influence of different cutting parameters and different cutting tools on surface quality is also observed under MQL system condition. The amount of Cu in the Al was 0%, 4% and 8%. Taguchi experiment design is used in the tests.

2. Materials and methods

2.1. Casting of specimens

Casting alloys were melted in a SiC crucible using 8 kg capacity resistance melting furnace with 1000 °C. Furnace lining was manufactured from CaO castable lining, which has a high thermal resistance. Commercially pure aluminum Etial 8E, which is supplied from Eti Aluminum, is used in casting of specimens. 99.8% pure Cu was used for Cu alloying elements. Spectromax X spectral analysis apparatus was used to control the chemical compositions. The chemical compositions of the Al alloy specimens are shown in Table I.

Micro structure images were taken using Nikon Eclipse L150A light microscope. Microstructure of Al, Al4Cu and Al8Cu alloys are presented in Fig. 1a, b and c, respectively.

*corresponding author; e-mail: fatihozen@sakarya.edu.tr

TABLE I

Chemical composition of specimens.

Alloy	Si	Fe	Cu	Mn	Mg	Al
Al	0.10	0.15	0.03	0.021	0.009	Rest
Al4Cu	0.13	0.12	4.11	0.021	0.011	Rest
Al8Cu	0.14	0.19	7.96	0.022	0.015	Rest

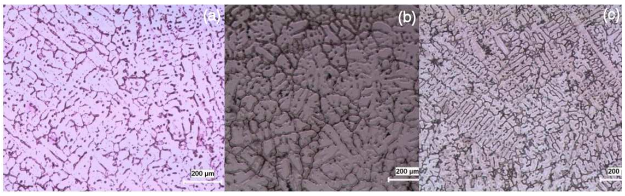

Fig. 1. Microstructure images of (a) Al, (b) Al4Cu, (c) Al8Cu.

2.2. Machining setup

Machining experiments were carried out on a Toss universal lathe with 5.5 Kw motor power. Werte MQL system was employed as the coolant system. The consumption of lubricant was adjusted to 100 ml/h. The scheme of experiment setup is given in Fig. 2. Uncoated k10 carbide (polished), TiB_2 coated K10 carbide and polycrystalline diamond were used as cutting tool materials. Tool insert type is TCGT 11 02 04, in accordance with ISO. The cutting conditions and other details are presented in Table II.

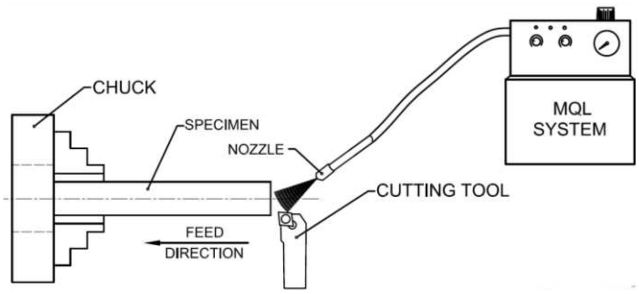

Fig. 2. Experimental setup.

TABLE II

Cutting conditions of experiment.

	I	II	III
Cutting speed	30	90	125
Feed rate	0.08	0.16	0.32
Cutting tool	Coated K10	Uncoated K10	PCD

3. Results and discussion

The SN ratios, based on "smaller is better" algorithm, are presented in Fig. 3b. It can be seen that as the Cu content in Al is raised, quality of surface roughness increases. This situation is attributed to decreasing ductility of Al. Decreasing ductility of aluminum gives raise to diminishing BUE formation and thus surface quality increases. Similar conclusions have been achieved by other researchers [10].

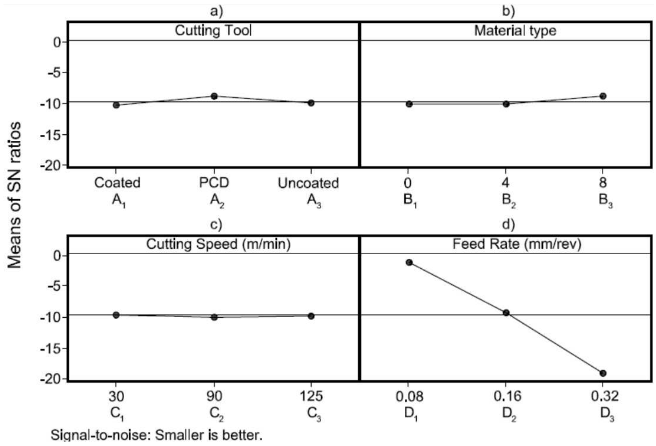

Fig. 3. Average data of surface roughness SN ratios (dB), in terms of (a) cutting tool, (b) material type, (c) cutting speed and (d) feed rate.

Figure 3 shows average data of the cutting condition results. The best conditions were obtained with 0.08 mm/rev feed rate, 125 m/min cutting speed, 8% Cu content and PCD cutting tool, which have provided the most proper cutting conditions. As seen from Fig. 3c and Fig. 4, the cutting velocity has no significant effect on surface roughness.

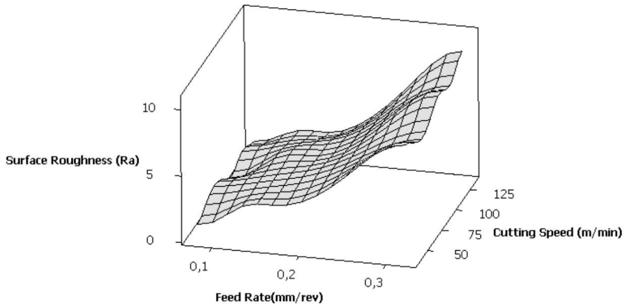

Fig. 4. Effect of feed rates and cutting speeds on surface roughness (Ra).

On the other hand, feed rate has the greatest effect. Based on Fig. 3d, it can be seen that as feed rate increases, surface roughness also increases. This situation is attributed to stronger friction between workpiece and tool interface and to the increase of the cutting zone temperature [11] at increased feed rates. Thus, surface roughness is deteriorated. These observations have been also supported by D'andorra and Sunil's study [12]. In this work, feed rates had the strongest effect. With low cutting speeds, better results were obtained. In addition, cutting speed has no important effect on surface roughness.

4. Conclusions

The following conclusions can be drawn based on this study:

1. As feed rate decreased, surface quality had increased in all experiments.
2. Feed rate was found to be the most influential factor on surface roughness.
3. Cutting speed has not shown a clear effect on surface roughness.
4. The higher surface qualities have been obtained with the PCD cutting tool.
5. As Cu content in Al was increased, the surface quality was also improving.
6. Specimen with 8% of Cu has shown a better quality than other tested specimens.

References

[1] İ. Asiltürk, M. Çunkaş, *Expert Syst. Appl.* **38**, 5826 (2011).

[2] M.S.H. Bhuiyan, I.A. Choudhury, M. Dahari, *J. Manuf. Syst.* **33**, 476 (2014).

[3] M. Elangovan, N.R. Sakthivel, S. Saravanamurugan, B.B. Nair, V. Sugumaran, *Procedia Comput. Sci.* **50**, 282 (2015).

[4] S. Ekinovic, H. Prcanovic, E. Begovic, *Procedia Eng.* **132**, 608 (2015).

[5] D. Carou, E.M. Rubio, C.H. Lauro, J.P. Davim, *Int. J. Adv. Manuf. Technol.* **75**, 1417 (2014).

[6] M. Hadad, A. Sharbati, *Procedia CIRP* **40**, 509 (2016).

[7] B. Li, C. Li, Y. Zhang, Y. Wang, D. Jia, M. Yang, *Chinese J. Aeronaut.* **29**, 1084 (2016).

[8] M.H.S. Elmunafi, M.Y. Noordin, D. Kurniawan, *Procedia Manuf.* **2**, 563 (2015).

[9] A. Gómez-Parra, M. Álvarez-Alcón, J. Salguero, M. Batista, M. Marcos, *Wear* **302**, 1209 (2013).

[10] Y. Ozcatalbas, *Mater. Des.* **24**, 215 (2003).

[11] D.G. Thakur, B. Ramamoorthy, L. Vijayaraghavan, *Mater. Des.* **30**, 1718 (2009).

[12] D.M. D'Addona, S.J. Raykar, *Procedia CIRP* **41**, 841 (2016).