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Research article

THE EFFECT OF COOLING METHOD ON SURFACE ROUGHNESS IN DEEP HOLE DRILLING OF ALUMINIUM ALLOYS

Tomasz Pałka[1]✉

[1] Lublin University of Technology, Faculty of Mechanical Engineering, Nadbystrzycka 36, 20-618 Lublin, Poland
✉ corresponding author: t.palka@pollub.pl

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ABSTRACT

This paper presents the results of an experimental study investigating the effect of usage of different cooling methods in drilling of aluminum alloys with different surface roughness properties of these materials. Two alloys were tested: EN AW2024 and AlSi10Mg with a high silicon content. A comparison was made between surface roughness parameters obtained as a result of the usage of different cooling and lubrication methods such as emulsion cooling, MQL and compressed air cooling. In the experiment, holes with the depth range from 5xD to 15xD were machined using different hole machining strategies.

KEYWORDS: drilling, surface roughness, minimum quantity lubrication, aluminum alloys

1. Introduction

The development of machining methods involves searching for solutions that would increase process efficiency and would be environment-friendly at the same time. The use of machining fluids is part of machining processes, and attempts to completely eliminate their use have been unsuccessful. The development of different cooling methods opens up the possibilities for reducing water consumption and use of cooling and lubricating agents that need to be stored and disposed of [1]. The availability of a wide range of cooling and lubrication methods results in reduced production costs, increased machining efficiency, lower tool wear, as well as higher stereo metric properties of the surface. This offers a vast spectrum of possibilities regarding the use of various cooling and lubrication methods [2].

Aluminum alloys are widely used in the aviation industry. EN AW7075 is an easily machinable grade with low cutting resistance and good chip-forming properties. It must, however, be remembered that like all aluminum alloys, this alloy is also susceptible to the formation of a build-up edge and – in extreme cases –to chip sticking. Therefore, the deep hole drilling operation poses a fundamental technological problem related to the plasticization and adhesion of the material at the cutting edge. AlSi10Mg alloy is a material with good cutting properties. A high content of silicon causes excessive wear of the cutting tool, which results in faster abrasion of the cutting surfaces. By taking advantage of the potential of different cooling and lubrication methods, it is possible to improve both the efficiency of the process and its individual parameters including surface roughness [3, 4].

2. Plan of the experiment

The objective of the study was to determine the effect of cooling and lubrication on the surface roughness parameters Ra and Rz of drilled materials. An uncoated carbide twist drill bit with a diameter of d=6mm and a tool length of L=100mm was used. Test specimens had the dimensions of 150mm x 60mm x 70mm. Blind holes were drilled with a drilling depth of 5 x d, l_a = 30mm. Deep holes were drilled with two drilling depths: 10 x d l_a = 60mm and 15 x d l_a = 90mm. Two different hole machining strategies were employed: simple drilling wherein the tool penetrated the solid material over the entire hole depth and drilling with chip removal. The tests were conducted on the Avia 800HS CNC milling center. Each test was repeated five times (Tab. 1). Surface roughness measurements were made with the Taylor Hobson T1000 profilometer. Tab.1 shows the plan of the experiment.

Table 1. Plan of the experiment

Material	Dry	MQL	Air	None
EN AW7075	5D/10D/15D	5D/10D/15D	5D/10D/15D	5D/10D/15D
AlSi10Mg	5D/10D/15D	5D/10D/15D	5D/10D/15D	5D/10D/15D

The tests were repeated for each material. Five test runs were performed for each measurement. Surface roughness was measured at three locations: in the center of the hole, 5mm below the surface of the hole and 5mm above the cylindrical part of the bottom of the hole. The photographs below show the test stand [5, 6].

Figure 1. Test stand and examples of drilled holes

3. Results

In this section the experimental results obtained in the study are discussed. Fig.1 shows the effect of selected cooling methods on the surface roughness parameter reobtained for the material machined to a depth of l_a = 30mm by simple drilling. It can be observed that the values of the Ra parameter decrease depending on the cooling and lubrication method. When the drilling process is conducted with air cooling or without it, the value of this surface roughness parameter increases. Higher Ra values can also be observed for the material with a higher silicon content. The highest values of this roughness parameter can be observed when MQL is used and no cooling is applied. This is associated with the formation of additional machining products in the form of quartz particles that cause damage to the machined surface.

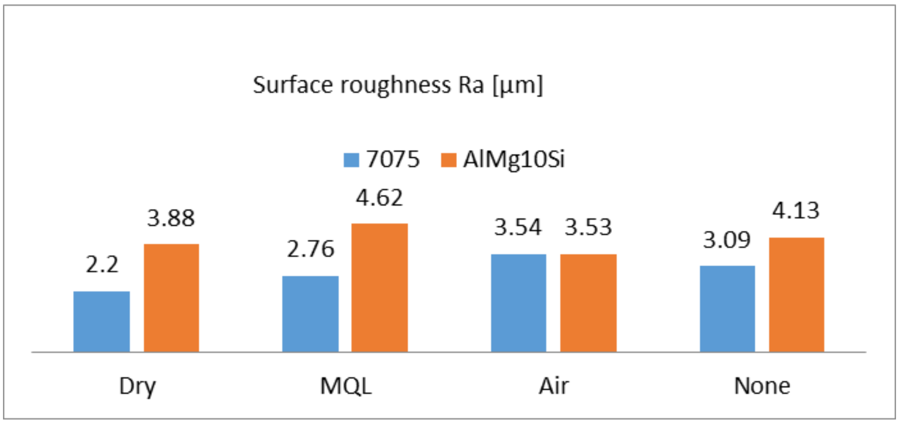

Figure 2. Effect of selected cooling and lubrication methods on the surface roughness parameter Ra in a simple drilling process conducted with l_a = 30mm

Results obtained in the chip-removal drilling process for producing a hole with a depth of 15 x d l_a = 90mm are shown in Fig.2. It can be observed that despite a greater stability of this process, the analyzed surface roughness parameter increased. This is related to the nature of tool work in this process. As a result of repeated penetration of the hole by the drill, the machined surface was damaged both by random chips and by the formation of a build-up edge. That means that even though the process was stable, the surface roughness of the material did not decrease. Also, it can be observed that the effect of the cooling method is of lesser significance.

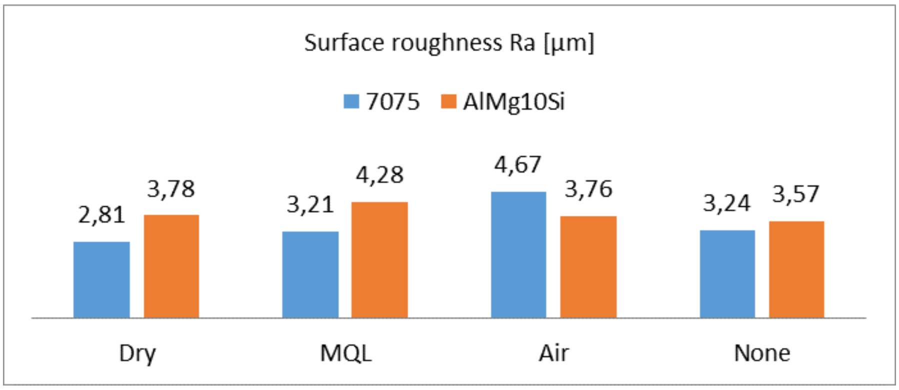

Figure 3. Effect of selected cooling and lubrication methods on the surface roughness parameter Ra in drilling with chip removal conducted with l_a = 90mm

Fig.3 shows the effect of selected cooling and lubrication methods on the surface roughness parameter Ra of EN AW7075 for holes drilled with depths of 5 x d, 10 x d and 15 x d. The holes were drilled using both simple drilling and drilling with chip removal. It can be observed that for the simple drilling strategy, the surface roughness parameter increases along with the depth of the hole. It can be concluded that this parameter's value depends on whether the chips are removed and on their length. There is a higher probability that the machined surface will be damaged by chips deposited in the chip space and, possibly, by double cutting effect. Two trend lines for simple drilling and drilling with chip removal are marked in the diagram. It can be seen that the line flattens for drilling with chip removal, which means that the roughness parameter value is at a constant level and does not change with the cooling and lubrication method. It can be concluded that both shallow and deep hole drilling conducted with $l_a \geq 10d$ is feasible regardless of the cooling and lubrication method employed, and that the obtained surface roughness parameter Ra values will be similar.

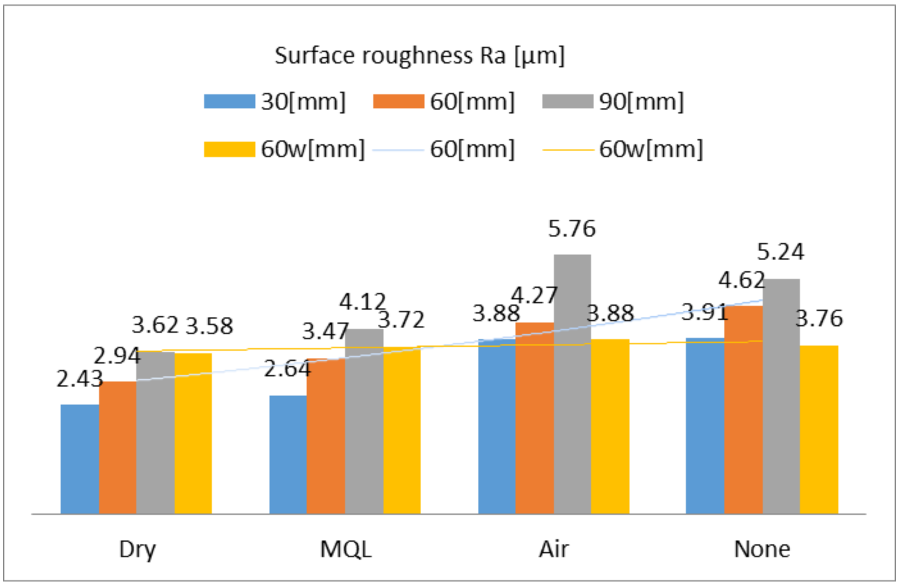

Figure 4. Effect of selected cooling and lubrication methods on the surface roughness parameter Ra of EN AW7075 when drilling holes with different depths and tool diameters

Fig.4 shows the experimental results obtained for AlMg10Si. It can be observed that the use of drilling with chip removal led to an increase in the roughness parameter Ra value when the drilling process was conducted without cooling lubricant. As for MQL, the surface roughness parameter did not decrease as was the case with hole drilling in EN AW7075. In the machining of alloys with a high silicon content, dust-like chips are produced. In combination with oil, these dust fractions form a specific abrasive film and cause further damage to the machined surface. Hence, the drilling process conducted without cooling lubricant in the depth range of $l_a \geq 10d$ caused no changes in the surface roughness parameter Ra of AlMg10Si.

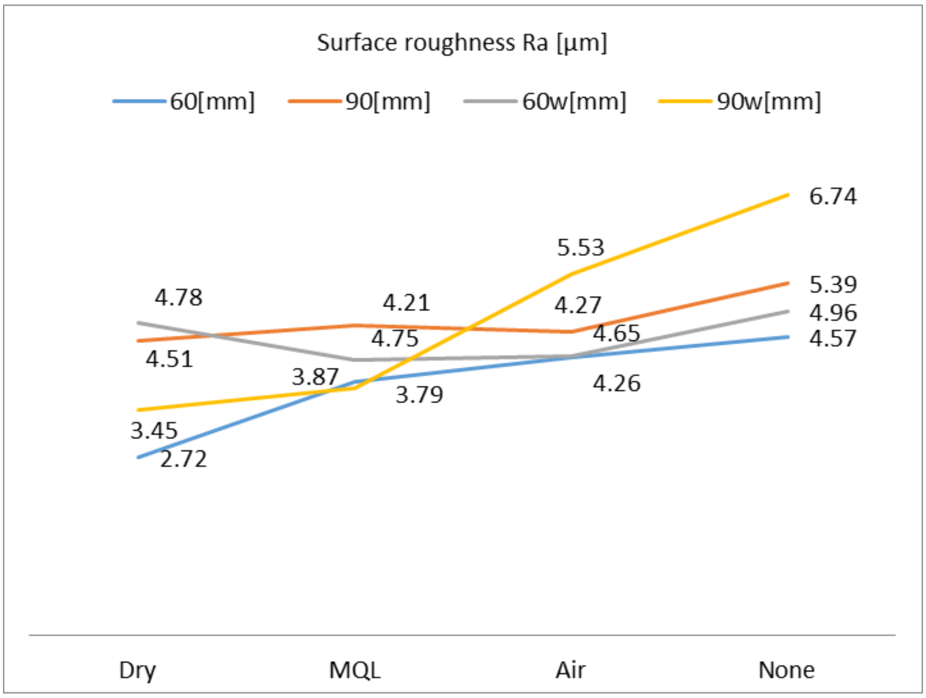

Figure 5. Effect of selected cooling and lubrication methods on the surface roughness parameter Ra ofAlMg10Siwhen drilling holes with different depths and tool diameters

The lowest surface roughness was obtained when the drilling process was conducted with emulsion cooling. This drilling strategy led to optimal removal of machining products such as chips and quartz dust. If effectively removed, quartz dust does not cause surface damage.

4. Conclusions

The following conclusions have been drawn from the results of this study. The hole drilling process conducted with the use of minimal lubrication in combination with emulsion cooling did not significantly affect the surface roughness of the EN AW7075 alloy. No significant differences were observed depending on the machining strategy used. In deep hole drilling, there was a periodic problem with chip sticking when the drilling process was conducted with either air cooling or no cooling at all. The EN AW7075 alloy is an easily machinable material with low cutting resistance. Therefore, with correctly selected cutting parameters and tool geometry, low surface roughness parameters will be obtained. What poses problems in the deep drilling of AlMg10Si is the presence of machining products in the form of chips (quartz dust) that cause damage to the machined surface, which means that standard cooling must be used for dust removal from the holes. The use of MQL is not recommended because it causes chip sticking due to high viscosity of oil.

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