Dry, Semi-Dry and Wet Machining of 6061-T6 Aluminium Alloy

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Additional information is available at the end of the chapter

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1. Introduction

In the industries, several techniques are used to reduce the manufacturing costs and to protect the environment. In machining process, the used of lubrication could play an important role in different parameter such as tool life, cutting temperature, surface finish, chip formation and metallic particle emission.

The use of cutting fluids is between 7 to 17% of manufacturing costs parts [1]. In this point of view dry machining could help to reduce the cost of cutting fluid and to protect the environment. The main problem of using the cutting fluid instead of reducing the cutting zone temperature is the aerosol generation during the machining process [2].

Sutherland et al. [3] showed in their study that the aerosol quantity produces in the lubrication machining could be 12 to 80 times higher compared to the dry machining. Anselmo et al. [4] carried out a study in dry machining of steel 1045 using two different tools. They found that dry machining requires a very hard tool material that is resistant to high temperature. They also found that tool life in dry machining could be similar in lubricated machining if the cutting depth is fewer with high cutting speed.

Although the good performance of dry machining, the major problem is still the tool wear under severe conditions which sometimes need the use of small lubrication fluid. Some researchers [1, 5, 6] developed a method using small lubrication fluid in machining process. Using the absorption characteristics of the ester model and the surface tool analysis some researchers [1, 7] carried out a study on a tribology of cutting performance in semi-dry.

In machining process, Islam et al. [8] in their work studied the turning performance in lubrication condition. They showed that the cutting fluid supply strategies have no influence on the surface finish but the amount of MQL (minimum quantity lubrication) could have an influence. Machado et al. [9] showed in their study on turning of carbon steel that the decreasing of the cutting fluid debit decrease the cutting force and improve the surface finish.

The surface finish is an indicator of the quality of the material following the machining process. Vikram Kumar et al. [10] carried out a study on surface roughness during hard turning in Dry, MQL and wet conditions on AISI 4340 alloy steel. The feed rate range use in this work was from 0.04 to 0.06 mm/rev. The authors showed that in the different lubrication condition the roughness against the feed rate is constant. The feed rate range use in this work is too limited to establish a good relationship between roughness and feed rate and also to observe that the cutting speed has no influence on roughness. At the same feed rate, the roughness is low in the MQL condition compare to wet and dry condition.

Another study was also carried out in a study of surface roughness during hard turning in Dry, MQL and wet conditions on AISI 4340 alloy steel [11]. In this study, the feed rate range was from 0.05 to 0.14 mm/rev and the maximum of cutting speed was 120 m/min. The authors observed that from 0.05 to 0.1 mm/rev feed rate range the roughness is approximately similar and constant at different lubrication condition. From 0.1 to 0.14 mm/rev, the roughness increases with the feed rate and is low in the MQL condition compared to wet and dry condition. In this work again, the feed rate and the cutting speed range larger still limited to establish a good relationship between roughness and feed rate. Ozawa et al. [12] also showed that using MQL gives good results about surface roughness.

Decreasing the chip size improves tool life, surface finish and the energy required for machining. Several research works have analyzed chip formation, including works by Hua et al. [13], Poulachon et al. [14] and Jawahir et al. [15], which have covered different types of chips: continuous chip, segmented chip and elemental chip. Dhar et al. [16] have done some investigations on turning of AISI 1040 steel in Dry, MQL and wet conditions. The authors studied the chip formation by analysing the chip reduction coefficient. In this study, the feed rate range was from 0.1 to 0.2 mm/rev and the cutting speed range was from 60 to 130 m/min. This study was also about turning of AISI 1040 steel. The authors observed that the chip reduction coefficient decreases when the cutting speed increases at different feed rate. In another hand the MQL condition present the lowest values compared to the wet and the dry condition.

Dhar et al. [16] have presented the effect of dry, MQL and wet lubrication on tool wear. This work presents the tool wear after machining during 45 min in the dry, MQL and wet condition in the turning process of steel material. The authors observed that the tool wear is less important in the MQL condition compared to wet and dry condition. In the case of aluminum alloys, the considered criterion for tool life is the tool breakage due to adhesion of the aluminum alloy on the tool as a result of the heat involved in the process or the wear experienced by the cutting tool. Nouri et al. [18], showed in their study in dry drilling of aluminum that the most important causes of tool wear are the diffusion and adhesion of the material, which could degrade the surface finish. Damir et al [19] and Diakodimitris et al. [20] also presented the effect dry, MQL and wet lubrication on tool wear in the milling process. In this work, the authors showed that MQL clearly improves the tool life reducing the tool wear drastically.

Machining processes generate aerosols (in dry, MQL and wet conditions) which are harmful both to the health of operators and to the environment [3, 16, 22, 23, 24, 25, 26]. Sutherland et al. [3], in their machining work, showed that particle emissions is high in wet machining compared to dry machining. They also showed that particle emissions increase with the cutting speed. Khettabi et al. [24] also carried out a study in particle emission during turning of the 6061-T6 aluminium alloy, and 1018 and 4140 steels, using carbide cutting tools. In their work they showed that there is two speed regimes were the particle emissions is minimize. This observation was also confirmed by Kouam et al. [25] in their work on drilling, and by Kouam et al. [26] in their work on friction.

The aim of this research is to investigate the effect of the lubrication (dry, semi-dry and wet) during the turning of 6061-T6 aluminum alloy. The process performance indicators investigated include the surface roughness, tool wear, chip formation and particle emission.

2. Lubrication effect on turning processes of 6061-T6

Turning tests were carried out on 6061-T6. The tool insert used had a TiB_2 PVD (Physical Vapor Deposition) coating over a very deformation-resistant unalloyed substrate with 80° nozzle angle and 11 relief angle.

The experiments were conducted on a lathe turn Darbert Machinery model and the experimental parameters were as follows:

- Cutting speed: 79.40-661.54 m/min.
- Feed rate: 0.0508-0.2845 mm/rev
- Cutting depth: 1 mm
- Lubrication condition: dry, semi-dry (3.06, 1.75 and 0.6 ml/min debit) and wet

The chemical composition of 6061-T6 is in Table 1.

	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
6061-T6	0.7	0.5	0.22	0.09	0.93	0.08	0.15	0.08	Balance

Table 1. Chemical composition of 6061-T6 alloys

In semi-dry condition, two lubricants (Mecagreen 550 and Microkut 400) were used and in wet condition, the commercial lubricant at 306 ml/min debit was used.

An original cooling and lubrication method is used here under the form of micro-lubrication or MQL (Minimum Quantity Lubrication) [19]. The main component of this MQL system is an airblast atomizer injector (as the SB202010 shown on Figure 1, with an oil nozzle diameter of 0.25 mm, from System Tecnolub Inc.). The injector operates with pressurized air. The pressurized air arrives to the system and passes through a filter equipped with a dryer; the air then goes through a pressure regulator and reaches the external channel of the atomizer. The oil is transported to the internal channel of the atomizer through a micro volumetric piston pump and various regulators.

Finite element methods were used by the ULB team to simulate and to optimize the obtained spray phenomenon. Computational fluid dynamics (CFD) simulations with FINE/Open 2.11.1 were used to study the air injection in the ambient environment (single phase flow simulations). In Figure 2, a cross section of the annular air channel of the SB-202010 nozzle shows the resulting velocity field for an air flow rate of 31 l/min. As it is observed in Figure 2, blue color characterize the low speed particle (between 0 to 2.5 m/s) and red color the high speed particle (between 17.5 to 20 m/s). The computational domain is made up of around 1 000 000 finite elements.

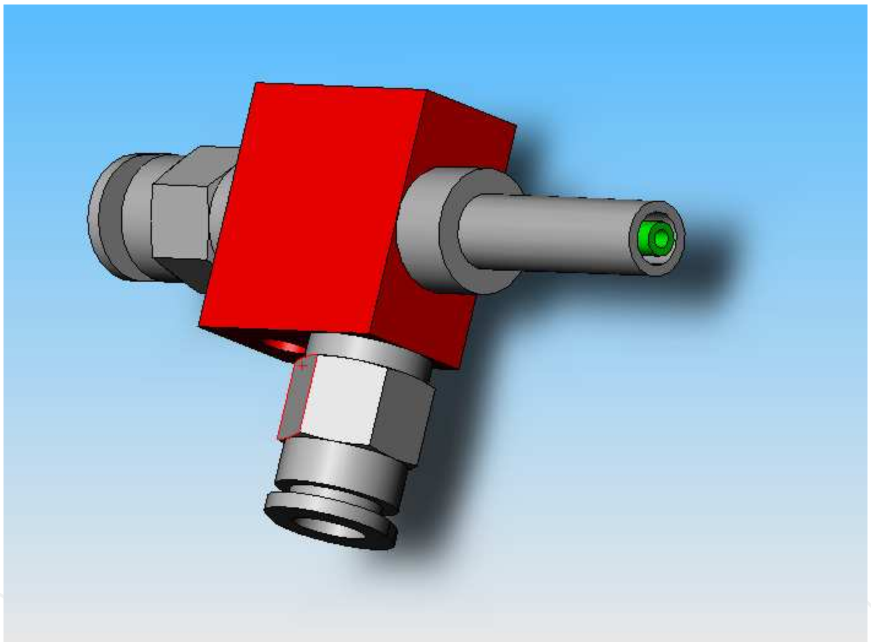

Figure 1. A typical MQL oil-air atomizer / injector

Experimental characterizations of the oil-air spray were also done at ULB in order to optimize the spray shape and precision and the corresponding injector geometry as well as its working parameters. An example of such a test result is shown on Figure 3 with a PIV (particle image velocimetry) measurement. This experimental testing (also done using PDA and laser diffraction measurements) was used in conjunction with two-phase flow CFD numerical simulations (also with the FINE software) of the oil-air spray.

The oil through the central channel of the atomizer can be either pure lubricating oil or an oil/water mixture (at a ratio like 5/95).

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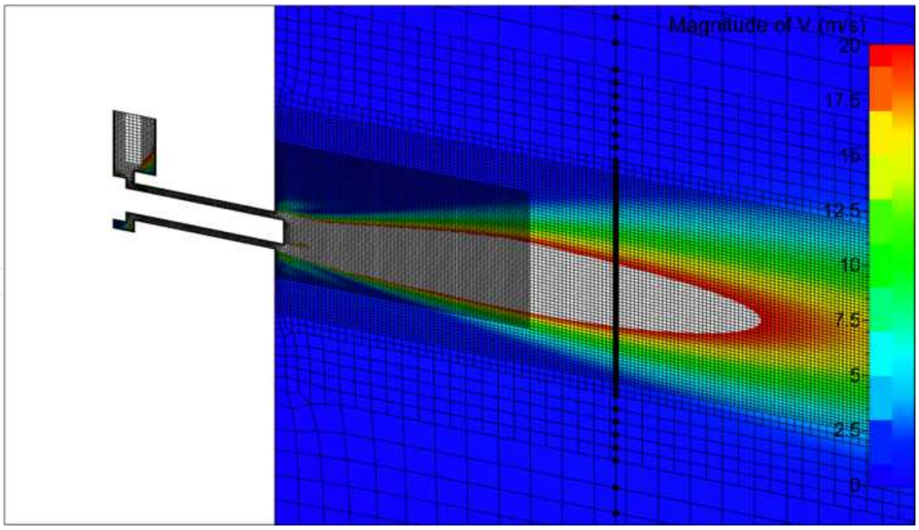


Figure 2. Illustration of the air velocity at the exit of the injector (m_g = 31 l/min)

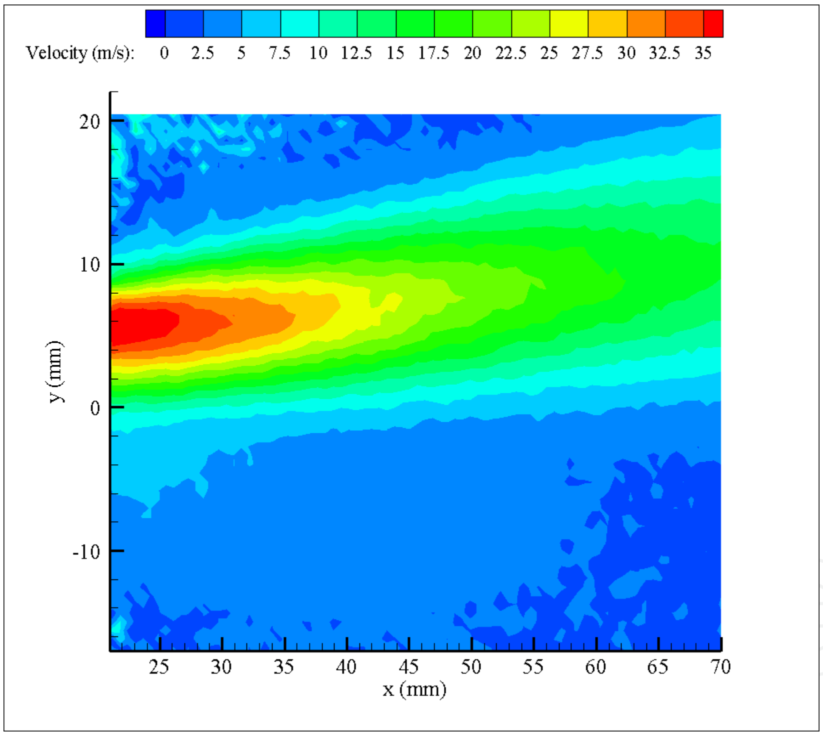
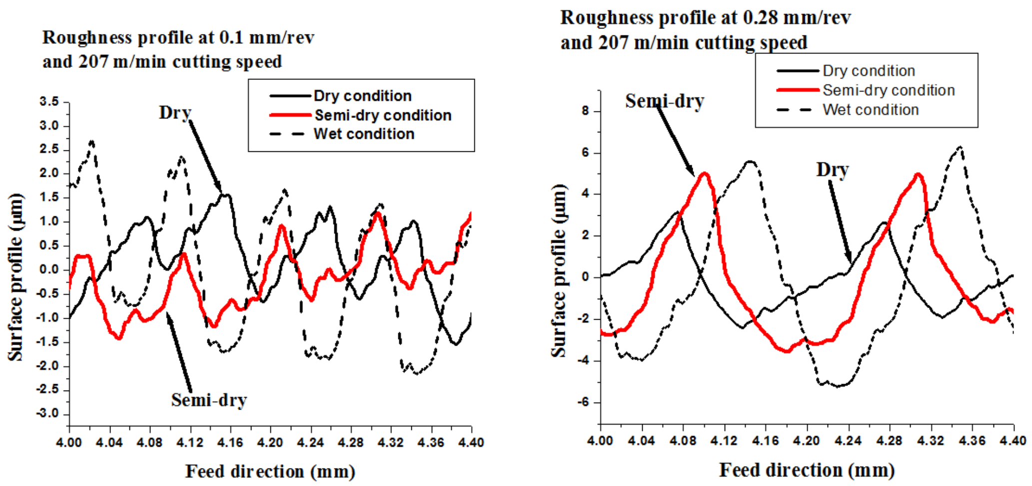


Figure 3. PIV measurement of the oil velocity after the injector

2.1. Effect of lubrication and cutting conditions on part quality

Figure 4 presents the roughness profile against different feed direction of 6061-T6 during turning at 207 m/min cutting speed in dry, semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet condition at low and high feed rate. The Mitutoyo SJ-400 equipment was used to measure the surface roughness. It is observed that in figure 4a (at low feed rate) the roughness profile is high in the wet condition compared to semi-dry (Mecagreen 550 at 3.06 ml/min debit) and dry conditions. In Figure 4b (at high feed rate) the roughness is high in the wet condition compared to semi-dry (Mecagreen 550 at 3.06 ml/min debit) and dry conditions as in Figure 4a. In this case (Figure 4b) the roughness profile is high the semi-dry (Mecagreen 550 at 3.06 ml/min debit) condition compared to the dry condition, which is the opposite of what is observed in Figure 1a.



a) at low feed rate

b) at high feed rate

Figure 4. Roughness profile against different feed direction at 207 m/min cutting speed

Figure 5 presents the roughness at different cutting speed and feed rate respectively. It is confirmed on Figure 5 that the cutting speeds does not influence the surface finish which is mostly influenced by the feed rate (Figure 6) and the lubrication conditions.

Figure 6 presents the roughness at different feed rate of 6061-T6 during turning at 207 m/min cutting speed in dry, semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet condition. It is observed that at low feed rates (0.05 and 0.10 mm/rev) the roughness is high in the wet condition compared to semi-dry (Mecagreen 550 at 3.06 ml/min debit) and dry conditions. The roughness is still high in the dry condition compare to semi-dry (Mecagreen 550 at 3.06 ml/min debit) condition. This observation was confirmed by the work done by Dhar et al. [16] and Kamata et al. [27]. In their work they showed that the cutting performance of semi-dry machining is better than that of dry and conventional wet machining. They have also shown that the dry machining is better than the wet cutting.

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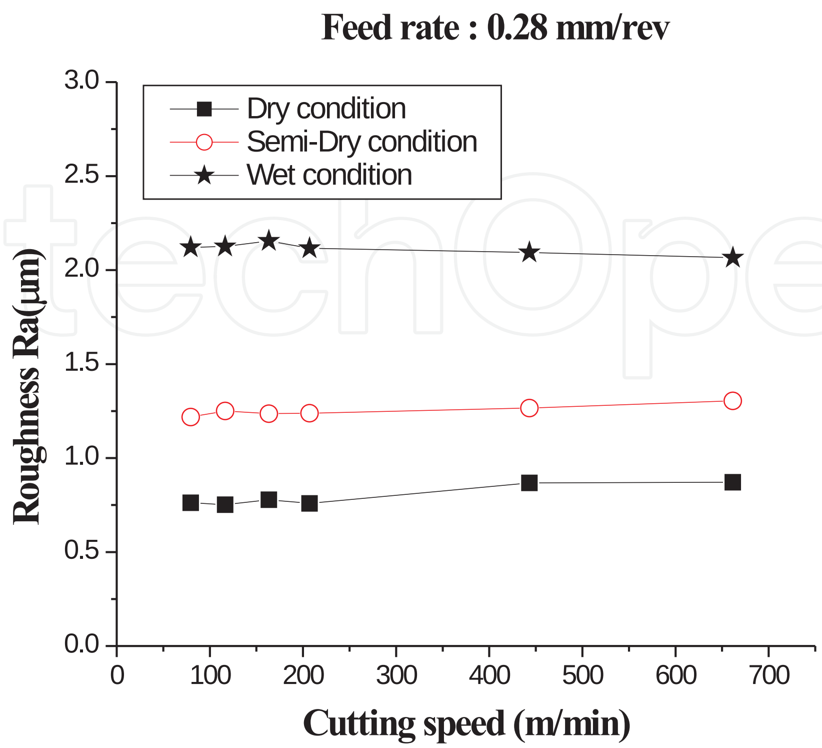


Figure 5. Roughness against cutting speed

In the work done by Vikram Kumar. [10] and Varadarajan et al. [11], they showed that the semi-dry machining is also better than that of dry and conventional wet machining but the wet is better compare to the dry cutting.

In general, the roughness is high in the wet condition compared to semi-dry and dry conditions. For feed rates higher than 0.10 mm/rev, the roughness is high in the semi-dry condition compared to the dry condition.

Figure 7 presents the roughness at different feed rate of 6061-T6 during turning at 207 m/min cutting speed in dry, semi-dry, wet condition and theoretical values. The theoretical roughness R_{ath} was obtained using Boothroyd et al. [28] formula in equation (1) as follow:

$$R_{ath} = 0.0321 \frac{f^2}{r_\varepsilon} \quad (1)$$

where f is the feed rate and r_ε is the tool insert nozzle radius.

It is observed in Figure 7 that at low feed rate (from 0.05 to 0.10 mm/rev feed rate) the theoretical roughness is low compared to dry, semi-dry and wet condition. At high feed rate (after 0.10 mm/rev feed rate) the theoretical roughness still be low compared to semi-dry and wet condition but be high compared to the dry condition which is the opposite of what is observed in the case of low feed rate.

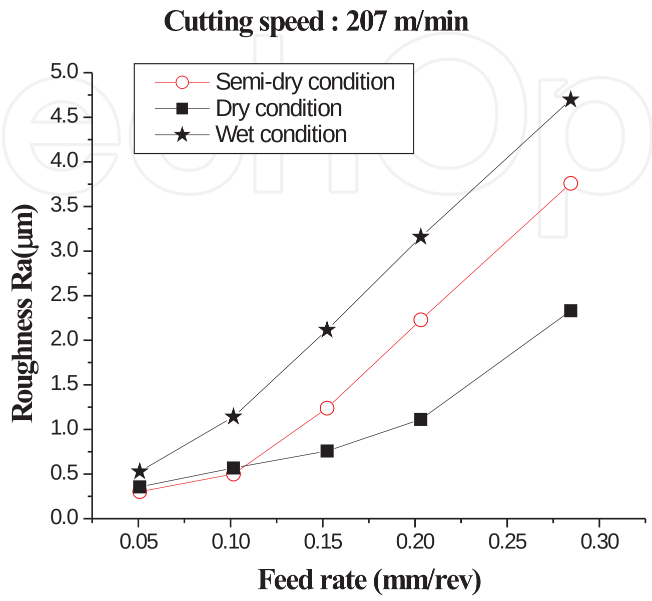


Figure 6. Roughness at different feed rate in in dry, semi-dry and wet condition dry, semi-dry and wet condition

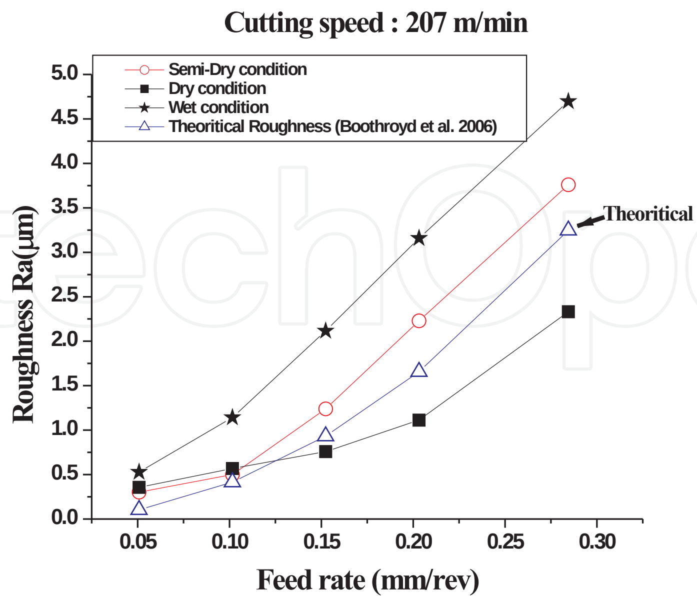
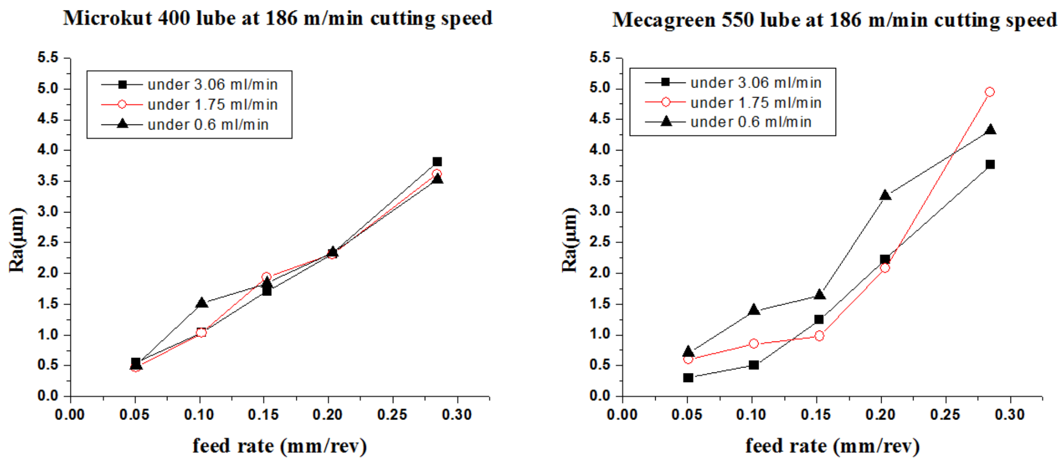


Figure 7. Roughness at different feed rate in dry, semi-dry and wet condition



a) Microkut 400 lubricant

b) Mecagreen 550 lubricant

Figure 8. Roughness at different feed rate at 186 m/min cutting speed at different lubrication debit using Microkut 400 and Mecagreen 550 lubricant

Figure 8 presents the roughness at different lubrication debit of 6061-T6 during turning at 186 m/min cutting speed using Microkut 400 and Mecagreen 550 lubricants. It is observed that the roughness in turning of 6061-T6 at different feed rate using microkut 400 lubricant (Figure 8a) is similar at different lubrication debit which is different in the case of Mecagreen 550 (Figure 8b). In Figure 8b it is also observed that the roughness is high at 3.06 ml/min debit compared to 1.75 and 0.6 ml/min debit. This observation could be due to the fact that in machining process Mecagreen 550 lubricant is generally used as a cooler of the cutting zone. The average roughness is low using Microkut 400 lubricant compared to Mecagreen 500. This observation confirmed the fact that Microkut 400 lubricant is the recommended one to be used to have a good surface finish in the turning process.

Figure 9 presents lubrication debit comparison on the roughness during turning process of 6061-T6 at the same cutting speed using Microkut 400, Mecagreen 550 and commercial lubricants. The commercial lubricant debit was 306 ml/min and Microkut 400 and Mecagreen 550 lubricant debit was 3.06, 1.75 and 0.6 ml/min.

The general observation (Figure 9a, 9b and 9c) is that the roughness is high when using the commercial lubricant compared to Microkut 400 and Mecagreen 550 lubricants. It is also observed that at 3.06 ml/min lubrication debit (Figure 9a), the roughness using Microkut 400 lubricant and Mecagreen 550 is similar at high feed rate. Using 1.75 ml/min lubrication debit (Figure 9b), the roughness using Microkut 400 lubricant is low compared to Mecagreen 550 high feed rate. Using 0.6 ml/min lubrication debit (Figure 9c), the lower tendency of the roughness using Microkut 400 lubricant compared to Mecagreen 550 high feed rate observed in Figure 9b is more pronounced. This observation confirmed the fact that Microkut 400 lubricant is more useful in the case of having a good surface finish in the turning process.

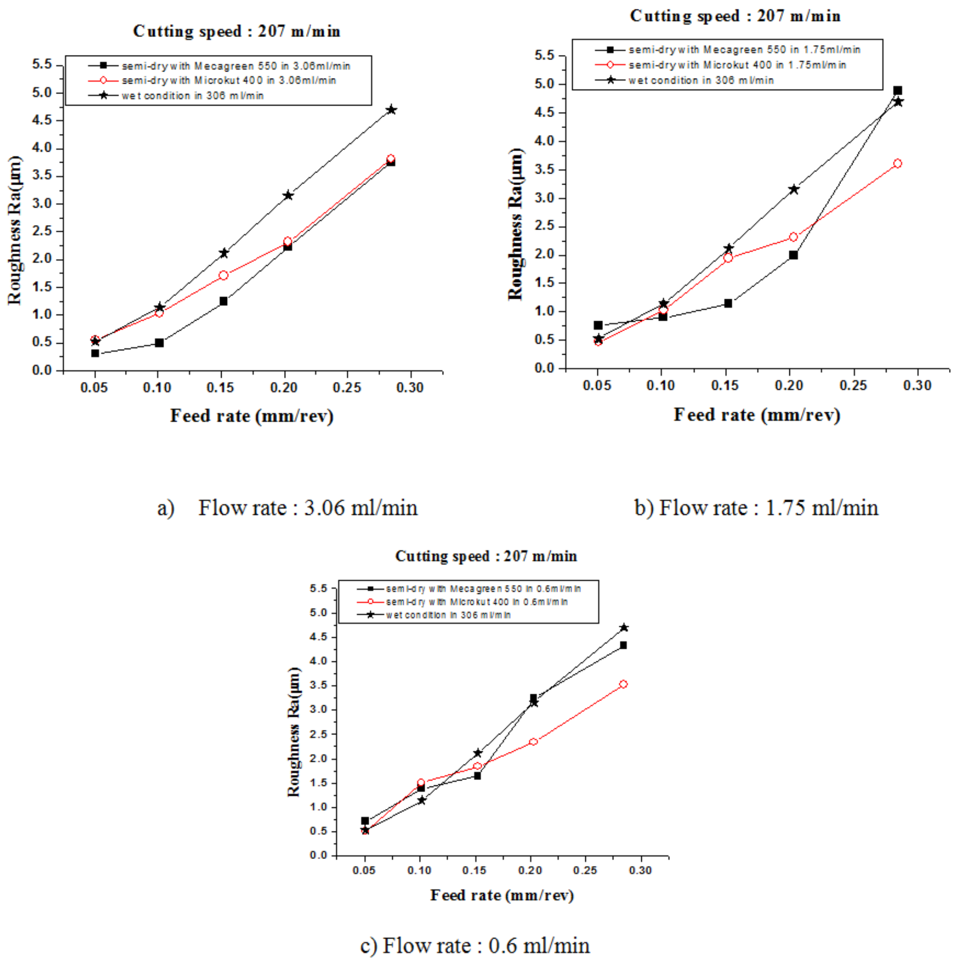


Figure 9. Lubrication debit comparison on the roughness during turning process of 6061-T6 at the same cutting speed using Mecagreen 550 and Microkut 400 lubricant

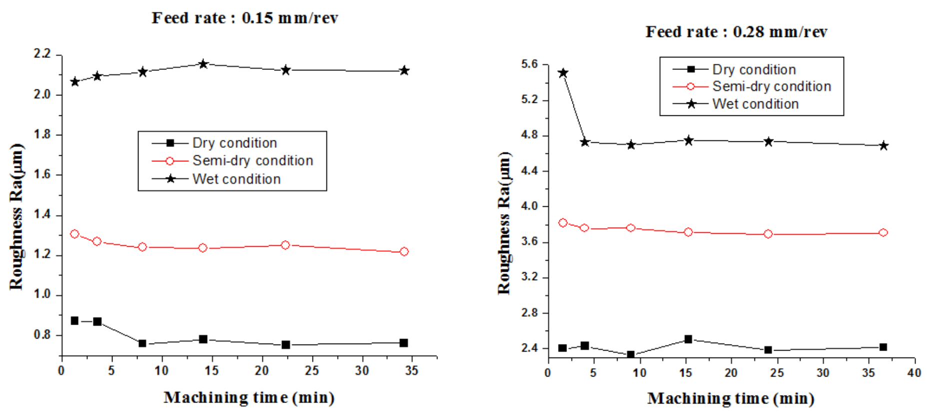


Figure 10. Roughness comparison at different machining time in dry, semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet conditions at 0.15 and 0.28 mm/rev feed rate

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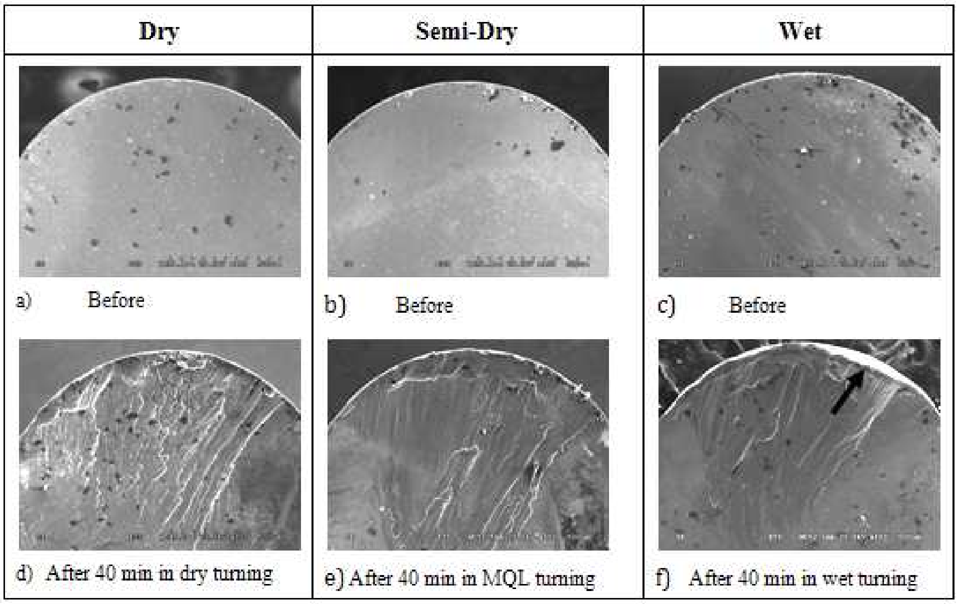


Figure 11. SEM insert tool wear images in dry, Semi-dry (Mecagreen 550 at 3.06 ml/min debit) and Wet conditions: magnification 100x

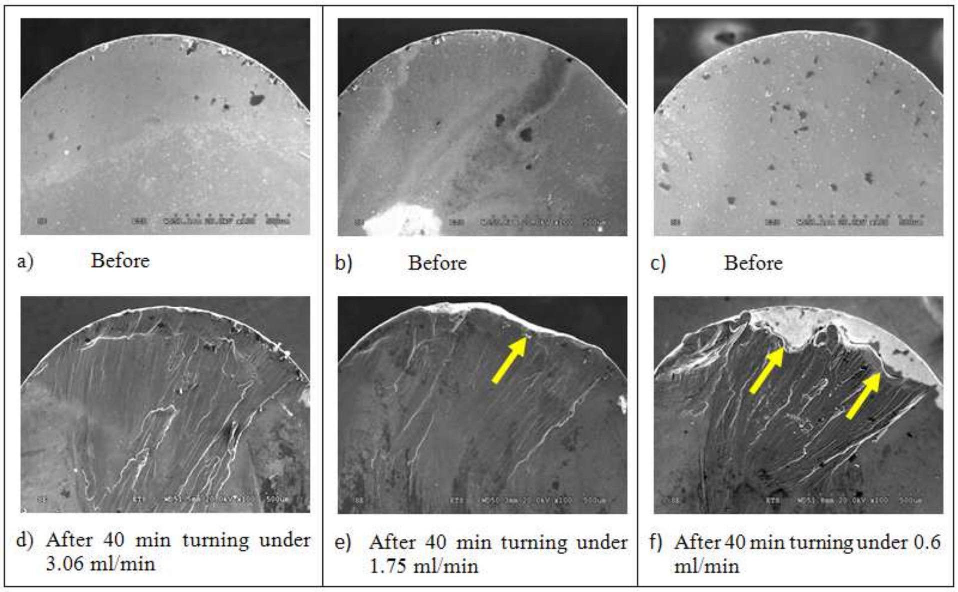


Figure 12. SEM insert tool wear images under Mecagreen 550 lubricant at different lubrication debit: magnification 100x

Figure 10 presents the roughness of 6061-T6 at different machining times in dry, semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet conditions during turning at 0.15 and 0.28 mm/rev feed rate. It is observed that under different lubrication conditions the surface roughness does not change much with the machining time. This observation is an indication that the tool wear after 40 min machining is not too significant (Figure 9).

2.2. Tool wear

Figure 11 presents SEM images of the cutting tool insert before and after in different lubrication conditions. It was observed that the separate tool insert used to machine the 6061-T6 aluminum alloy exhibited a normal tool insert life under the test conditions used and no premature tool insert wear or breakage occurred during the turning tests.

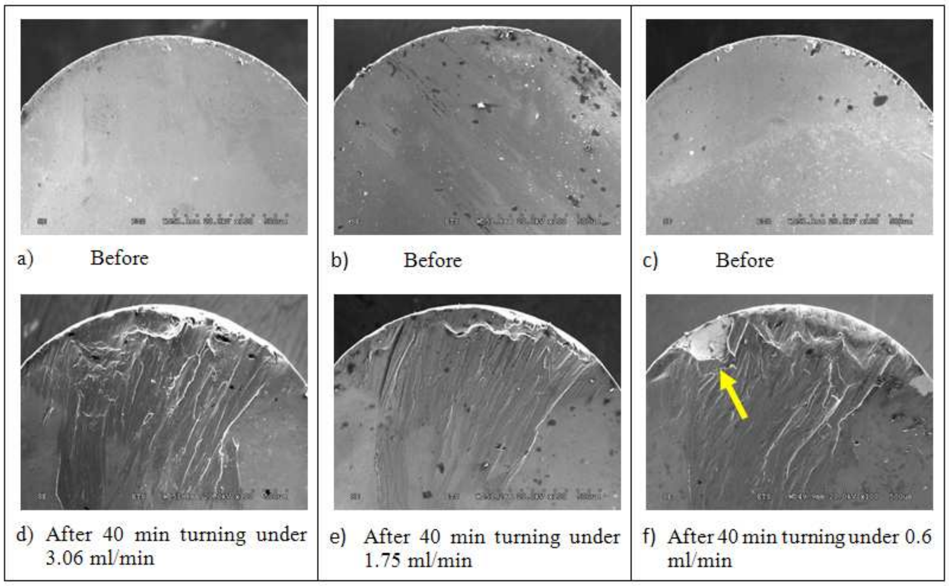


Figure 13. SEM insert tool wear images under Microkut 400 lubricant at different lubrication debit: magnification 100x

After 40 min in turning process, it was observed that in the dry and semi-dry (Mecagreen 550 at 3.06 ml/min debit) conditions (Figure 11d and 11e), no significant wear occurred for the cutting tool insert lip. Figure 11f shows that the cutting tool insert lip became worn and exhibited a small wear in the wet conditions.

Figure 12 presents SEM images of the cutting tool insert before and after at different lubrication debit of 6061-T6 after 40 min turning process using Mecagreen 550 lubricant. As in Figure 11 (a, b and c) it was observed (Figure 12a, 12b and 12c) that the separate tool insert used to machine the 6061-T6 aluminum alloy exhibited a normal tool insert life under the test conditions used and no premature tool insert wear or breakage occurred during the turning tests.

After 40 min in turning process, it was observed that in 3.06 ml/min debit condition (Figure 12d), no significant wear occurred for the cutting tool insert lip. Figure 12e shows that the cutting tool insert lip became worn and exhibited a small wear in 1.75 ml/min debit. In 0.6 ml/min debit (Figure 12f), the cutting tool insert lip became more worn and exhibited wear more pronounced compared to 1.75 ml/min debit (Figure 12e). This observation confirmed the relationship between roughness (Figure 8b) and tool insert wear during turning process.

Figure 13 presents SEM images of the cutting tool insert before and after at different lubrication debit of 6061-T6 after 40 min turning process using Microkut 400 lubricant. As in Figure

11 (a, b and c) and Figure 12 (a, band c) it was observed (Figure 13a, 13b and 13c).It was observed that the separate tool insert used to machine the 6061-T6 aluminum alloy exhibited a normal tool insert life under the test conditions used and no premature tool insert wear or breakage occurred during the turning tests.

After 40 min in turning process, it was observed that in 3.06 and 1.75 ml/min debit condition (Figure 13d and 13e), no significant wear occurred for the cutting tool insert lip. Figure 13f shows that the cutting tool insert lip became worn and exhibited a wear.

In 0.6 ml/min debit the cutting tool insert lip exhibited wear more pronounced using Macagreen 500 lubricant (Figure 12f) compared to Microkut 400 lubricant (Figure 13f). This observation confirmed the relationship between lubricant and tool insert wear during turning process.

2.3. Chip control and chip quality

Figure 14 presents the chip thickness at different cutting speed and different feed rates using Microkut 400 lubrication at two flow rates : 3.06 ml/min and 0.6 ml/min. It is observed that at low feed rate the chip thickness is similar at different cutting speed. But at the high feed rate the chip thickness decrease with the increasing of the cutting speed. The effect of the lubricating flow rate does not seem to affect the chip thickness.

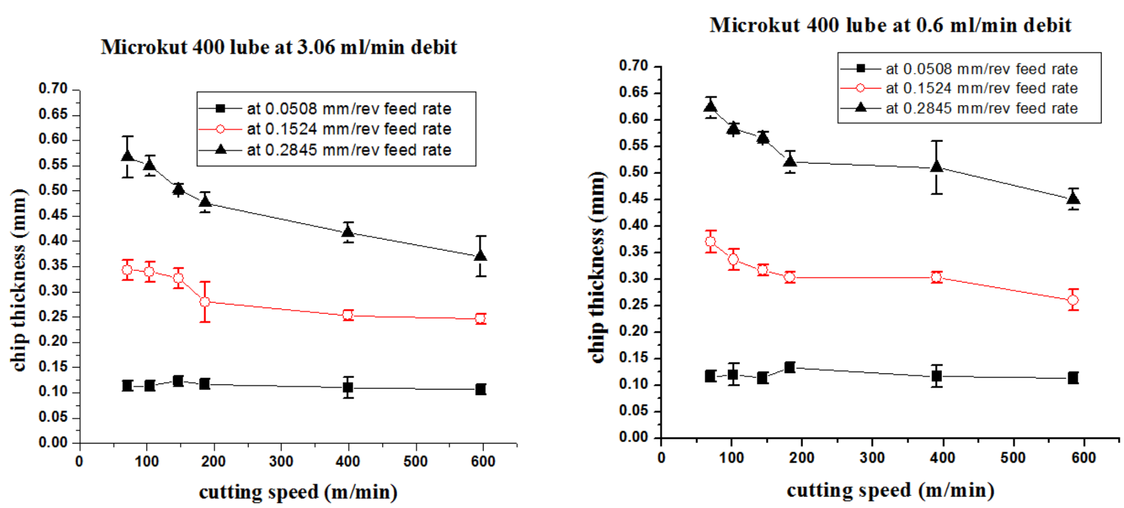
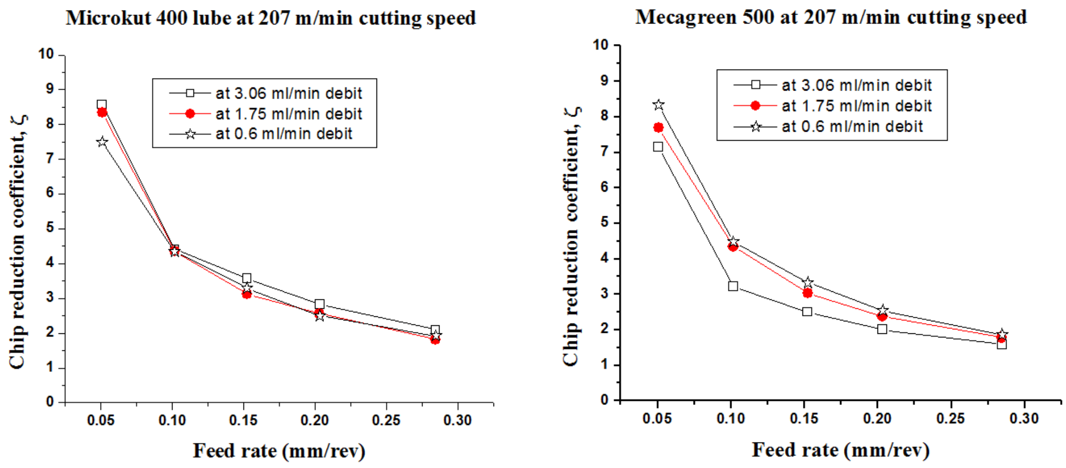


Figure 14. Chip thickness at different cutting speeds and debits

Figure 15 presents the chip reduction coefficient at different feed rate and different lubrication debit using Microkut 400 and Mecagreen 550 lubricant. The chip reduction coefficient (ratio of depth of cut to the chip thickness) permits to have an indication on cutting energy and cutting temperature. The general observation is that the chip reduction decrease when increasing feed rate which confirmed the work done by Dhar et al. [16]. It is also observed that the chip reduction using Microkut 400 lubricant (Figure 15a) decrease with the decreasing of the lubricant debit and inversely it increase with lubricant debit in the case of Mecagreen 550 lubricant (Figure 15b).



a) Microkut 400 lubricant b) Mecagreen 550 lubricant

Figure 15. Chip reduction coefficient at different feed rate and different lubrication debit using Microkut 400 and Mecagreen 550 lubricant

Figure 16 presents lubrication debit comparison on the chip reduction coefficient during turning process of 6061-T6 at the same cutting speed using Microkut 400 and Mecagreen 550 lubricants. It is observed that at 3.06 ml/min lubrication debit (Figure 16a), the chip reduction coefficient using Microkut 400 lubricant is high compared to Mecagreen 550 lubricant.

Using 1.75 ml/min lubrication debit (Figure 16b), the chip reduction coefficient using Microkut 400 lubricant and Mecagreen 500 is similar in high feed rate. In low feed rate (0.05 mm/rev) the chip reduction coefficient (Figure 16b) is high using Microkut 400 lubricant compared to Mecagreen 550 lubricant but fewer than using 3.06 ml/min debit (Figure 16a). Figure 16c shows the inversion of the chip reduction coefficient which is low using Microkut 400 lubricant compared to Mecagreen 550 lubricant. This is an indication that Microkut 400 lubricant could be more useful in the reduction of energy consumption compared to Mecagreen 550 in the turning process.

X-ray diffraction analysis (XRD) was used to characterize the chip grain size of each material. To do this, from the X-ray diffraction peaks, the Scherrer relation was used to determine the average size of the chips analyzed.

The X-ray diffraction peaks are characterized by diffraction angles θ_{hkl} and I_{hkl} intensities, depending on the lattice cell and on the wavelength radiation, λ, used. The hkl Miller indexes correspond to the diffracting crystallographic planes (d_{hkl} is the distance between them). These three parameters are connected through the Bragg [29] in equation (2) as follows:

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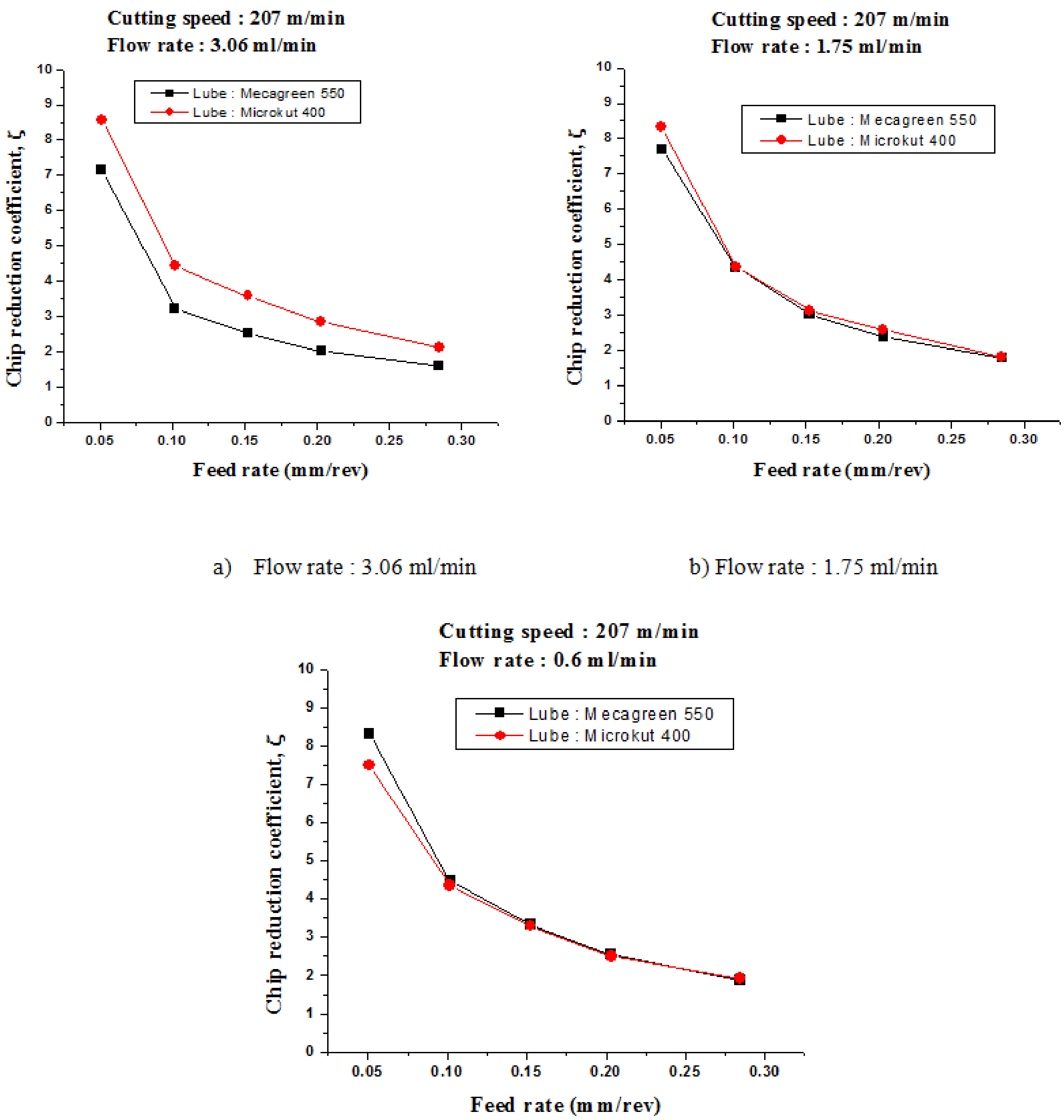
$$2d_{hkl}\sin\theta_{hkl} = n\lambda \tag{2}$$

Figure 17 presents the XRD diagrams of the 6061-T6 material of the diffraction intensity at different diffraction angle and Miller index. It is observed that the (111) Miller present the high intensity peak diffraction value.



a) Flow rate : 3.06 ml/min

b) Flow rate : 1.75 ml/min

c) Flow rate: 0.6 ml/min

Figure 16. Effect of lube and flow rates on chip reduction coefficient

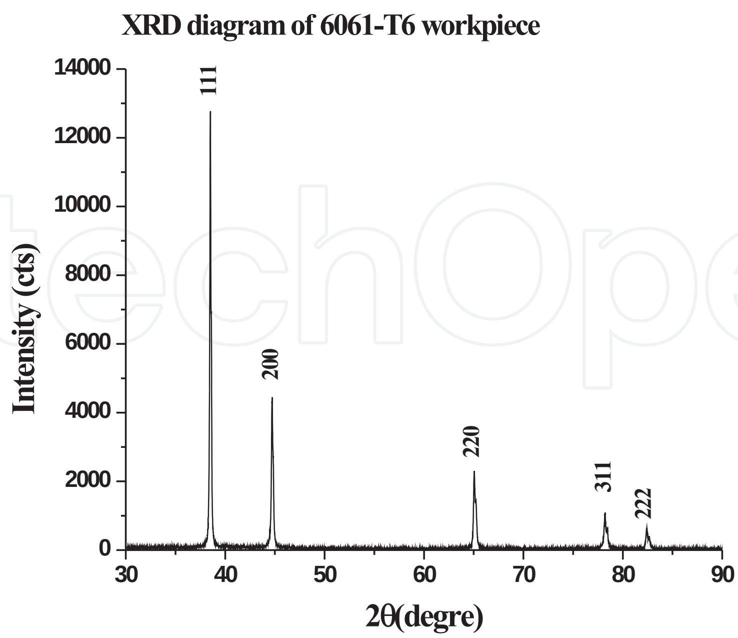
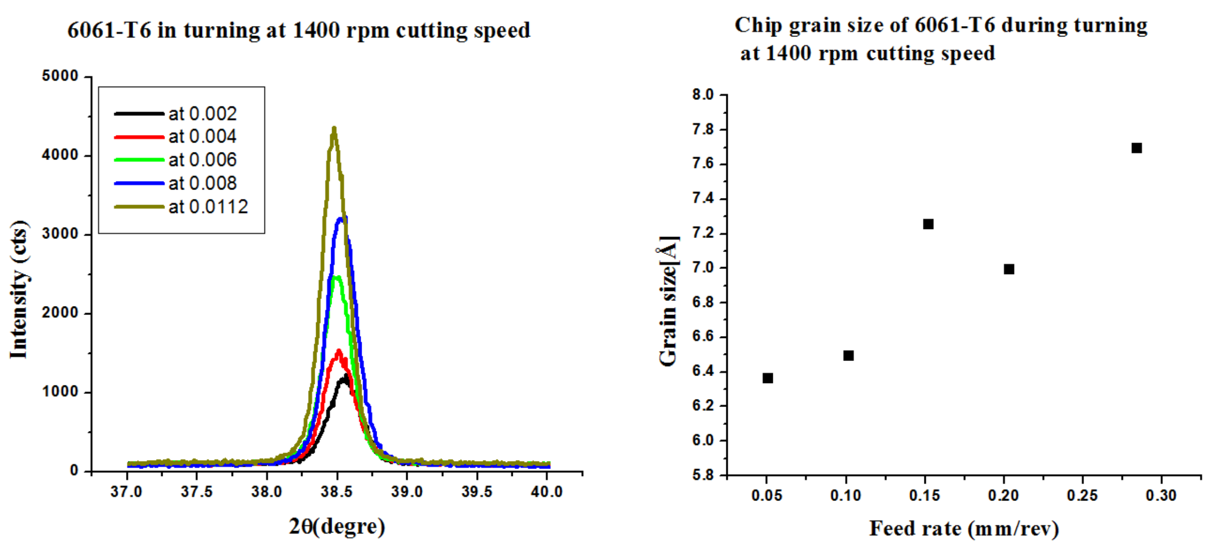


Figure 17. XRD chip diagram and chip grain size at different feed rate



a) XRD chip diagram b) chip grain size

Figure 18. XRD chip diagram and chip grain size at different feed rate during semi-dry machining

Figure 18 presents the XRD (x ray diffraction) and the grain size of the chip thickness different feed rate. Figure 17a presents the XRD chip diagram and Figure 17b presents the chip grain size. From Figure 18a the XRD diagrams were analysed according to the deconvolu-

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tion of the peak in two Lorentzians corresponding to the two components $\lambda_{K\alpha 1}$ and $\lambda_{K\alpha 2}$ of the wavelength $\lambda_{K\alpha}$ of copper. This procedure yields a measurement of a width for each peak of the full width of the peak at half maximum intensity (FWHM) (parameter ω), corresponding to a well-defined wavelength, and has been applied to the whole diagram. Kouam et al. [30] showed in their work how to decompose these peaks without further decreasing their intensity.

The chip grain size d_m has been obtained from equation (3) using Sherrer formula as follow:

$$d_m = \frac{k.\lambda}{\omega \cos\theta_{hkl}} \tag{3}$$

where k is a constant close to 0.9; *hkl* are the Miller indexes, θ_{hkl} is the diffraction angle, λ is the wavelength of the incidental radiation, and ω corresponds to FWHM (full width of the peak at half maximum).

It is observed in figure 18a that the peak intensity at the same cutting speed increase with the increasing of the feed rate. This observation is confirmed in Figure 18b in which the grain size increase with the increasing of the feed rate and could be interpreted as owing to crystallographic effects due to the increase in the chip temperature during the drilling process. This change could help determine the chip temperature.

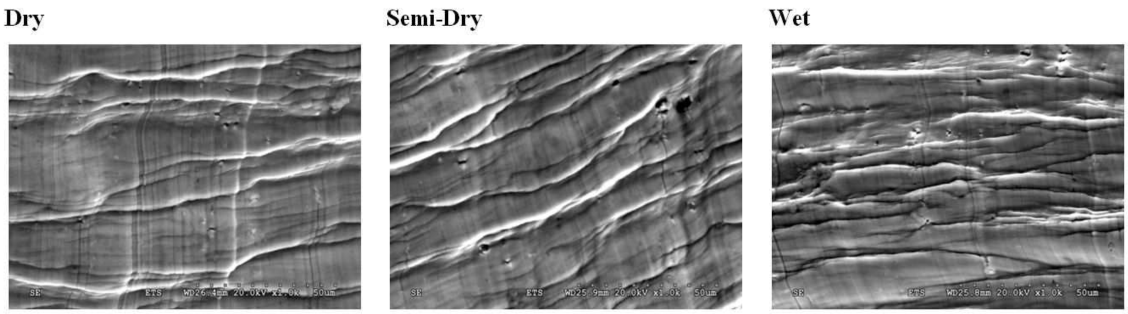

Figure 19. SEM chip segmentation at different lubrication conditions (1000 X magnification).

2.4. Chip formation

Figure 19 presents SEM images of the chip segmentation at different lubrication conditions. The magnification (1000 X) used was enough to show any significant segmentation of the chip at 207 m/min cutting speed and 0.28 mm/rev feed rate.

The segmentation could be defined by the segmentation band density parameter η_s. According to the formulation of Becze and Elbestavi [31], the chip segmentation density parameter η_s can be estimated by the equation (4):

$$\eta_S^{-1}(A + B\exp(CV)) * \left(1 + D\left(\frac{f - f_0}{f_0}\right)\right) \quad (4)$$

where f is the feed rate, V is the cutting speed, and A, B, and C are empirical constants.

Khettabi et al. [32] developed a simple method for determining the chip segmentation density parameter η_s using the distance (l) corresponding to 10 segmentation bands (Equation 5).

$$\eta_s \frac{1}{l_b} = \frac{10}{l} \quad (5)$$

where l_b is the band width.

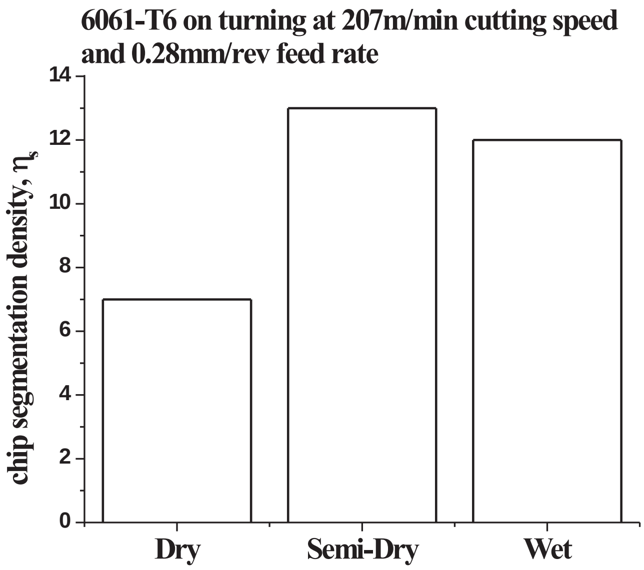

Figure 20. Chip segmentation density η_s for different lubrication conditions

Figure 20 presents the chip segmentation density parameter η_s for different lubrication conditions at 207 m/min cutting speed and 0.28 mm/rev feed rate. Figure 20 is obtained using equation (5). It is observed that the chip segmentation density parameter η_s is low during dry machining compared to the semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet conditions.

2.5. Metallic particle emission

The machining of metallic components produce also aerosol (wet and dry) which can deteriorate the working shop floor environment. Figure 21 presents the total mass concentration at different cutting speed in dry, semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet conditions. It is observed that at low cutting speed the total mass concentration increase and decrease at high cutting speed. These two speed regimes were observed by [24] in their work on turning, by [25] in their work on drilling, and by [26] in their work on friction.

At the same cutting speed the total mass concentration is low in dry condition compared to semi-dry (Mecagreen 550 at 3.06 ml/min debit) and wet conditions. This phenomenon could be due to the fact that when the chip becomes brittle, dust emission decreases significantly [32], [34]. This observation is confirmed by what has been previously obtained in figure 20.

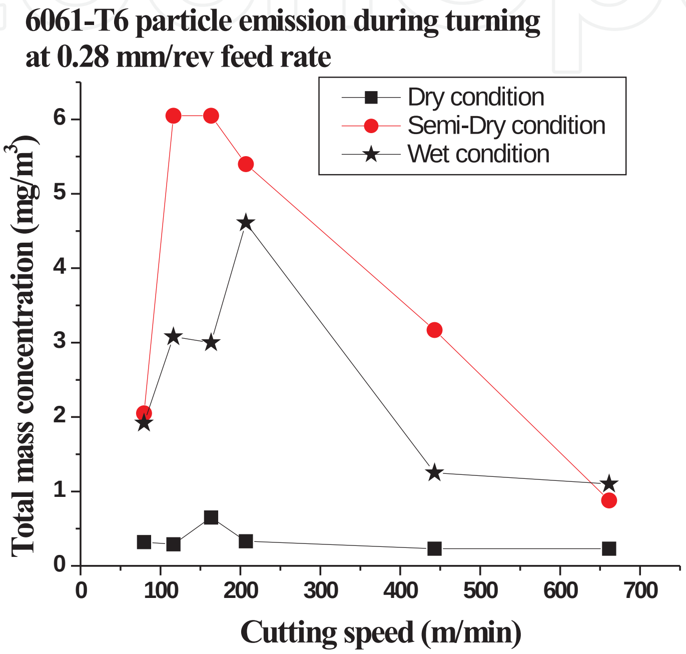

Figure 21. Total mass concentration at different lubrication conditions

3. Conclusion

In this work the effect of the lubrication condition in the turning process was studied. It was found that during this process, the surface roughness, the tool wear, the chip formation and the metallic particle emissions depend significantly on lubrication and cutting conditions.

- At different lubrication conditions, it was found that the surface roughness depends only on the feed rate and not on the cutting speed. At low feed rate the surface roughness is low in the semi-dry lubrication compared to the wet and dry lubrication. In another hand Microkut 400 lubricant is more efficient for a good surface finish in the turning process compared to Mecagreen 550.
- For the tool insert wear the dry and semi-dry (Mecagreen 550 at 3.06 ml/min debit) condition has no significant wear was occurred for the cutting tool insert lip. In the wet condi-

tion the cutting tool insert lip exhibited a small wear after 40 min turning process. At low lubrication debit (0.6 ml/min) the cutting tool insert lip exhibited wear more pronounced using Macagreen 500 lubricant compared to Microkut 400 lubricant. This observation confirmed the relationship between lubricant and tool insert wear during turning process.

- For the chip reduction coefficient it was found that Microkut 400 lubricant could be more useful in the reduction of energy consumption and chip temperature compared to Mecagreen 550 in the turning process.
- From the XRD diagram, the increases in chip grain size with changing cutting conditions confirmed the change of microstructure of chip during the turning process and could for the chip temperature.
- Metallic particle emissions were found to be affected not only by the lubrication condition but also by cutting conditions. At very low speeds, the amount of particles is low, and then increases, reaches a maximum value, and eventually decreases. This observation could help reduce dust emissions, which can have serious consequences on the health of the operator. In the case of cast aluminum alloys, increasing the feed rate led to lower metallic particle emission. In general, the use of semi-dry produce more metallic particle which can be due to the generation of aerosol.

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