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Impact of cutting fluids on surface topography and integrity in flat grinding

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Abstract — Flat grinding is an abrasive process considered as a finishing process. The lubrication plays an important role, in terms of friction and thermal load. Besides, it also influences the macro and micro-geometry, residual stresses and the metallurgical aspect. The objective of the present study is to show, explain and model the impact of the lubricant on the integrity of the final surface in the case of flat grinding. Residual stresses characterization was performed using X-ray diffraction procedure; load measurement was executed with a Kistler force sensor.

Keywords — grinding, residual stresses, surface topography, cutting fluids

1. Introduction and experimental set up

Grinding is usually studied in an academic environment in dry conditions. Many researchers [1] consider that this process can be modelled as a thermal flux caused by friction at the wheel-work piece interface. In terms of residual stresses in the final piece, compression values are usually measured in the case of metallurgical transitions and, in the opposite situation, only traction is observed.

But in real life coolant systems are present and their action is in term of lubrication (reduction of the friction coefficient) and cooling.

In this paper, the impact of the lubricant on the integrity of the final surface in the case of flat grinding is studied (Figure 1).

A white corundum based, grit 60 grinding wheel was chosen, structure 8 and hardness I. The lubricant was a water-soluble micro emulsion with 30 % mineral oil in concentration. It was tested in 2 other concentrations in the water, as 5% and 15%.

Grinding tests were performed on tempered bearing steel 100C6 and the grinding machine was H. ERNAULT - SOMUA FU500.

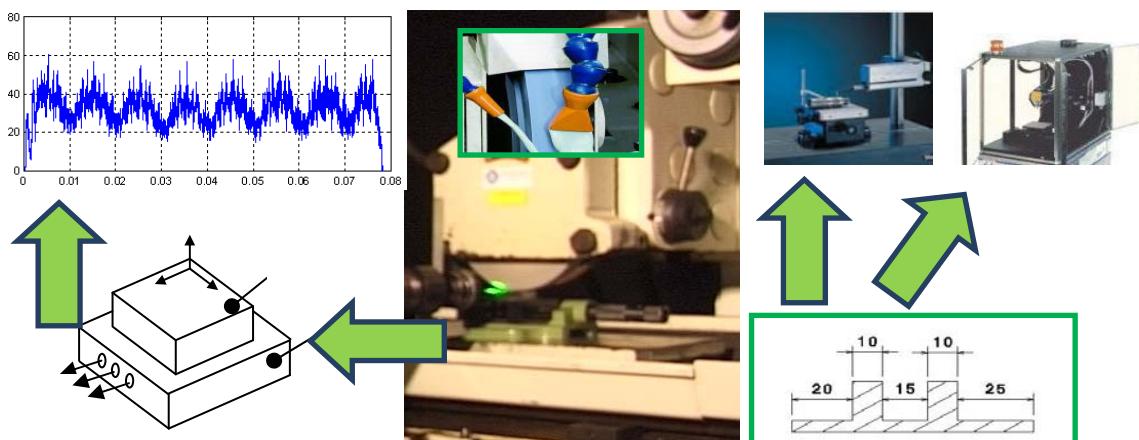


Figure 1 – Work material grinding sketch and measurements

The measurement of grinding forces was made using a dynamometer Kistler 9257 A with a sampling frequency of about 2 KHz. Residual stresses measurements were performed using the X-ray diffraction machine PROTO. It was decided to choose 3 different feed rates (V_w) and 4 different cutting depths (a_p) for every V_w . Between each test series, it was necessary to put the sample into a furnace in order to release the stresses induced by machining and also, between each test, a stone dressing was employed. Four types of parameters were selected to check the impact of the lubricant: surface roughness (horizontal and vertical), residual stresses, loads during machining, qualitative study of the surface after machining.

2. Results and discussion

2.1. Load measurements

In figure 2 and 3 are presented experimental values in terms of grinding forces. It is visible that the loads are higher during the dry test than with the lubricant tests. Lubricant action is located at the chip grain interface and between the work material grain interfaces. It induced the drop in friction. With a low cutting depth a_p (10 µm), loads decrease with the feed rate V_w , which is explained by the drop of the local friction coefficient between grain and work piece. On the contrary, loads increase with cutting depth a_p . In this case in addition of the friction forces it is possible to act local cutting forces between grain and chip. A high tangential load needs more power from the machine and it is possible to notice the increase of grinding temperatures [2]. Normal loads on the work piece (F_n) increase with feed rate and cutting depth.

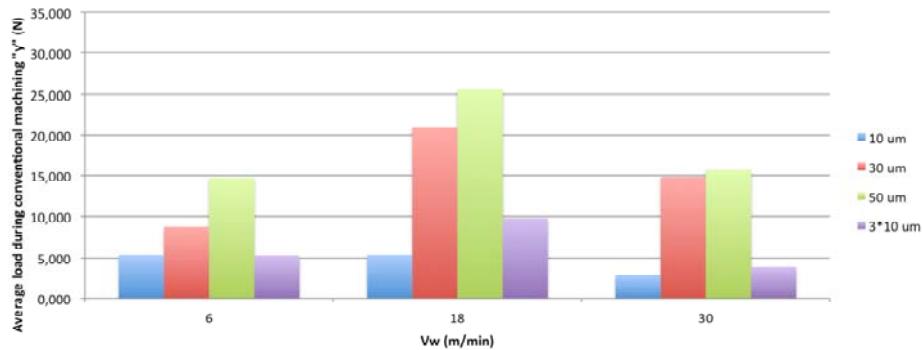


Figure 2 – Tangential force F_t in the case of the concentration of 15%

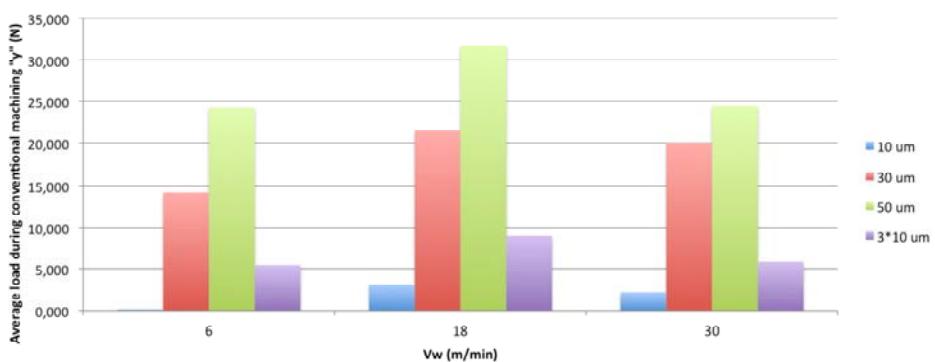


Figure 3 – F_t in the case of dry conditions

2.2. Roughness measurements

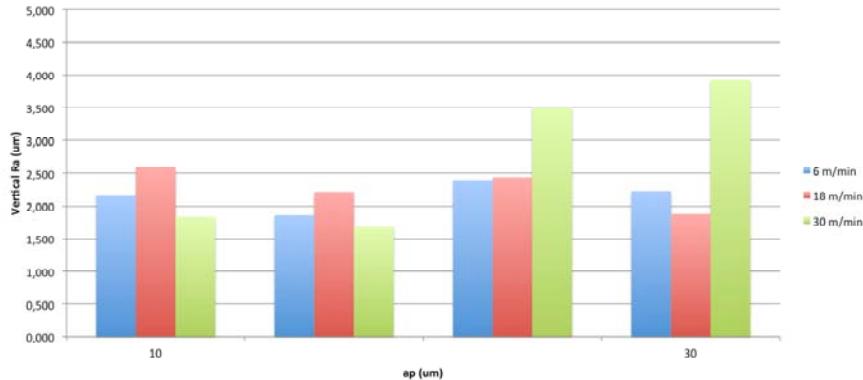


Figure 4 – R_a in the case of the concentration of 15%

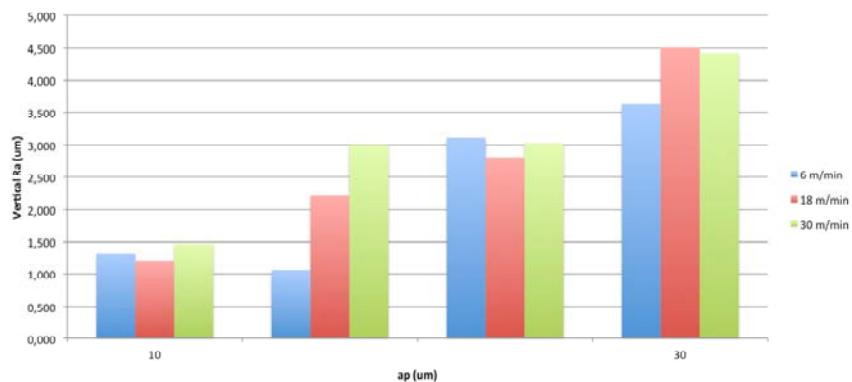


Figure 5 – R_a in the case of dry condition

From figures 4 and 5 it is possible to see that, with a low cutting depth a_p , the surface quality is better during dry test than lubricant tests (based on R_a results). Therefore, lubricants and a high cutting depth allows to have a good surface quality in terms of R_a . In the case of the lubricated test it is possible to see that there is more plowing than dry conditions and roughness increases with the cutting depth. In fact the grain gets deeper in the material. It's even more visible on the dry test results; lubricant allows the wheel to “slide” on the material.

2.3. Residual stresses

It is possible to notice (Figures 6 and 7) that for the dry conditions residual stresses at the surface, the higher the feed rate is, the more traction appears. This phenomenon exists also with the lubricant. The deeper the cutting depth is, the more is traction appears. Concerning residual stresses in the feed direction, the values are very similar between the different tests. In the lateral direction, it appears clearly that there are less residual stresses with the lubricant. Lubricant action reduces frictions but the impact on cooling and consequently residual stresses needs more experimental actions and modelling.

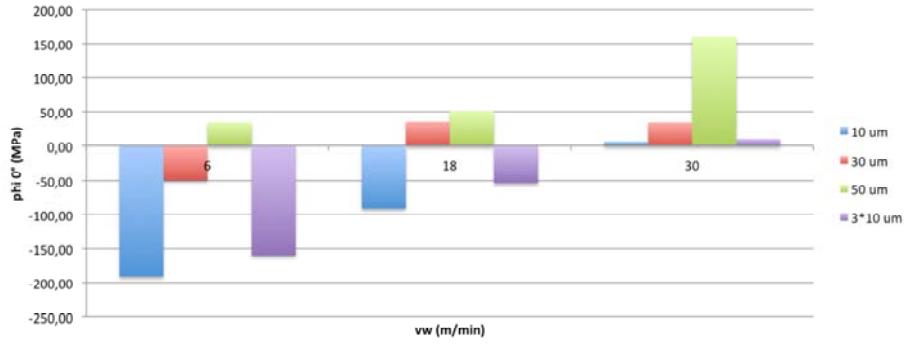


Figure 6 – Residual stresses in feed direction in the case of dry condition

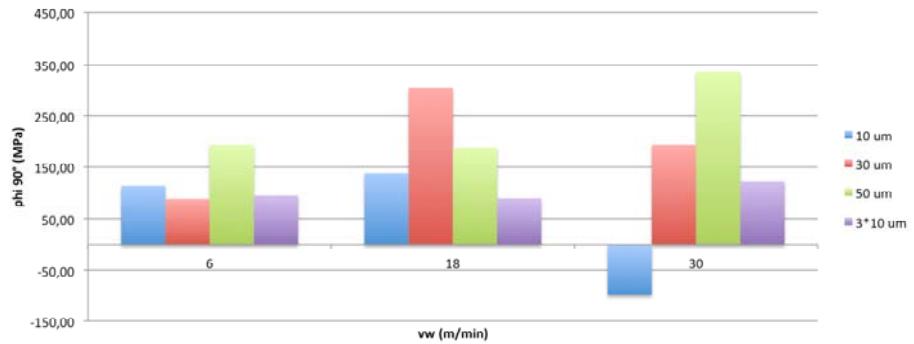


Figure 7 – Residual stresses in lateral direction in the case of the concentration of 15%

3. Conclusions and outlooks

Grinding processes, and in general abrasion, impact residual stresses, roughness and forces. Particularly lubricant action reduces grinding forces because of the reduction of the local friction coefficient at the interface grain work piece. Concerning residual stresses, and for the same reasons, lubricant actions reduce traction.

Concerning roughness 2 different trends can be established. In the case of small a_p , roughness is better when dry conditions are achieved. It is possible to explain this phenomenon using an analytical method [3] and consequently act that lateral burrs caused by grains are more important in the case of lubricant use. In fact when dry conditions are achieved the higher local friction coefficient pulls over the chip in the grinding direction and lateral burrs are less apparent. In the opposite situation, when a_p is high, grains produce chips and less adhesions at the interfaces can be observed.

Many outlooks can be planned after the presented study. Particularly the different between water-soluble lubricants and mineral oils, the cleaning action of the lubricant in the grinding wheel and his impact on roughness. A numerical modeling of the grain action can help understand the physics.

References

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