

## COLD AIR DRY MACHINING Part 2: SEM AND METALLOGRAPHIC ANALYSIS OF THE CHIP

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### ABSTRACT

*Dry machining and near-dry machining were developed as an alternative to flood and internal high-pressure coolant supply to reduce metal working fluids consumption. In dry machining, compressed air introduces into the cutting zone, while near-dry machining supplies very small quantities of lubricant into the cutting zone. Both these techniques have been introduced with the aim to reduce the use traditional coolant and lubricant. One of the many dry machining techniques is the usage of cooled compressed air.*

*SEM and metallographic analysis of the chip during dry machining are presented in this paper. Machining tests were performed by turning of three grade of workpiece materijal: alloyed steel, aluminium bronze, and pure aluminium. Three ways of dry machining are performed: machining without the use of coolant and lubricant, cold air dry machining and with a cooling of workpiece before machining. Analysis of produced chips shows some advantages of dry machining, mainly in the process of chips segmentation, even in cases of machining very ductile material.*

**Keywords:** Cold Air Dry Turning, Steel, Aluminium Bronze, Pure Aluminium

### 1. PREPARATION AND ANALYSIS OF THE CHIPS

According to the experimental setup shown in Part 1, obtained chip was analyzed metallographically, and also by scanning electron microscopy. Results of these analysis during machining of alloyed steel Č.5432 (according to BAS standard) are shown in Figure 1. Workpiece hardness is 48 HRC. Tool used: CNMG 120404 SM AH 645.

Other information concernig machining conditions are noted on Figure 1. Chips is continuous, with a pronounced jagged edge on the opposite side of the workpiece. For the different machining conditions (Figure 1.c, d, and e), the chip compression factors are 0.6, 0.8 and 0.4, respectively. It is interesting that with increasing cooling of the cutting zone, cracks on the outside of chips increased from 0.023 mm for machining without the use of coolant and lubricant, over the value of 0.028 mm for the cold air dry machining, up to a value of 0.04 mm when machining pre-cooled workpiece, Figure 1.c, d, and e. SEM photos (Figure 1.f, and g) very clearly show the lines of materijal flow during the deformation, arrow A, and crack on the outer side of the chips, arrow B (machining without use of coolant and lubricant). In conclusion it can be said that with the increase of cooling, makes it easy the formation of cracks in the chip.

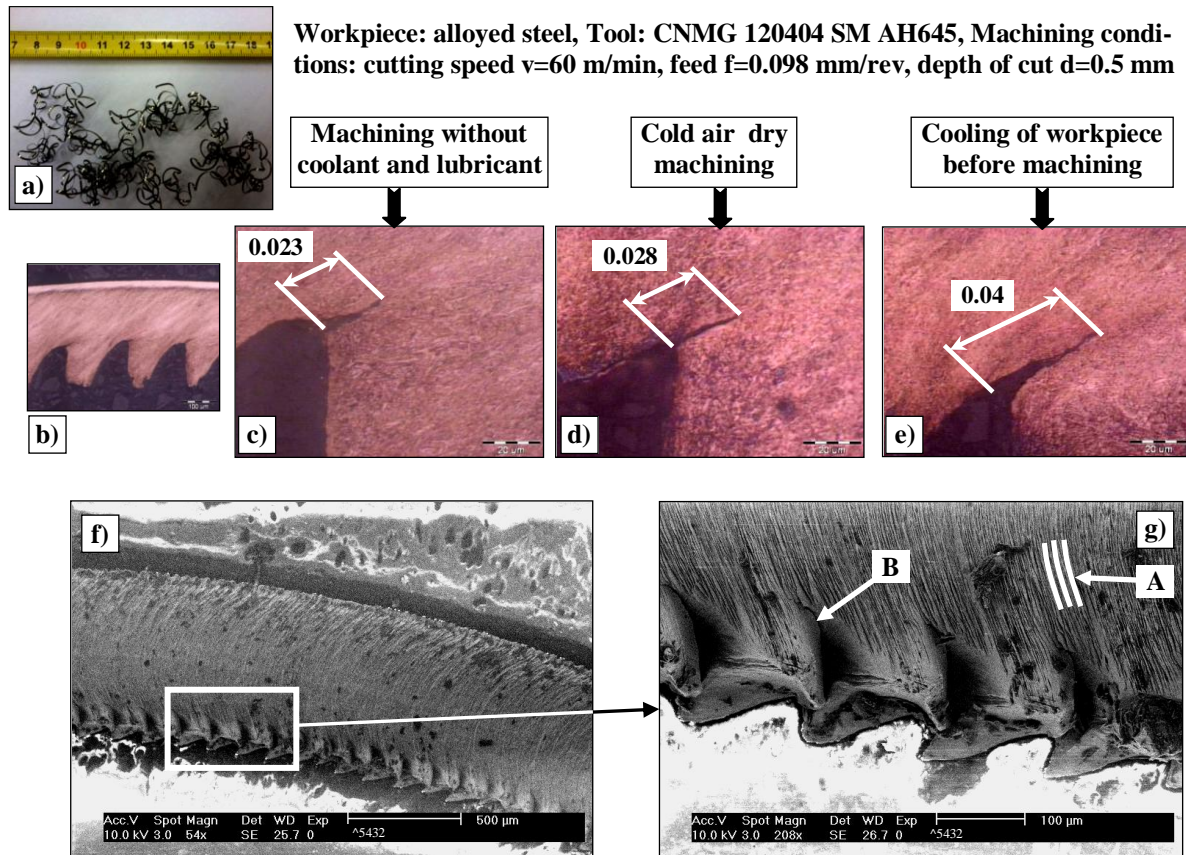


Figure 1. Metallographic and SEM analysis of the chip during machining of alloyed steel

Results of chip analysis during machining of aluminium bronze ( $\text{Cu}85.5\text{Al}10\text{Fe}2.5\text{Mn}2$ ) are shown in Figure 2. Workpiece hardness is 150 HB. Tool used: CNMG 120404 SM AH 645. Other information concernig machining conditions are noted on Figure 2. For all three dry machining conditions, chips is segmented. Unlike the previous case, the cracks on the outside of the chips occurs here only in the case of cooling the workpiece, Figure 2.d. For the different machining conditions (Figure 2.b, c, and d), the chip compression factors are 0.2, 0.3, and 0.3, respectively. Also, it was noted that the machining of the pre-cooled workpiece (Figure 2.d), is occurring non-stationary (instability) in the chips segmentation.

This can be explained by the increasing brittleness of workpiece material due to cooling. In addition, here is observed bending of chips segment by its width, which is also a possible reason for the instability of segmentation. This can be clearly seen from the SEM photos, Figure 2.f, and g. Thus, looking at the width of the chips, there are two clear regions: stable and unstable chips segmentation. SEM photos represent chip produced by cold air dry machining. In conclusion it can be said that with the increase of cooling, results in an increase of the chips segmentation instability.

Results of chip analysis during machining of pure aluminium (99.5%) are shown in Figure 3. Workpiece hardness is 35 HB. Tool used: CNMG 120404 SM AH 645. Other information concernig machining conditions are noted on Figure 3. For all three dry machining conditions, chips is highly plastically deformed. But, only in the case of cooling the workpiece, Figure 3.d., the cracks on the outside of the chips occurs, although it is a very ductile material of the workpiece. Figure 4 shows SEM photos of the outer and inner side of chips in the case of pre-cooled of wokpiece before machining (metallographic photos – Figure 3.d).

It is interesting that in this case on the outer side of chips appears small cracks, Figure 4.a, and b. At the same time, traces of BUE are visible on the inner side of the chip, i.e. chip produced under conditions of intense adhesion, Figure 4.c, and d.

Workpiece: aluminium bronze, Tool: CNMG 120404 SM AH645, Machining conditions: cutting speed  $v=85$  m/min, feed  $f=0.2$  mm/rev, depth of cut  $d=1$  mm

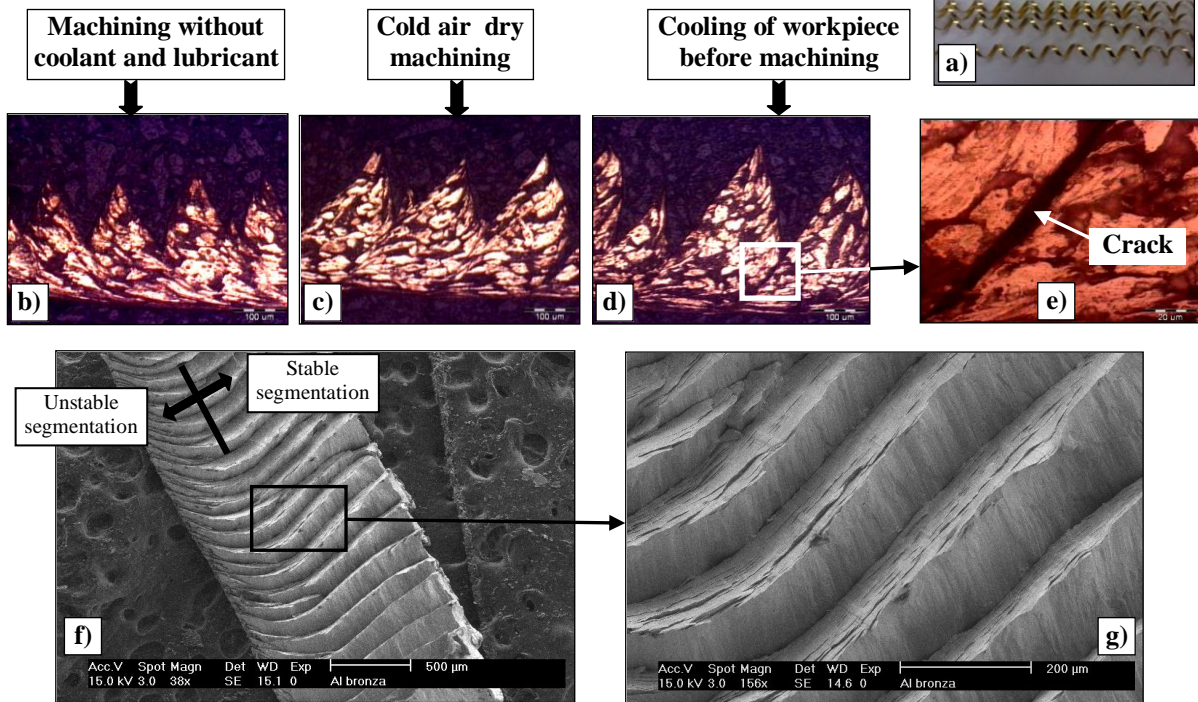


Figure 2. Metallographic and SEM analysis of the chip during machining of aluminium bronze

Workpiece: pure aluminium, Tool: CNMG 120404 SM AH645, Machining conditions: cutting speed  $v=70$  m/min, feed  $f=0.2$  mm/rev, depth of cut  $d=1$  mm

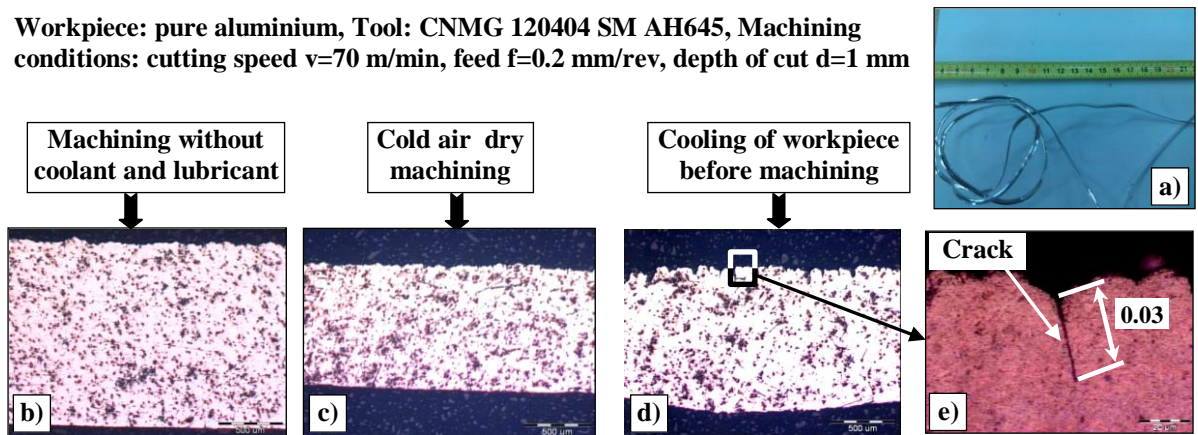


Figure 3. Metallographic analysis of the chip during machining of pure aluminium (99.5%)

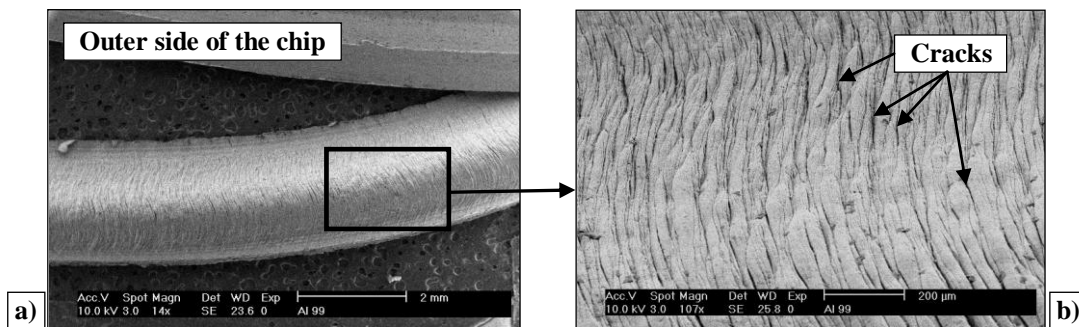


Figure 4. SEM analysis of the chip during machining of pure aluminium (99.5%)



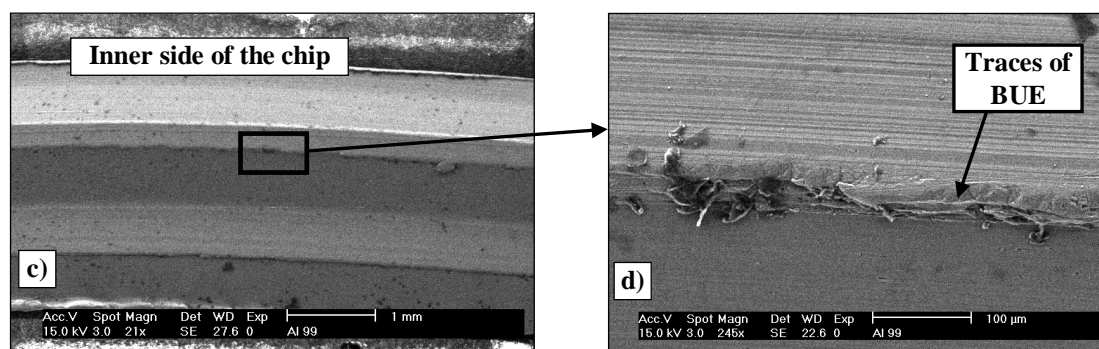


Figure 4. Continuation – The end

## 2. CONCLUSION

Results of SEM and metallographic analysis of the chip for three ways of dry turning of different workpiece materials: alloyed steel, aluminium bronze, and pure aluminium are presented. Based on the obtained results, the following conclusions can be made:

- When using dry machining technology it is possible to affect the morphology of the chips,
- One of the successful ways of dry machining is the use of cooled compressed air,
- For a three different workpiece material, alloyed steel, aluminum bronze and pure aluminum, the use of cooling the cutting zone, or at pre-cooled workpiece, chips morphology changes in all tested workpieces material,
- Formation of cracks on the outer side of the chip appears always, even in the case of pure aluminium machining.

## 3. REFERENCES

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