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Influences on Burr Size During Face-Milling of Aluminum Alloys and Cast Iron

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INFLUENCES ON BURR SIZE DURING FACE-MILLING OF ALUMINUM-SILICON ALLOYS AND CAST IRON

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ABSTRACT

The Exit Order Sequence (EOS) theory discussed by previous LMA students predicts the size of burrs formed during face milling. Other influences are tool geometry, coolant use, and material properties in aluminum silicon alloys and cast iron. Used, worn tools also increase the size of the burr. The effect of speed and feed are also discussed, particularly with regards to cast iron.

INTRODUCTION

Face milling is a common procedure during manufacturing processes but is plagued by burrs which are difficult and expensive to remove.

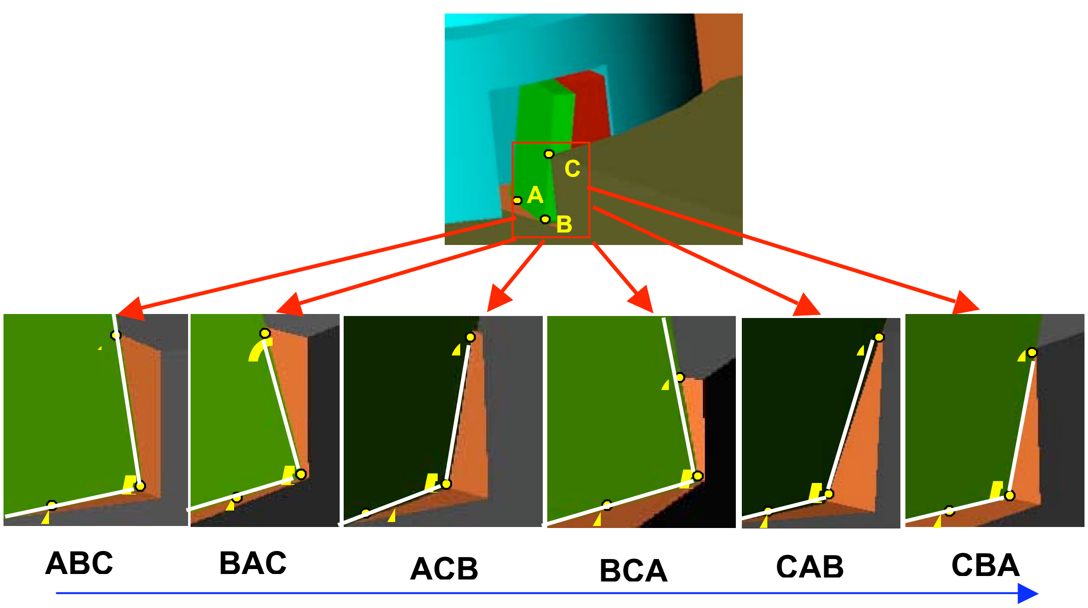


FIGURE 1. EXIT ORDER SEQUENCE.

Burr formation can be reduced or eliminated by understanding how machining conditions relate to burr size. The conditions that affect burr size are feed, speed, material, tool geometry, and exit angle (related to exit order sequence, EOS).

Exit Order Sequence Theory

The exit order of the insert during a milling operation has been discussed and researched by past LMA students. The size of the burr formed depends on how the tool exits the workpiece. If Figure 1 below, point B is the outside tip of the insert, farthest from the axis of the tool. Point C is the point on the primary cutting edge of the tool that is in contact with the top surface of the workpiece. Point A is the point on the secondary cutting edge of the tool (roughly perpendicular to the axis of the tool) that is in contact with the surface of the material. When point A exits the material first, followed by B and C, the material is cut and a small or no burr forms. The burr size increases as the exit order sequence of the tool changes, as shown from left to right in Figure 1. When the EOS is CBA, the material is pushed over, rather than being cut, and forms a larger burr [1]. The exit order sequence can be calculated from the tool geometry and cutting conditions [2].

Experiments

In order to achieve the greatest number of exit order sequences possible, workpieces similar to the one at the right in Figure 2 were used. A block of aluminum silicon alloy or cast iron was machined by milling two opposite sidvvvvvvvvvvvvvvvvvs. The offset was measured from the axis of the milling cutter to the edge of the workpiece. The cutter rotated clockwise and the feed was such that the side being machined would form an exit burr. The exit angle and the exit order sequence of the tool changed as the offset changed.

Burr Measurement

Burr height and thickness measurements were taken both on the side and the end. Since the exit angle changes across the machined edge on the end, the measurements of the burrs on the end have no meaning since the exact location on the edge where they were located was not recorded. The burr size along the sides has the most meaning because along that edge,

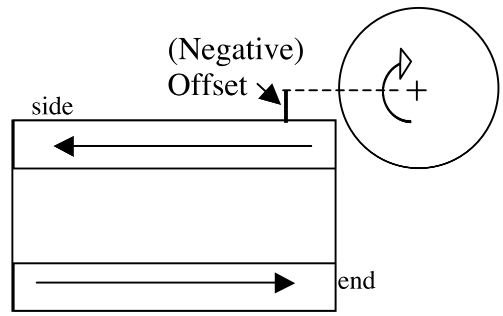
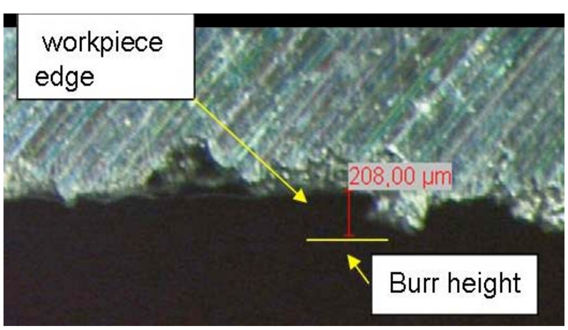


FIGURE 2: BURR EXPERIMENT SETUP.

the exit angle is constant. The burrs were measured as shown below in Figure 3.
The burr height measurements are made from the edge of the workpiece to the tip of the burr. The burr thickness is measured from the edge of the workpiece to the bottom of the burr, an area that appears black in images of the burr. The burr height and thickness are proportional when any breakout is taken into effect [3]. Since the burr height measurements do not account for



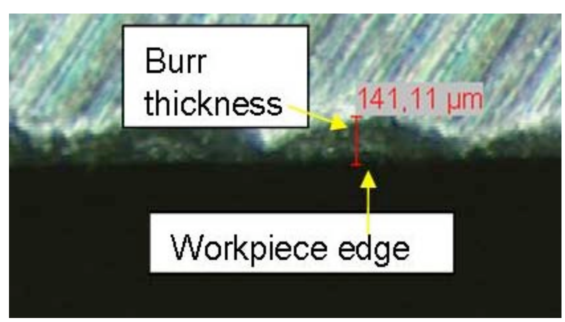


FIGURE 3. MEASUREMENT OF BURR HEIGHT AND THICKNESS.

edge breakout, the burr thickness measurement is the most representative measurement of the burr size and is subsequently used to compare burrs from different experiments and to theories regarding burr formation.

ALUMINUM-SILICON ALLOYS

Experiments

Three different alloys, AlSi7MgWa, AlSi9Cu3, and AlSi10MgWa were tested with three different tools. The PCD inserts used were the Planmesser and Mapal 1, and Mapal 2 inserts from the Mapal company with a 63 mm face mill and one type of insert from Kennametal with a 100 mm face mill. Experiments were run at conditions close to those used in production. The depths of cut were 0.5 and 2 mm, representative of finishing and rough cuts during productions. The feed rates were approximately 0.15 mm per insert and the cutting velocity was between 1800 and 2800 meters per minute. To avoid problems with dynamics and differences in the positions of inserts, experiments were run with just one insert in the tool (i.e. flycutting).

Material and Exit Order Sequence

According to the exit order sequence theory, it is expected that exit order CBA, occurring when the tool is the most engaged in the material, should give the biggest burrs. The exit order sequence ABC, the most negative offset as measured in these experiments, should give the smallest burrs. As can be seen in Figure 4, the ABC exit order sequence does, as expected, give the smallest burrs. For the Mapal 1 and Mapal 2 tools, the greatest tool engagement (at CBA) does give the largest burrs but the Mapal planmesser and Kennametal inserts resulted in small burrs. Figure 4 shows only the Mapal 2 and planmesser tools, but the Mapal 1 and Kennametal inserts show burr sizes similar to the Mapal 2 and planmesser inserts, respectively.

Clearly there is some other tool geometry that influences burr formation and size that has not been identified yet. It is possible that the factor having has such a large effect on burrs under these machining conditions is an edge or corner radius that is not usually measured when tools are characterized.

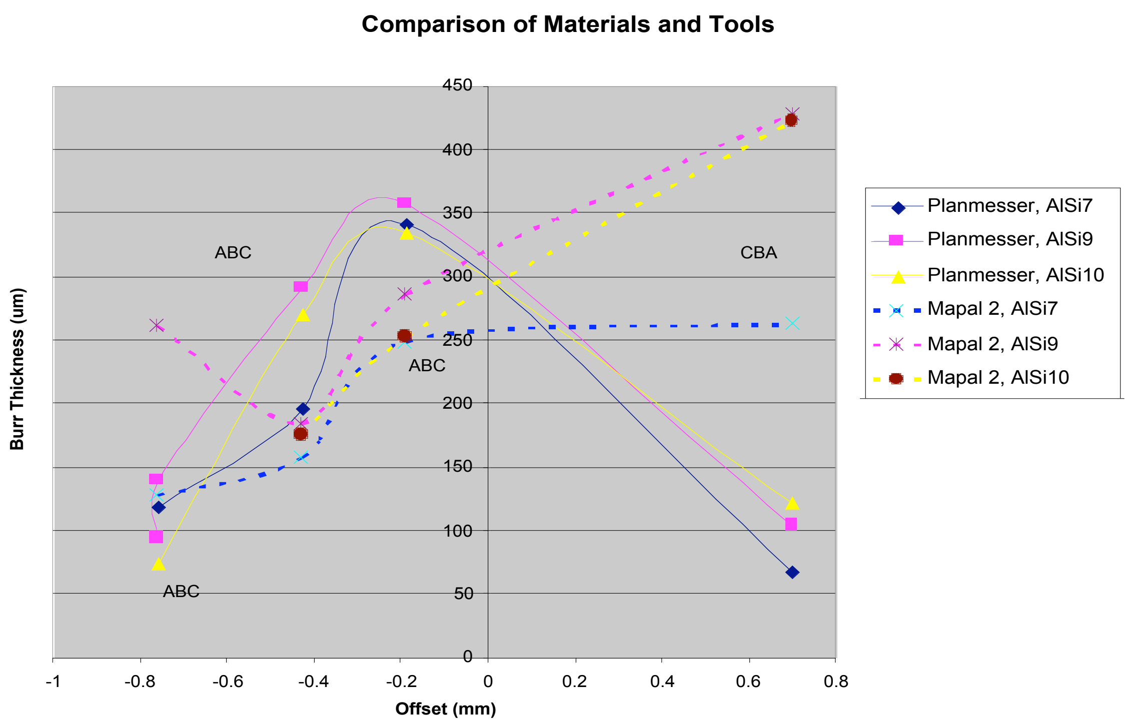


FIGURE 4. MATERIAL AND TOOL INFLUENCE ON BURR FORMATION.

For all of the tools, the AlSi9MgWa had the biggest burrs at most offsets, followed by the AlSi10Cu3 then AlSi7MgWa alloys. However, there was little difference in the size of burrs due to material compared to the other factors, such as exit order sequence, tool wear, and coolant use.

New vs. Old Tools

Two Mapal planmesser tools that had been used in production were used in a few experiments to see how burr size and formation changes as tools wear and break. Since these tools do not wear in the same manner, as can be seen in Figure 5, it is not expected that the burrs formed when using used tools would be all the same. The burrs formed by used tool number 2, shown on left in Figure 5, are about 85% the size of the burrs formed by used tool number 1. The burrs formed by the new planmesser tool are about 55% the size of the burrs formed by the new tools. Obviously, new tools, or old tools in good condition, should be used whenever possible to avoid large burrs.

The difference in sizes of the burrs formed with the used tools shows why it was necessary to use new tools in experiments, even though in production most tools being used are probably closer to the used tools than to the new tools.

Effects of Coolant

Decreasing the amount of coolant used during machining is desirable because of the possible side effects of coolant. In a factory, the coolant often makes hazardous working conditions, such as making the floor slippery. The chemicals in coolants are also suspected to cause health and environmental problems. The ability to machine without coolant would eliminate these effects and help manufacturing companies be more environmentally responsible.

The effect of coolant on burr formation was measured using two used tools run at the same cutting conditions with and without coolant. At both low and high tool engagements, the burrs were slightly larger during experiments without coolant. There was not enough of a difference in size to eliminate the possibility of dry machining. The factor that would become more of a problem is the overheating of the material. Even just machining the one straight cut for the experiments heated up the material significantly.

CAST IRON

Experiments

Two different materials, GG40 and GG26 were tested using two insert types, a honed one designed to maximize tool life, and a sharp one to minimize burrs. As with the aluminum alloys, the machining conditions were similar to those used in production, as shown in Table 1 below.

TABLE 1. CUTTING CONDITIONS WITH CAST IRON

Cutting Velocity	250-350 m/min
Depth of Cut	0.5 mm
Feed Rate	0.3-0.53 mm/insert

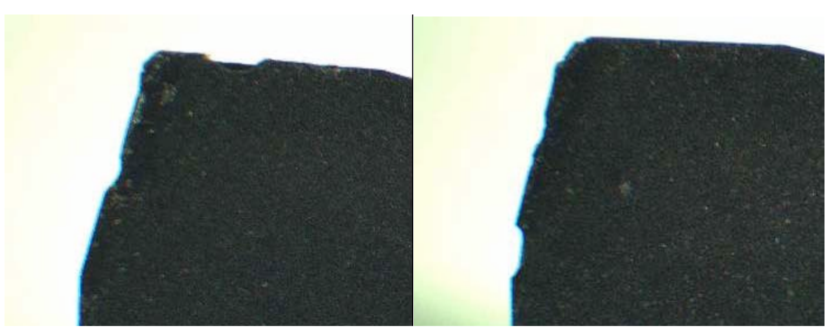


FIGURE 5. USED MAPAL PLANMESSER TOOLS 1 (LEFT) AND 2 (RIGHT).

Exit Order Sequence

The burr size in cast iron corresponded well to what is predicted by the EOS theory for all cutting conditions for all tool and material combinations.

Speed, Feed

As can be seen in Figure 6, the burr size increased as the cutting velocity increased. The largest increase in burr size was when the speed went from 250 to 300 m/min. As the

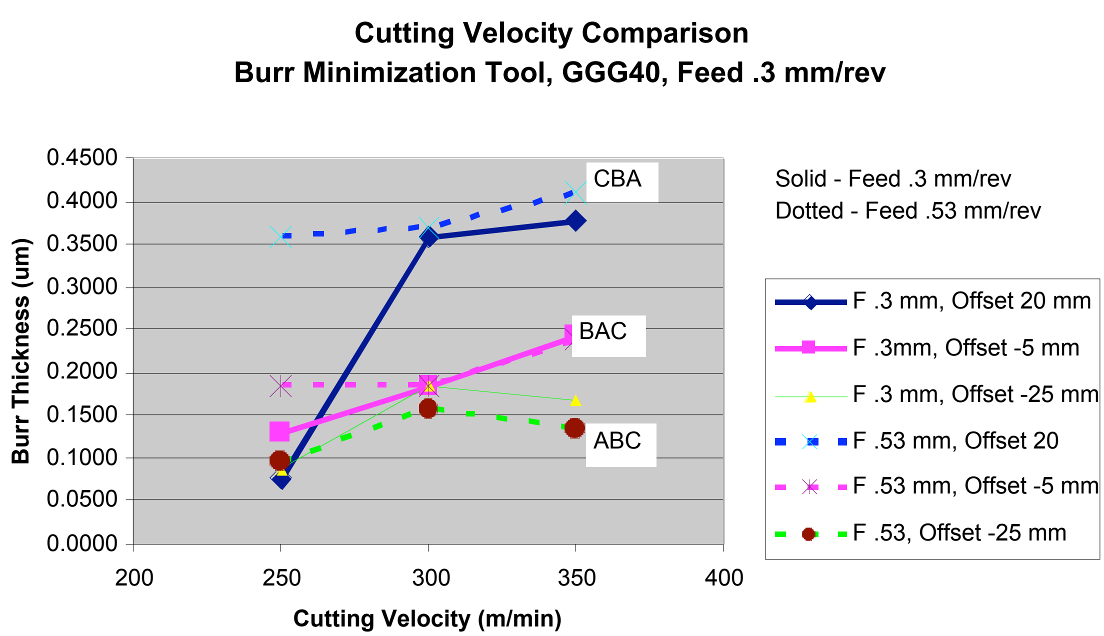


FIGURE 6. THE EFFECT OF CUTTING VELOCITY ON BURR SIZE IN CAST IRON.

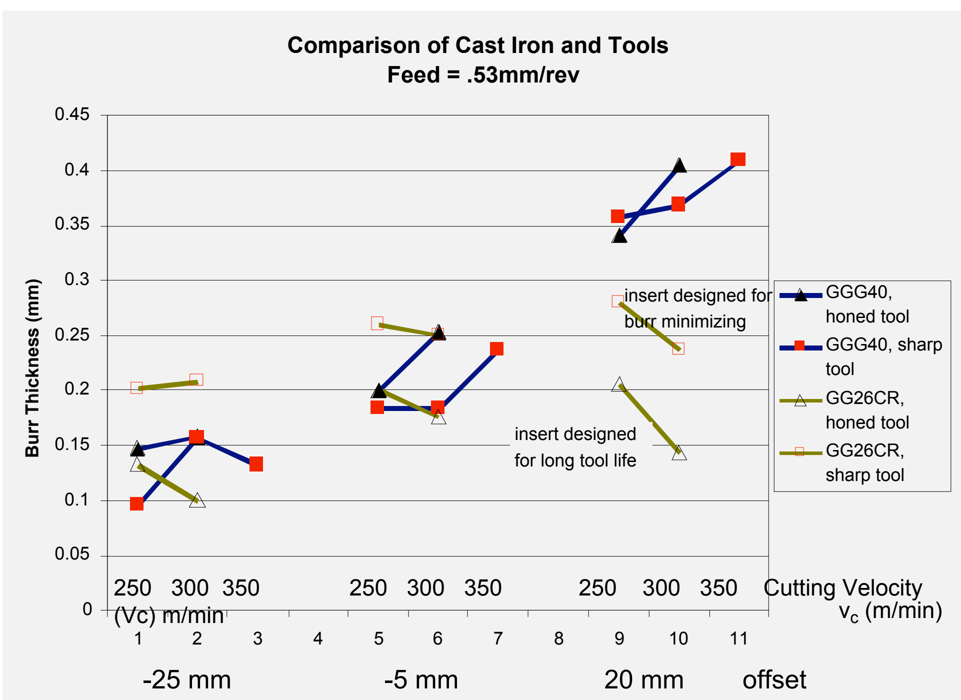


FIGURE 7. MATERIAL AND TOOL INTERACTION IN BURR FORMATION OF CAST IRON.

speed increased, the temperature in the workpiece increased substantially because the experiments were run without coolant. To keep burrs small and to be able to machine without coolant, it is best to machine at a lower velocity, if possible.

The feed rate had only a very small influence on the burr size, especially when compared to other factors such as cutting velocity or exit order sequence of the insert.

MATERIAL AND TOOL EFFECT ON BURR FORMATION

As with the aluminum alloys, there is some interaction between the tool and material that is not completely understood but has a significant effect on burr formation. As Figure 7 shows, the material GGG40 has smaller burrs with the sharp tool, as can be expected. The material GG26 is the opposite and has the smaller burrs with the honed tool that was designed for long life, rather than the sharp tool designed for burr minimization.

CONCLUSION

In addition to confirming that the exit order sequence is a valid predictor of when small burrs will occur for several aluminum and cast iron materials, the following observations were made:

- In aluminum, some tools give small burrs at the CBA EOS also.
- Old worn tool inserts form larger burrs than new tools.
- Coolant decreases the burr size a small amount.
- In cast iron, there is an interaction between the tool and the material that influences burr size.

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