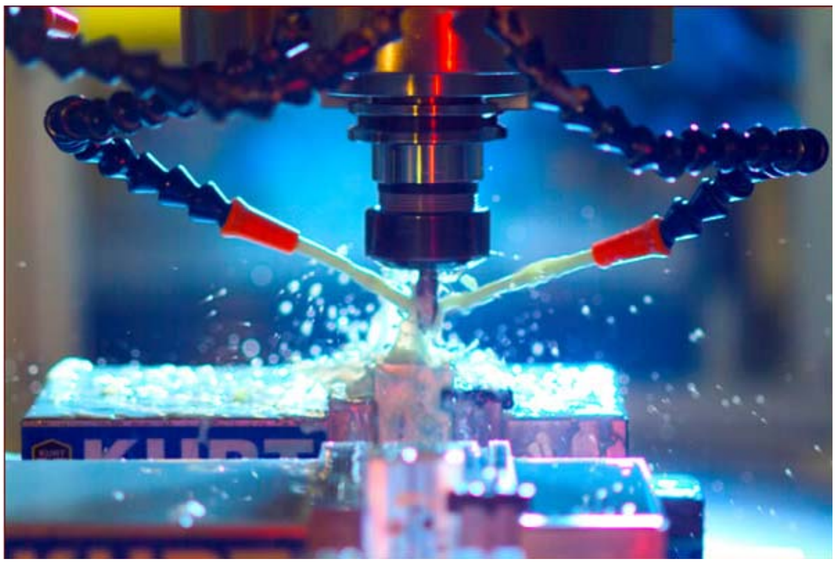
Metal working: Milling



[1]

http://www.youtube.com/watch?v=pc_TAFn5_Bw

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Introduction

The purpose of this flow visualization assignment was to illustrate and to highlight the beauty of metal working processes. This second team assignment was used to demonstrate two different metal working processes and to show the behavior of the metal that is being removed. Part of the team used a metal grinder and was grinding on a carbon-steel angle-iron and sprayed the glowing metal chips into a water-filled tank. This generated some beautiful images with glowing sparks shooting through the air. The other part of the team, including myself, was taking high speed videos of a milling process. This generated slow-motion videos of the cutter removing metal from an aluminum plate. Both of these imaging techniques can be used to explain the physics behind both of these metal working processes.

Experimental Setup

This experiment was conducted in the Durning lab machine shop of the engineering building on Monday March 18th, 2013. The team used two 500-Watt construction-lights for lighting, a two axis prototrak mill, a ¾ inch thick aluminum 6061 sheet, and a one inch diameter end mill cutter. The work piece (aluminum sheet) was fed into the rotating cutter at various feed rates until appropriate chip formation was achieved. The spindle speed of approximately 2000 rpm was recommended by the shop machinist Greg Potts. The working area was lubricated frequently using a brush and water based cutting fluid. Two cutting techniques were used including conventional milling and climb milling. The work piece was cut to specific dimensions of 8.5 by 10 inches. This aluminum sheet now serves as a base plate for an attachment to a dynamometer for torque and power output tests of cordless power drills.

Cutting Physics

As mentioned before, there were two different cutting techniques used to remove metal from the work piece. The first cutting technique is called conventional milling and an illustration of this technique can be seen in figure 1. As the work piece moves into the rotating cutter, the cutter starts at a zero chip thickness and maximum chip thickness is achieved right as the chip is ejected. With this technique, the cutter is sliding across the surface and the work piece has to be pushed into the cutter until enough pressure is generated before the cutter bites and starts to remove metal. Due to the immense pressure needed before chips are actually removed, the work piece is plastically deformed at point A (figure 1) which results in work hardening the metal and dulling the cutter. Consequences of this cutting technique are that this cutting method is rarely used since cutters have to be replaced more frequently and it leaves a poor surface finish [2].

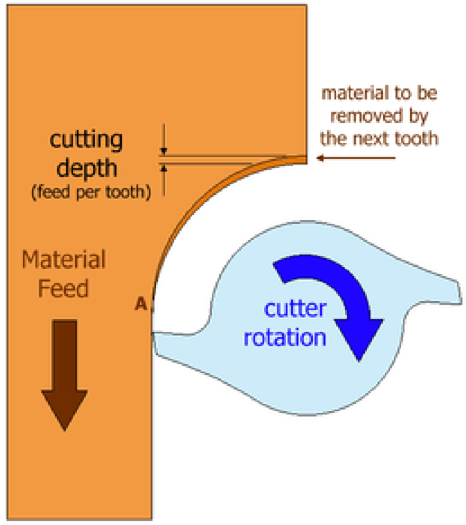

Figure 1: Conventional Milling

The second milling technique is called climb milling and an illustration of this cutting technique can be seen in figure 2. As the work piece moves into the rotating cutter, the cutter starts removing material at maximum chip thickness and finishes at zero chip thickness as the chip is ejected. This results in no sliding of the cutter against the work piece and no work hardening of the finished surface. The cutter lifetime increases and a better surface finish can be achieved [2].

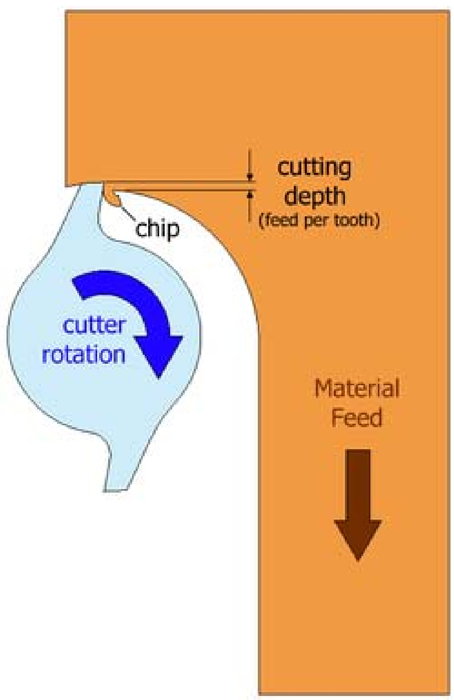

Figure 2: Climb Milling

Frequent lubrication of the work piece and cutter provides a slick interface between cutter and work piece. The lubricant also serves as a heat dissipating agent to remove heat from the cutter by transferring the heat into the fluid and evaporating it. The lubricant also allows the chips to slide off of the cutting edge along the flute. The flute is the area just inside of the cutting edge and serves as an area for the chip material to build up before it is being ejected. Keeping this area lubricated also reduces swarf buildup. Swarf is material buildup on the leading cutting edge of the cutter and can ruin the cutter [3].

Imaging Techniques

The final media was actually a short movie and ended up being a 2:41 min video. The video shows several different angles of the cutter and the work piece interacting. The cutting area was illuminated and filmed with a CASIO EX-ZR 100 camera on high speed video settings. In this high speed mode the camera was recording 240 frames per second. All high speed video files were imported to iMovie and the best parts of each file were selected and arranged in a new project file. As a soundtrack, the song “Ho Hey” by the Lumineers was added.

Conclusion

The final movie demonstrated the two different cutting techniques and had close up shots of chip formation and ejection from the cutter. Also, the lubricant was observed to evaporate and evaporate at a higher rate as the cutting-interface-temperature increased. The most beautiful camera shot in this sequence is at the end of the video where metal chips are projected directly at the camera and are bouncing off the lens. If one was to do this specific shot again, a protective barrier between metal chips and camera lens is highly recommended. Luckily no harm was done to the lens even though there were direct impacts of the metal chips on the lens.

References:

[1] Picture by http://www.shuttleaerospace.com/milling.html

[2] Machinery’s Handbook, by Erik Oberg, Franklin D. Jones, Holbrook L. Horton, and Henry H. Ryffel, Industrial Press; 28th edition (Feburary15, 2008)

[3] http://en.wikipedia.org/wiki/Swarf