Group Project 2 - Showers of Sparks

Flow visualization
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Group members (in alphabetical order):
Lok Kin Lee
Christopher McCray
Taylor Simonson
Melissa Talmage

Introduction

The purpose of this assignment is to capture an image of the fluid mechanics of dynamic metallic sparks in order to observe the fluid flow phenomena. To accomplish this goal, the Makita Abrasive Cut-Off Saw is utilized to cut a metal tube to provide the sparks. Unlike friction sawing, abrasive sawing does not rely on heat to soften the hard work material. Instead, it uses ceramic grains that are harder than the metal being cut, so that the cutting edges of each abrasive crystal cut a small chip at rates of 20 cubic-in [1]. The goal of this project is to visualize and identify the fluid behavior by generating metallic sparks and observing their motion.

Experimental Setup

Figure1: The Eperimental Setup.

A picture of the Makita Abrasive Cut-Off Saw is shown in Figure 1, which is located at the manufacturing center in the ITLL basement. The cut-off saw consists of a 355 mm diameter cutting wheel and rotating at approximately 3,800 RPM. A 1.25 in mild steel square tube is used as the cutting material. Some of the variables that are controllable are listed below:

- Velocity of cutting speed
- Light sources
- Shutter speed
- Differences in cutting different materials

Visualization Technique

The visualization technique used was the molten sparks traveling forward through the air and bouncing off a sheet metal guard placed behind the grind wheel. The lighting used was the ambient light in the room as well as the light given off by the sparks. No flash was used in order to increase the contrast between the sparks and the background.

Photographic Techniques

The camera used to take the image was a Sony Cybershot with 4.0 Megapixel. Some of the details of the photographic techniques are listed below:

- Size of field of view – 8 in by 8 in
- Distance from object to lens – 15 in
- Lens focal length and other lens specs:
  - Focal length – 24.0 mm
  - ISO light sensitivity of 400
- Type of camera – Sony Cybershot DSC-P9
- Exposure specs
  - Aperture – 6.3
  - Shutter speed – 1/125 sec
  - F-Number – F/5.6
  - Exposure time – 1/40 sec

Figure2: Spark Shower - Original Image

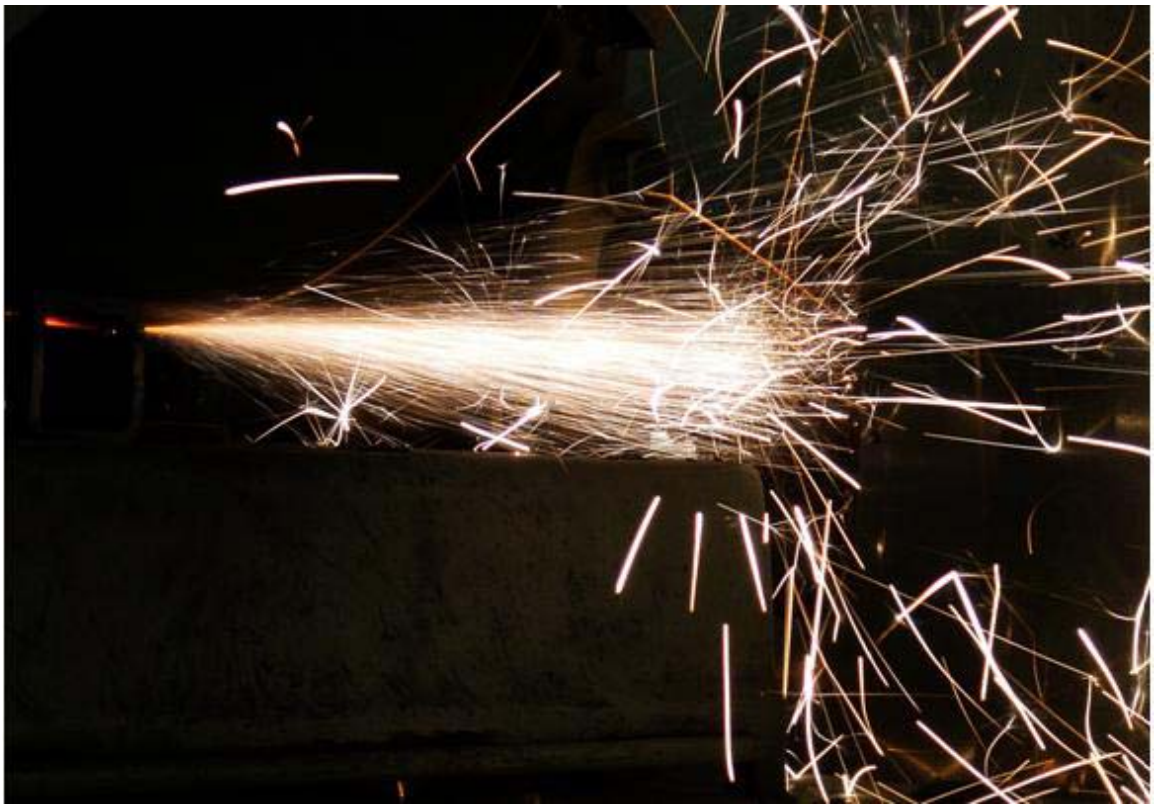

Figure3: Spark Shower - Final Image.

Adobe Photoshop is used to process the image shown in figure 3, which is the final image. The bottom and left sides of the original image were trimmed to eliminate any unnecessary distractions. Some adjustments have been made to create a more dramatic image, and they are:

- Brightness Contrast – The contrast level was increased to make the sparks brighter and the background darker.
- Curves – The curves were also adjusted to accentuate the sparks making the background darker.

Fluid Dynamics

The sparks flying off the cutoff wheel are, in reality, chips of molten steel. The high temperature of the sparks causes them to glow as they are in a melted state. The sparks are undergoing an exothermic reaction, gaining heat as they react with the Oxygen in the atmosphere [2]. Without the Oxygen, sparks are not visualized due to the lack of chemical reactions. As the particles travel through the air, heat is also lost convectively to the colder environment they're traveling through. As the reaction is occurring, the temperature of the chip initially stays close to the melting temperature, then, as the chip decreases in velocity the temperature also decreases below the melting point. Since we're visualizing the chips impacting the guard, we're unable to visualize this temperature decrease gradually as it slowly decreases in velocity. Instead, we are visualizing the sudden velocity and temperature drop as the chips are impacting the guard. Since each chip is a different shape and temperature, they bounce off the surface of the guard at different angles. These impact sites can be seen in Figure 3. The speed of the chips is estimated to be traveling in the range of 60 ft/s to 180 ft/s. Using the rotational speed and the diameter of the cutting wheel, the speed of the cutting wheel is calculated to be approximately 65 ft/s.

Conclusion

This visualization technique produced a very astatically pleasing image that illustrates the dynamics of the molten steel particles. The longer shutter speed allows the viewer to see the path taken by the particle as it flies through the air. This image shows the behavior of molten particles as they react with the fluid (air) and shows the particles

motion over a period of time. One positive aspect of this image is the contrast between the bright particles and the dark background. Another positive aspect of this image is that it shows the impacts of the particles and how they react when coming in contact with another surface. An aspect of this image that we were not completely satisfied with is that the image was taken though a glass shield to protect the camera from the molten sparks; this affected the focus of our image. Questions that our group had are: What happens to the particles when they impact the guard? What kind of collision is occurring, elastic or inelastic? Improvements that could be done in further imaging would be to use a camera with better shutter speed adjustability so that we could have a faster shutter speed and perhaps we would be able to get different information out of the picture. We would also like to have experimented cutting different metals and see how their sparks compared and using different gasses in the cutting environment and see how this would impact the visualizations.

References

[1] http://www.thefabricator.com/Sawing/Sawing_Article.cfm?ID=395

[2] Nathan, Krishnamurty, and Nathan. “In-process monitoring of grinding burn in the cylindrical grinding of steel”. Journal of Materials Processing Technology. 28 November 1997. <http://www.sciencedirect.com>.

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Image Assessment Form
Flow Visualization
Spring 2006

Names: Nigel Gorbold, Lok Kin Lee, Christopher McCray, Taylor Simonson, Melissa Talmage

Assignment: Group 1 Date: 03/15/2006

Scale: +, ! = excellent √ = meets expectations; good. ~ = Ok, could be better. X = needs work. NA = not applicable

Art	Your assessment	Instructor assessment
Intent was realized		
Effective		
Impact		
Interesting		
Beautiful		
Dramatic		
Feel/texture		
No distracting elements		
Framing/cropping enhances image		

Flow	Your assessment	Instructor assessment
Clearly illustrates phenomena		
Flow is understandable		
Physics revealed		
Details visible		
Flow is reproducible		
Flow is controlled		
Creative flow or technique		
Publishable quality		

Photographic technique	Your assessment	Instructor assessment
Exposure: highlights detailed		
Exposure: shadows detailed		
Full contrast range		
Focus		
Depth of field		
Time resolved		
Spatially resolved		
Clean, no spots		
OK, simple print		
Mat		
Mounting		

Report		Your assessment	Instructor asssessment
Describes intent	Artistic		
	Scientific		
Describes fluid phenomena			
Estimates appropriate scales	Reynolds number etc.		
Calculation of time resolution etc.	How far did flow move during exposure?		
References:	Web level		
	Refereed journal level		
Clearly written			
Information is organized			
Good spelling and grammar			
Professional language (publishible)			
Provides information needed for reproducing flow	Fluid data, flow rates		
	geometry		
	timing		
Provides information needed for reproducing vis technique	Method		
	dilution		
	injection speed		
	settings		
lighting type	(strobe/tungsten, watts, number)		
	light position, distance		
Provides information for reproducing image	Camera type		
	Camera model		
	Field of view		
	Focal length		
	aperture		
	shutter speed		
	film type and speed		
	# pixels (width X ht)		
	Photoshop techniques		
	Print details		
	"before" Photoshop image		