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Material determination using spark observation

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ABSTRACT: Knowledge of material properties, production methods and manufacturing processes are each important subjects in the materials science discipline. Material testing methods are standardised by several organisations, such as ASTM [1]. Materials are tested and their mechanical properties are tabulated in handbooks. This article will explain a study conducted on how a certain number of steels/cast iron might be identified through the observation of the sparks projected when a specimen is held against a grinding wheel. There are many factors that can change the spark patterns that are projected, but the main goal of this article is to attempt to standardise a method of spark testing and how it is performed. The study was conducted on fourteen different grades of steels/cast iron that are commonly used in manufacturing processes. A reference manual was created from the experimental data cataloguing the spark pictures. This manual can be used by students and potentially by machine shops to identify samples of the included materials. This can lead to significant savings for machine shops by using a relatively easy, user friendly method, to identify unknown stock sitting around in the shop.

Keywords: Materials, spark testing, material science, material identification

INTRODUCTION

A study of identifying common steels/cast iron was conducted under the UGROW programme at Midwestern State University. UGROW stands for Undergraduate Research Opportunities and Summer Workshop and was started in the summer of 2005. The UGROW programme focuses on research done by undergraduate students under the supervision of professors and offers scholarships to the students and a stipend to the professors involved. About 17 professors and about 15-20 students participate in these projects currently. Sometimes multiple students team up on one project. The subjects studied come from a variety of disciplines ranging from the health sciences to engineering.

This particular engineering project was to determine whether or not the identification of steels would be feasible through the observation of spark patterns emitted when a specimen is held against a grinding wheel. The process started by looking through existing research and determining a new and easier approach that could be easily replicated. The proposal of spark observation was instigated as a cost effective way for machine shops to determine unknown steels/cast iron from either a scrap source or mislabelled material instead of using expensive methods, such as spectrometer emission analysis that not every machine shop can afford. An enormous amount of cost savings can be obtained by the correct identification of scrap metal and prevention of improper material selection [2].

SPARK OBSERVATION AND MEASUREMENT

Spark testing began around 1909 and continued on into the 1970’s. However, these studies required a special or dedicated grinder and an experienced metal worker. An unknown piece of steel would be placed against a grinding wheel and the experienced worker would observe the sparks, the worker would then compare the spark patterns to the spark patterns of known pieces of steel. This identification process took years of experience to perfect a technique that would give consistent results. Since the force applied to the grinding wheel can change the amount and length of sparks emitted, standardising the testing procedure was a key element in the study described below [3].

The grinder used in this study is a Baldor model 8123WD eight inch bench grinder rated at ¾ hp and 3,600 RPM. This will be used in conjunction with a coarse 36 grit and medium 80 grit aluminium oxide grinding wheels. During experimentation, the low carbon steels rapidly fouled the medium 80 grit grinding wheel. The lengths of the sparks emitted were rapidly shortened due to the fouling and gave inconsistent results. It was, therefore, decided to only present the results of the 36 grit aluminium oxide wheel. The force of gravity was utilised to create a constant force between the steel specimen and the grinding wheel. By attaching a custom built arm to the eight inch bench grinder, the force on the grinding wheel was kept at a constant force of 3.3 Newtons. This meant that any variation in the spark stream would be due to a variation in the steel/cast iron instead of the force applied to the specimens. The variations that were present in the spark stream were used to help determine the identification of the steel/cast iron.

The study focused on the length of the sparks, the angle that the sparks were projected from the horizontal axis, the angle of extremes and other details of the sparks. This method was a different approach from previous other studies conducted in the sense that the data is measurable instead of a purely observational identification of the spark pattern. There is an ever growing number of steel alloys and cast irons that are being formulated, so in order to meet the deadline for UGROW, the study was limited to 14 steels and gray cast iron that are commonly used in current manufacturing processes [1]. A similar study on many more materials could be performed in the future. These steels included: 1015, 1018, 1045, 1075 and 1095 plain carbon steels; 1215, 4140 and 4340 alloy steels; O1 and D2 tool steels; 17-4, 303 and 316 stainless steels, as well as gray cast iron [4]. Each of the specimens were placed in the clamp of the swing arm attachment designed specifically for the study and placed against the grinding wheel (see Figure 1).

Figure 1: Steel specimen mounted.

With the lights dimmed, three photos of each specimen were taken with a flash, perpendicular to the spark stream. The grinding wheel was conditioned using a dressing tool, as needed. This was done in order to keep the grinding wheel true and clean. A black backboard with an inch scale drawn on it was used to provide contrast with the spark stream (see Figure 2).

Figure 2: Picture of test in progress.

The inch scale was used in conjunction with ImageJ software [5]. Data was gathered using this ImageJ software in which photos of the sparks were uploaded. ImageJ uses drawing tools and references pixels to measure the length of lines drawn. The scale was set by drawing a line of a known distance, in this case an inch, and setting the number of pixels for that distance.

The length was then measured by drawing a line down the centre of the spark stream and the software calculated the length and stored it in an Excel table. Some human judgment was made in this process to *catch* most of the sparks within the limits in order to make the measurements of the spark length and the angle of extremes.

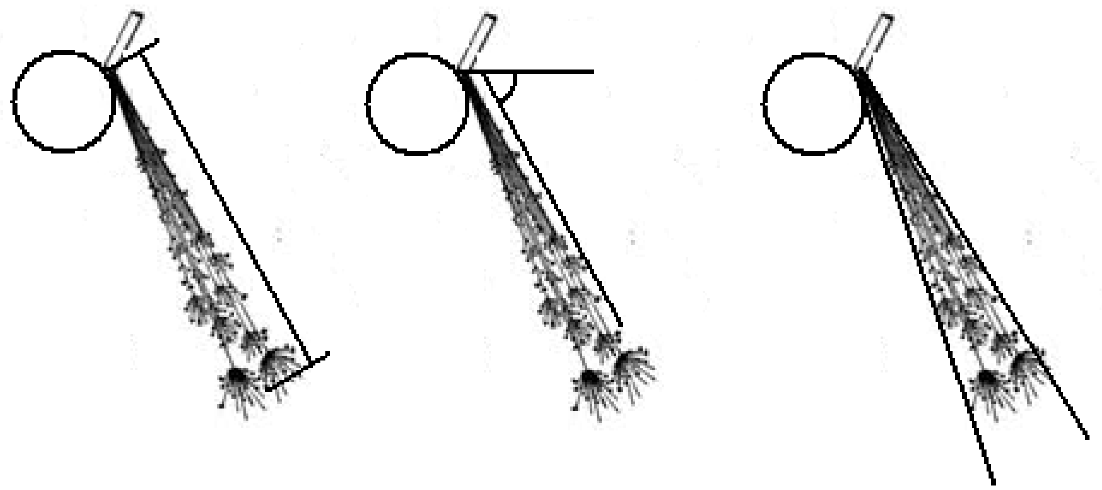


Figure 3: Measurements made using ImageJ on a typical pattern.

The data was tabulated along with Brinell and Rockwell hardness readings to further help with the referencing of the steel [6]. See Table 1 for the results obtained in this study.

Table 1: Results obtained for 14 known materials.

Spark testing and hardness reading results				
Type of Steel	HRC	Brinell	Length (inch)	Angle of Extremes (°)
1015	55.67	560	44.82	17.36
1018	50.67	475	35.93	27.08
1045	61.00	670	38.83	34.48
1075	83.00	N/A	30.96	27.62
1095	86.67	N/A	24.73	25.94
1215	57.33	601	40.13	27.86
4140	60.33	653	33.98	27.01
4340	53.33	530	37.41	32.25
O1	61.67	670	28.24	26.12
D2	58.00	620	14.26	16.72
17-4 Stainless	79.33	N/A	22.86	30.32
304 Stainless	75.33	N/A	12.51	25.26
316 Stainless	78.00	N/A	22.13	25.79
Gray Cast Iron	58.67	620	5.24	11.64

Another part of the study involved obtaining a spark pattern density for each specimen. A 3” x 5” note card was placed in front of the spark stream, six inches from the point of contact (see Figure 4).

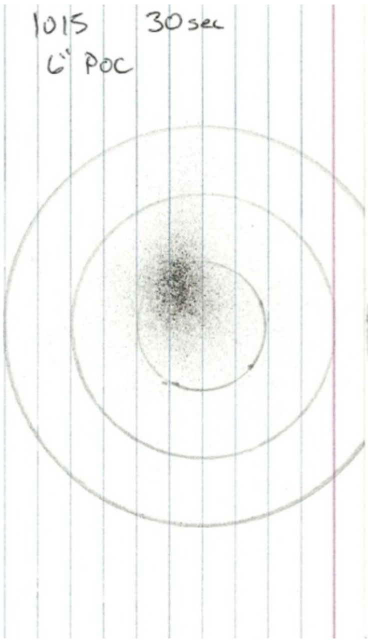
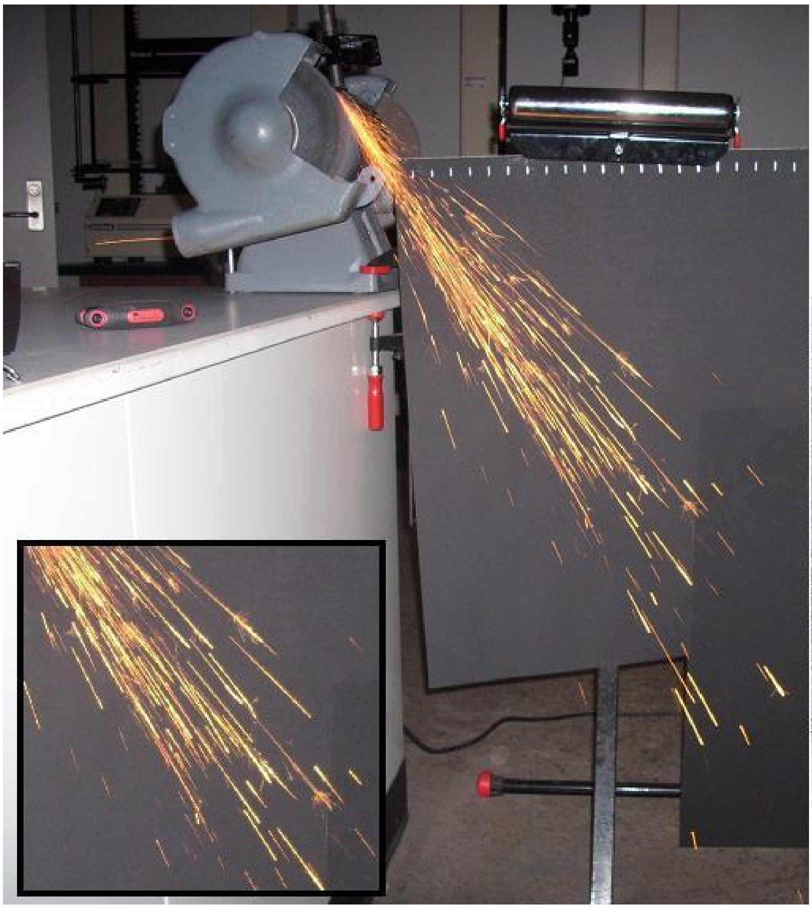


Figure 4: Spark density pattern.

The sparks were allowed to hit a note card for ten seconds, then a second card for thirty seconds. This was repeated for each specimen. There were no discernible burn patterns in any of the pattern density cards. However, the cards did provide a relative reference tool that was combined with the other data gathered and joined together in a reference manual. For some of the steels tested, the ten second pattern density cards left too light of mark. The thirty second cards were shown in the reference manual (see Figure 5).



Type of Steel	4140
HRC	60.33
Brinell	653
Spark Length	33.98 in.
Angle of Extremes	27.01°

30 Second Blast
6" from Point of Contact

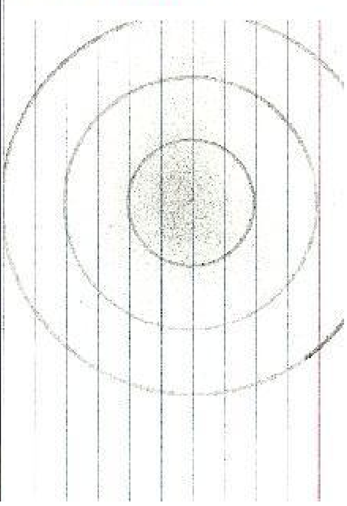


Figure 5: Reference manual page.

In the case of the plain carbon steels, the spark stream left a carbon looking haze on the cards. As the carbon content of the steel went up, the haze began to lighten. The 1215 steel left a distinguishable pattern on the pattern density card, this was more than likely due to the lead content of the steel [1].

The tooling and stainless steels left very light patterns but still had subtle differences that, with little experience, could be used to distinguish between the different steels/cast iron. The lightening effect of the density patterns seemed to have a relationship with the hardness of the steels [7]. The authors noticed that the harder the steel, the lighter the density pattern.

FUTURE RESEARCH

The material science course in mechanical engineering at the McCoy School of Engineering at Midwestern State University will begin offering a new spark testing laboratory in the fall semester of 2013, because of this research. Students will be divided up in small groups and the groups will be asked to identify three unknown steels/cast iron using this reference manual and by performing the spark test using the grinding wheel apparatus. The results will be used to refine the study and possibly observe a learning curve by students in the future.

Initially, an idea to use an infrared thermometer to capture the temperature of the sparks coming off of the grinding wheel was attempted. This idea was quickly abandoned as the infrared thermometer takes an average temperature over a certain surface area. The surface area read was the specimen, the grinding wheel and grinding wheel housing. The temperatures gathered were erratic and showed no trends.

Potential future research could use a thermal imaging camera. A thermal imaging camera focusing on the hottest point in the camera lens and capturing the image will hopefully be used next year. The image can, then, be uploaded onto a computer where the temperature can be calculated. A small preliminary study using a thermal imaging camera has already been attempted by focusing on the temperature of the sparks and the capture of the image. The sparks did not retain heat long enough for the camera to capture an image.

There were two possible solutions presented, consisting of a direct temperature measurement and an indirect temperature measurement. The direct method would use a ceramic insulation plate in place of a pattern density card. This might give a way to capture the spark temperature directly since the ceramic will retain little heat from the sparks. The indirect method would use a plate of aluminium or copper in place of the density card, the plate will absorb the heat of the sparks and the thermal imaging camera might be able to capture and record an indirect spark temperature.

Spark testing is a viable, cheap method of steel and cast iron determination and deserves further research.

ACKNOWLEGEMENTS

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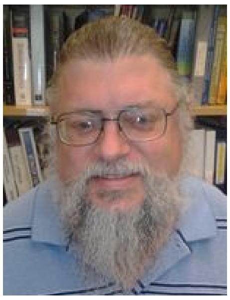
REFERENCES

1. American Society of Metals. *Metals Handbook: Properties and Selection: Irons and Steels*. (9th Edn), United States of America, 238-251 (1978).
2. Stookey, D. and Dargan, N., *Spark Testing Training Manual.* Manorville, New York: Island Steel Company (1967).
3. Tschorn, G., *Spark Atlas of Steels.* New York, New York; The Macmillan Company, 97-156 (1963).
4. Kalpakjan, S. and Schmid, S.R., *Manufacturing Engineering and Technology.* (6th Edn), Upper Saddle River, New Jersey: Pearson Prentice Hall, 144-146 (2010).
5. ImageJ. Image processing and analysis in Java, http://rsbweb.nih.gov/ij/
6. Azzouz, S., Brink, J. and Weller, J.M., *Material Science Lab Manual.* Ann Arbor, Michigan: Xanedu, 25-111 (2011).
7. DeGarmo, E.P., Black, J.T., Kohser, R.A. and Klamecki, B.E., *Materials and Processes in Manufacturing.* (9th Edn), United States of America: Hamilton Printing, 124-145 (2003).

BIOGRAPHIES

Raymond Dalke is currently pursuing his BS in mechanical engineering and a Petroleum Certificate at Midwestern State University. He has an extensive background in the automotive industry as a repair technician. He recently assumed the role of an Auto Center Manager and oversees the processes of operation. Areas of interest include material sciences, chemistry and design. He also enjoys problem solving and troubleshooting many systems including hydraulic, electrical and computer programming.

Dr Jan Brink has a background in industrial engineering. He obtained his PhD from the University of Texas at Arlington in 1997. He obtained a MS in industrial engineering from Texas Tech University in 1985 and a BS degree in Industrial engineering also from Texas Tech University in 1983. His interests are in industrial hydraulics, robotics/automation and manufacturing. He has been teaching in a Manufacturing Engineering Technology programme at Midwestern State University from 1985 till 2007 and in the Mechanical Engineering programme at the McCoy School of Engineering from 2007 till now. He has given many industrial seminars for industry in hydraulics, pneumatics, industrial robotics applications and programmable logic controllers. He is also interested in motion and time studies and work sampling techniques and material identification thru spark observation.



J. Mark Weller works in the McCoy School of Engineering at Midwestern State University in Wichita Falls, Texas, in charge of coordinating faculty and student fabrication and coordinating the engineering laboratories. Mr Weller has a background in conventional and CNC machining, as well as additive manufacturing (3D printing). Mr Weller has extensive experience in computer systems and controls.