Titanium, Aluminum or Steel?

Thomas G Stoebe
Professor Emeritus, University of Washington, Seattle, WA
and
National Resource Center for Materials Technology Education
Edmonds Community College
20000 68 Ave West
Lynnwood, WA 98036
425-890-4652; tgstoebe@earthlink.net

Abstract: Testing of metals is usually undertaken with sophisticated instruments. However, you can demonstrate to your students the basic differences between certain classes of metals using the simple spark test, presented here. You can even have your students test their “titanium” sports equipment to see if it really titanium! In many cases, they will find that the name “titanium” is used for marketing but little will be found in the product. In the process, students see the visible result of the carbon content in steel, and the lack of carbon in other materials, plus realize the reactivity of titanium metal.

Module Objective: This simple demonstration provides an introduction to materials and materials testing. Even though this technique is limited to certain metals, it helps the student understand that different materials are different, and that materials that look alike are not necessarily the same. It also provides an opportunity to describe ferrous and non-ferrous materials and their basic differences, and one effect of heating on these different materials. Titanium is sufficiently reactive in air that it gives off sparks even with no carbon present. Since so many products today indicate that they are made of titanium, this test also provides a simple means to test for titanium in a product. This demonstration can also be expanded into a lab experiment to identify unknown materials.

Student learning objectives: Students will be able to

- identify differences in sparks emitted by a material when grinding
- recognize that grinding causes the material to be heated
- observe that analysis of metals can be undertaken non-destructively
- determine that steel contains carbon
- recognize that spark testing applies only to certain materials
- explain why titanium might or might not be used in place of other metals in a golf club

MatEd core competencies covered:

0.B Prepare tests and analyze results
6.B Apply concepts of fluids, heat and thermal conduction

7.A Identify the general nature of metals
8.C Perform visual and nondestructive testing methods for solids
9.A Define and describe consititents, properties and processing of steel
9.C Identify types, properties and processing in aluminum and its alloys
9.H Identify uses and processing of titanium and its alloys

Key words: steel, titanium, aluminum, alloys, property testing

Type of Module/Mode of Presentation: Demonstration with discussion or lab.

Time required: 15 minutes

Pre-requisite knowledge and skills: none

Target grade levels: Community college manufacturing courses, Technical college introductory courses or advanced high school technology courses.

Table of Contents

Equipment and supplies needed:

1. A grinding wheel is needed. This should be an ordinary gray alumina type of medium grit (the type usually found in shops). If not readily available, grinding wheels are usually available in rental shops. A 6” grinding wheel running at 3000 RPM would be best.
2. A supply of known materials. Many types of materials can be obtained at hardware stores, metals suppliers or junkyards. Some types include the following:
    - low carbon steel (nails, fasteners)
    - high carbon tool steel (hammer, chisel, cutting tools)
    - high speed steel (drill bits)
    - cast or wrought iron (horse shoes, cookware, engine block parts)
    - stainless steel (knives, tableware, cooking utensils)
    - titanium (get a real titanium bolt to make sure you really have titanium)
    - aluminum and/or brass
3. Hand-held vice for holding smaller samples

4. Safety glasses and gloves for the demonstrator
5. Location with a dark background for visibility of the spark train

Curriculum overview and notes to instructor:
Iron and titanium are example metals that react with air. Adding carbon to the iron to make steel adds another reactive element, carbon. These factors together lead to interesting observations when metal samples are heated by holding them on a grindstone. Looking at the carbon content of iron and steel, we have the progression

wrought iron—nearly pure iron
low carbon steel (.1 to .3 % carbon)
high carbon steel (.4 to 1% carbon)
cast iron (usually about 2% carbon)

Alloy steels contain carbon and other elements. Stainless steels come in two classes—those with the body centered cubic structure of carbon steels but with chromium as a major alloying agent, and those with a face centered cubic structure due to the additional presence of nickel (which makes this class of stainless steel non-ferromagnetic). Iron itself is reactive in air, with or without carbon being present, and burning iron atoms are visible usually as a red stream of sparks in this experiment. For background, refer to the experiment showing how steel wool will burn (see reference 1). Corrosion is another measure of iron's reactivity.

With carbon present, the carbon reacts with air and causes a delayed bursts of sparks that adds to the red stream of iron sparks, the amount of bursts being roughly dependent on carbon content. Alloying elements in the steel (in addition to the carbon) change the nature of the stream and the bursts. Experience can teach a technician which carbon content or which alloy is being tested based on the spark pattern. This used to be used more generally as a mode of analysis of steels; today it is used only to determine general types, most often to determine if all steel in a batch is the same, or in classifying steels in general terms for recycling.

Titanium and its alloys do not contain carbon. However, titanium is reactive in air, especially at high temperatures (see reference 2). As is illustrated in this experiment, titanium emits a bright white stream of sparks. Aluminum, copper, brass and other metals do not generally contain carbon and do not react to this experiment.

As a demonstration, the instructor can test known materials in front of a class or in a laboratory or shop. As indicated below, the contrast between titanium and iron is a key point and should be emphasized. To some extent this demonstration is a test of the students' observation abilities and the differences will be obvious with titanium giving bright white sparks and the iron a duller red. The addition of carbon to the iron adds the bursts to the sparks, with different effects for different additions. This is an example of non-destructive testing. Only a small amount of material needs to be removed from the sample to obtain the result. This should be made clear to the students during the demonstration.

Two options for follow-up to this demonstration may be suggested:

1. The class can be invited to bring metal samples (perhaps their titanium golf clubs) for testing in a subsequent class period. Many materials marketed as titanium are actually steel or aluminum (hopefully with bits of titanium somewhere to validate their claims) and this can be an eye-opener for the students.
2. As a lab, students can be given unknown samples of metals and they can identify them using the spark test. This lab is written up in reference 4. To be more specific with identification, certain rules need to be followed:
    a. note especially the safety precautions above for each student
    b. always use the same pressure on the grinding wheel
    c. clean the grinding wheel if needed between samples to avoid cross contamination (especially if aluminum is tested)

For a more specific list of potential observations, utilize the information and charts in references 3 – 6.

Module procedure:

1. **(Day before homework)** Have the students define each of the key words.
2. Discuss the key words and their definitions.
3. Use one sample of steel and one of titanium that look similar. Ask the class how to determine what materials they are.
4. Produce the grinding wheel and proceed to show the class the sparks from each. Ask the class what they observe and ask them to describe precisely what they see. Ask for explanations as to the differences they observe.
5. Discuss steels and their compositions and show again the class the steel sample. Point out the basic red sparks which are from the reaction of iron with air. Add another steel sample with different carbon content. Ask the class to explain the differences.
6. Discuss carbon content and how carbon can react with air and cause the observed bursts.
7. Test the titanium sample. Ask the students to identify the differences from the steel samples. Discuss testing samples to determine their compositions.
8. Ask the students what they would expect from aluminum. Then test and discuss.
9. Optional: discuss the question of whether titanium is really in the products that advertise titanium. Ask the students to bring in samples to test.

Supporting materials:

Diagrams and tables for steel testing are available in many metals technology books and references. One source is given in reference 4. These diagrams are useful and could be handed out or displayed on the screen after the demonstration. Referring the students also to references 3 – 6 is useful for follow-up on the overall lesson.

References:

1. MatEd Experiment H-1.
2. General information on titanium and its reactivity can be found, for example, at http://www.key-to-metals.com/Article126.htm
3. "Titanium or Plain Ol' Steel? by Theodore Gray, Popular Science: http://www.popsci.com/diy/article/2007-12/titanium-or-plain-ol-steel; also http://www.popsci.com/diy/gallery/2007-12/truth-sparks
4. Spark Testing for Mystery Metals: http://www.ohiosteel.org/homepage/Spark%20Testing%20for%20Mystery%20Metals.pdf
5. Spark Test of Steels: http://shopswarf.orcon.net.nz/spark.html
6. Spark testing of Ferrous Metals: http://www.alexdenouden.nl/04/vonkset.htm

Acknowledgements

The work was partially funded by National Science Foundation Advanced Technology Education Grant # 0501475.

Evaluation Packet:

Student evaluation questions (discussion or quiz):

1. Why does titanium behave differently from steel?
2. Why does carbon content make a difference the sparks from steels?
3. Why are there not sparks from aluminum?
4. Would you expect sparks from copper or brass?
5. Explain how the sparks are generated.

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the demonstration work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material on steels and titanium sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the demonstration/lab generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including
   comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Course evaluation questions (for the students)

1. Was the demonstration clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?