Abstract:

Sand casting is often utilized in industry (automotive, aerospace, etc.) to make parts that are comprised of iron, bronze, brass and at times aluminum. The metal of choice is melted in a furnace and poured into a mold cavity formed out of sand. Sand casting is used because it is inexpensive and the process is relatively simple. However, flaws are common in sand cast parts and these flaws can affect the properties of the cast materials. As a result, this exercise can be used both to teach the sand casting process and also to demonstrate the effect processing has on defect formation.

This module builds upon previous modules and experiments located on the MatEd website, listed under suggested prerequisites. If the needed equipment and furnaces are not readily available, see the modules on Materials Processing and/or Effects of Processing on Structure and Properties for a potential substitution. These modules can be accessed online at:

http://www.materialseducation.org/educators/mated-modules

Module Objectives:

This demonstration or lab provides an introduction to the sand casting method for metals. It can also provide the basic knowledge required to understand how materials processing can change the properties of a metal, as demonstrated through experimentation.

Student Learning Objectives: The student will be able to
• Demonstrate and discuss the sand casting process
• Identify the limitations of the sand casting process
• Discover how sand cast materials can have defects and small voids that are not visible on the surface
• Determine how properties of a metal can be altered through processing

MatEd Core Competencies Covered:

1. C Demonstrate Laboratory Skills
7. A Identify the General Nature of Metals
7. I Explain the Causes for Differing Materials Properties
8. E Perform Appropriate Tests of Metallic Materials
9. C Identify Types, Properties and Processing of Aluminum and its Alloys
16. A Explain Effects of Processing and Manufacturing Variations on Materials Properties
16. B Describe the Effects of Defects on Materials Properties
17. B Describe techniques used for Materials Processing

Key Words: Sand Casting, Materials Processing, Aluminum, Hardness

Type of Module: PowerPoint presentation with lab exercise or in-class demonstration, depending on availability of equipment

Time required: two 50 min sessions

Recommended Prerequisite: (available on the MatEd website)

1. Effects of processing on Structure and Properties Part 1 and 2. These modules give the students the necessary knowledge required to fully understand the concepts and ideas that are covered in this module.
2. Hardness Testing of Materials
3. Materials Processing Module
These modules can be found at http://www.materialseducation.org/educators/mated-modules/

**Target grade level:** Advanced High School, Introductory College/Technical School

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**Equipment and Supplies Needed:**

- PowerPoint projection system
- Electric Furnace
- Aluminum ingots for casting
- Medium to large crucible
- Large plastic or metal container with lid
- 10 lbs. of silica or fine sand
- Fine metal mesh screen
- 1.2 lbs. of powdered Bentonite clay
- Trowel and fine brush
- Molding box with gating system and casting components
- Small item to be used as a model for the molding
• Slag stick and metal Pliers
• Wooden or metal rammer
• Pre-cut metal samples (to observe possible flaws)
  ▪ Same material, whole, halved and cut into smaller sections

<Most of these materials can be found at art, hobby, hardware stores and metal shops>

Information on alternative methods and materials can be found at the end of this module.

Curriculum Overview and Notes for Instructor

Sand casting has various parts associated in the process. These parts have historical names, and are presented here for completeness and can be found in the appendix for future reference. Typical molds, often called two-part flasks, are used in sand casting and have upper and lower halves that contain the various parts that are significant in the casting process.

![Diagram of a two-part sand casting mold](http://www.efunda.com/processes/metal_processing/sand_casting_intro.cfm)

A metal or wooden frame called the flask is made up of upper and lower halves, known as the **cope** and **drag**. The flask contains the sand and provides support when the molten metal is poured into the mold. The upper half, the cope, contains the upper portion of a **pattern** which is the duplicate of the real part known as the **model**, along with a **riser** and **sprue**. The model used for patterns (and for the other parts) are often made of wood and/or metal in order to
retain external features and the shape. Risers are introduced to create a void in the mold to create an overflow area for the molten metal. Risers are an important component in sand casting, because the molten material will shrink as it cools and solidifies. It also helps in eliminating and at times preventing voids in the main casting. The sprue is an opening that is attached to the external pouring cup and extends down to the gating system, placed near the parting surface, which directs the flow of the molten metal into the pattern and riser. The parting surface is the line that separates the top and the bottom half of the mold.

Initially the drag is filled partially with sand and a pattern is made carefully by packing sand around the mold. **Cores** are placed within the mold if any are needed to help retain internal features such as holes and/or internal passages. The gating system is then assembled and placed near the parting line. Next, the cope, with the models for the sprue and riser, is assembled to the drag and sand is poured on the cope half, covering the pattern, core, and the gating system leaving the sprue and riser partially visible. The sand is compacted carefully by hand, vibration or small hammer.

Once all is compacted, the cope is removed from the drag, and the pattern, sprue and riser are carefully removed in order to retain the surface features and cavities. The main objective of sand casting for a two part mold is to remove the pattern without breaking the mold cavity. After doing this, the flask is reassembled and pins are placed on the flask in order to maintain structural integrity of the mold. It is now ready to be filled with the molten metal.

The molten metal can be prepared prior to the lab (if molten metal is not available this portion can be skipped).

**Safety of the student is of the highest concern. When this experiment is carried out, prepare students beforehand. Proper safety attire should always be required. Students should be advised to wear jeans and closed toed shoes. Be sure to have a leather apron, face shield and high temperature gloves for the individuals responsible for handing the crucible and pouring of the molten metal.**

If a student is helping to demonstrate, have them pour the molten metal into the mold. Place a pouring cup into the sprue to aid in placing the liquid into the mold more efficiently. Be sure to
skim off the top layer (slag) of the liquid metal with a slag stick and a pair of pliers. Steadily pour the molten metal into the pouring cup. This will aid in preventing overfilling and clogging. Once the mold is filled and the riser fills up, stop pouring. Use safety in handling any hot material. Leave the mold for an adequate amount of time to solidify. This will work out well if the class meets the next day or a few days later.

During the next class period, remove the pins in the flask and unpack the sand to locate the cast part. Show the students the cast part and pass the item around. Have them follow the instructions in the procedure portion of this module.

This exercise can be carried out as a demonstration, individually, or in groups. If used in a demonstration several cast metal pieces including pre-cut samples should be utilized and students encouraged to be involved by visually inspecting the samples to determine differences and imperfections, as well as to make predictions on how the material properties would be affected by any defects.

The overall set-up, fundamental concepts and analysis are discussed in more detail in the PowerPoint presentation.

Module Procedure (There are additional videos and information online available to assist in setting up equipment and preparing the mold)

1. Display a set of cast samples on a hard surface and discuss the importance of sand casting and the varying factors that are involved.
2. Display similar samples that have been pre-cut. Ask the students if they can find any defects on the sample(s) and if they can predict if the material has other defects internally and how they would go about finding this out. Discuss hardness in materials in order to expand on the concept. (The hardness of materials module on the MatEd website would be a great addition to aid in teaching this concept.)
3. Show the PowerPoint presentation and discuss each slide.
   a. Slide 1-2: Introduction to sand casting (key concepts)
   b. Slide 3-9: Typical Equipment and supplies
   c. Slide 10-12: Experimental Set-up
d. Slide 13: Sand Cast Parts

e. Slide 14: External and Internal Flaws

f. Slide 15: Safety guidelines and importance of safety

g. Slide 16-18: Questions, recap, basic terms

4. Perform demo/lab

If a demonstration is used be sure to show the students samples of sand cast materials. If identical samples are available, ask students to comment if they notice any differences and to make predictions if internal voids will be present. Obtain or prepare samples that are cut in half, or in sections. Display halved/sectioned pieces of the sample to the students as this will allow them to see that sometimes there are imperfections in materials that are not apparent on the surface.

If a lab, have students (individually or in groups) make up their molds utilizing the same model for each the mold.

If equipment is available a full lab experiment can be accomplished by following the steps provided. **Lab instructor should handle the molten metal preparation.**

Mold Preparation

1. Preparation of the green sand: Sift the silica with the fine metal mesh and mix with the Bentonite clay in a large container. The mixture should be moist to the touch. Test wetness by grabbing a handful of the mixture and squeezing it. If there is water it is too wet and more silica should be added. If it crumbles then it is too dry and more clay should be added. The green sand is ready to be used when you can squeeze it and no water is visible and it can retain its shape without falling apart. Once it’s ready place a top on the container in order to seal it and prevent it from drying out.
2. Place the drag, bottom portion of the flask, on a hard surface.

3. Place model into the middle of the drag and layout the runner so that is touches your model. The model and runner should lay flat and be at least 1 inch from either side of the drag’s edge. Sprinkle on parting powder. This makes it easier to remove them after the green sand is packed.

4. Lightly sprinkle the green sand mixture into the drag slowly covering the model and runner. Once completely covered pack the edges using the rammer and then the top until sand is completely compacted.

5. Carefully Flip the drag onto its bottom side and attach the cope. Spread more parting compound onto the surface.

6. Place the riser and pouring cup into the flask and lightly spread green sand into it.

7. Once the sand has completely covered the surface use the rammer to pack the sand once again.

8. Once the sand is safely compacted open the flask and carefully remove the cope.

9. Remove the pouring cup and riser pieces from the cope as well as the model, runner and gating system from the drag. Take care to remove everything carefully to ensure that you do not disturb the mold.

10. Use a fine pain brush to eliminate any particles of sand that has fallen into the molded areas. Gas vents can be placed using a very small file on the cope if needed.

11. Attach both pieces of the flask together. Your mold is ready for use. Keep it covered while you are preparing the molten metal.

Below is a diagram of what the flask will look like once all the steps are completed
Molten Aluminum preparation  

Lab Instructor only

Be sure to wear all safety equipment in order to avoid injury.

1. Ramp the temperature up on furnace. Set temperature slightly above the melting temperature for aluminum. Look up the specs on the melting temperature online.
2. Place aluminum ingots in a crucible into the heated furnace using metal tongs.
3. Wait until metal is completely molten. If the mold is ready remove the crucible from the furnace.
4. Have a helper remove the slag using a slag stick held by a pair of pliers. Place the slag into waiting crucible or other designated area for hot materials.
5. Pour the molten aluminum into the flask slowly and evenly into the pouring cup
6. Once the riser is filled with the molten metal, stop pouring.
7. Place crucible in an area to cool down or place it back into the furnace, if making additional parts.
8. Place a sign to notify anyone there is something very hot in the area, if left unattended. Wait until next class period and disassemble the flask and remove the cast part.
9. Note the quality of the cast piece and have students draw conclusions from the experiment.
As an additional activity and to help concrete the concept of how materials properties change from processing, such as sand casting, cut at least two sections of the final castings and perform hardness testing on them. (See Hardness Testing of Materials Module)

5. Ask the students to identify possible variables that can affect a final casting of the material and have them explain why.

   If various (identical) castings were made, ask students to compare them for flaws or differences, ask them what they would do in order to prevent them from occurring in future castings and why. They can also be sectioned to look for voids and other irregularities.

6. Conduct a class discussion on the exercise to determine what the students have learned.
   Were their predictions correct?
   Repeat the PowerPoint in order to solidify/emphasize specific concepts. Have students answer the experimental analysis questions and to identify variables that could possibly cause the results to change.

Optional:

**Lab report** - Have students report, presenting their results and discussing any variables involved in differences in the castings in order to reiterate the key concepts involved in the sand casting evaluation for materials.

**Activity** - In order to help highlight the concept of how and why sand casting of materials can affect hardness, the Materials Processing Module or Hardness Testing of Materials could be added to the current lesson plan.

**Supporting Materials and References**

Please see accompanying PowerPoint
There are also a variety of videos that are on the internet that can help as a visual aid.

Acknowledgments

The author wishes to thank the Professor T. Stoebe and Professor Fumio Ohuchi in developing and editing this module, and the suggestions from all the reviewers. The Materials Science & Engineering Department at the University of Washington provided the equipment needed for the development of this module.
Evaluation

Student evaluation (discussion/quiz)

1. If castings were made, did you find the process to be difficult? Was it what you expected?
   If not, please explain.
2. Is there a difference in each casting if you used an identical mold? Explain.
3. Why is it important to have a choke? How can you test your material in order to check if
   it worked?
4. Is it important to compact the sand prior to pouring the molten metal? If so, explain.
5. How does sample preparation affect the final casting?
6. How is sand casting utilized in current industries? (Automotive, aerospace, etc.)?

Instructor evaluation

1. What grade level and class was this module utilized for?
2. Were the students able to grasp the key concepts introduced in the module?
3. Was the level and rigor of the module acceptable for the grade level of the students? If
   no, how can it be improved?
4. Was the demonstration/lab work as outlined? Did it help the students in learning the
   material? Were there any problems encountered?
5. Was the background on sand casting sufficient for your understanding and for the
   discussion with the students?

Any comments and/or suggestions on improving this module are encouraged.

Course evaluation questions

1. Was the demonstration/lab clear and understandable?
2. Was the instructor’s explanation comprehensive and thorough?
3. Was the instructor interested in your questions or concerns?
4. Was the instructor able to answer your questions thoroughly and to your satisfaction?
5. Was the importance of sand casting made clear?
6. What was the most interesting thing that you learned about in regards to sand casting?

**Definitions**

- Casting flask – two piece, cope and drag, metal or wood frame that holds the molding sand.
- Crucible – clay container used for melting metals.
- Cope – upper part of the casting flask.
- Drag – bottom portion of the casting flask.
- Gating system – pathway for the molten metal.
- Ingot – metal that is shaped for ease of processing
- Slag – unwanted metal semi-solid formed on the surface of the molten metal.

Helpful sites and additional tips

There are a multitude of videos and information on the web such as

http://www.asminternational.org/portal/site/www/NewsItemVideo/?vgnextoid=595e67ea3b143310VgnVCM100000621e010aRCRD

http://flamingfurnace.com

Step by step instructions on setting up the flask with pictures:

http://dtzone.com/resmat/m_ind_sand_casting_step_by_step.htm

Video that goes over sand casting

Part I: http://www.youtube.com/watch?v=UVGmsS-7tIE&feature=relmfu

Part II: http://www.youtube.com/watch?NR=1&feature=endscreen&v=9g_JfhjcBAU