Lesson 2: Steamin' Ahead

Adopted/Revised From
"A Model Geothermal Steam Engine," Edison Science Education Series 1992 and
Geothermal Power: http://www.energyeducation.tx.gov/pdf/51ainv.pdf

Grade Level
6-8

Objectives
- Construct a steam turbine
- After building the first turbine, determine criteria for a "good" design, collect and analyze data on those criteria
- Modify design for maximum efficiency

Overview
Students construct a steam-powered turbine, experiment with the materials for the turbine blades and hub and angle of the blades to produce a smooth, easy spin. As a class, students determine what characteristics are common in the good design, rate each turbine on those characteristics, and discuss how electricity is generated by using a steam powered generator.

Materials
Per participant
- 1 newspaper (complete section) for each coffee can
- 1 coffee can with plastic lid (1lb either metal or plastic)
- 1 pair scissors
- 1 protractor
- 1 plastic spoon
- 1 Styrofoam cup
- 1 pencil and paper

Group materials
- 2-4 rolls duct tape
- Water (access to a faucet is ideal)
- 10-15 lbs dry ice (**See safety instructions below before purchasing dry ice**)
- 1 cooler (thickly lined with newspaper – at least 28 quart size)
- **Gloves and tongs (for the teacher to handle dry ice)**
- Hammer to break dry ice into chunks
- Scale (optional)

Turbine hub suggested materials (others materials can also be suitable)
- Jumbo push pins
- Large paperclips
- Golf tees

Turbine blade suggested materials (others materials can also be suitable)

- Aluminum foil – heavy duty
- Gallon plastic milk jug (emptied and clean)
- Styrofoam cups (offer this material in the 2nd round, during the redesign)

Estimated Cost of Materials
$8/student or group

Computer Required
No

Duration
3–4 class periods

Primer References
1.1 Forms of Energy
1.6 Electricity Generation

Related Articles
N/A

Engagement

1. What is the difference between a generator and a turbine?
2. The blades of a wind turbine are pushed by the wind. What other forms of power can we utilize to spin turbines?
3. Some areas of Colorado have hot springs. How can this form of power be used to spin a turbine?
4. Renewable energy comes from sources of power that are not finite (like oil). How many can you name? Do they all work the same?

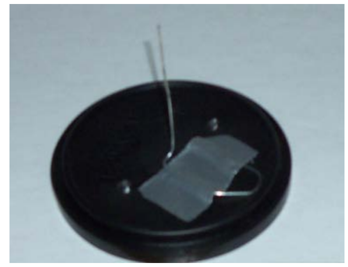
Investigation
We are going to build a steam powered turbine that can use the energy contained in various fuel sources to generate electricity. Each student will build their own turbine prototype, with the goal of building the most efficient design. You will have several different kinds of materials to use for the blade design and the hub of the turbine. We will determine what characteristics are common among the most efficient designs, and use those criteria to collect data on each turbine.

1. Distribute the "per participant" materials.
2. Have a central location for the shared "group" materials, and go through the different materials available for the turbine hub and the turbine blades.
3. Discuss how each material is different (for example, the weight of the aluminum foil, Styrofoam, and milk jug plastic compared to the overall strength of each material). How will each material impact the overall blade design?
4. Discuss variables in this experiment. When students begin their modifications on their design, they will have more success when they test only one variable at a time. Please see Instructor Notes on ideas for developing criteria for analyzing each design.

Base of steam turbine:

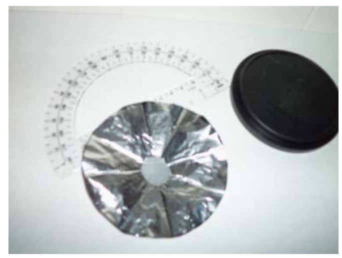
1. Put the lid on the coffee can. With scissors, carefully punch a hole in the coffee can lid located 1-2" from the rim. On the opposite side of the lid from your first hole, punch another hole located 1-2" from the rim.
2. Use all the newspaper to wrap the sides and bottom of the coffee can. Be sure that you leave enough of a lip on the can to secure the coffee can lid. Secure the newspaper ice.

Hub of steam turbine (*i.e.* push pin or golf tee):



1. You have several kinds of hubs to select based on your best guess of which will allow the blades of the steam turbine to spin the best. Pick which hub you want to use.
2. Attach your hub to the center of the lid of the coffee can (point up) with duct tape.
3. When you have the option to modify your design, you can try different hubs.

Blades of steam turbine (*i.e.* aluminum foil or plastic milk jug):



1. The basic blade design on this steam turbine is made from a single circle of your chosen material, and then cut into 8 wedges (like cutting a pie into 8 pieces).
2. If you select the milk jug, use a side that is the flattest.
3. Remove the lid from the coffee can, and use the pencil or a permanent marker to trace the coffee can lid on the blade material you selected (plastic milk jug, foil, Styrofoam…). Cut out the circle.
4. The hub point will be the pivot point for the blades at the very center of your blade circle. Use a piece of duct tape in the center of the blade material that the point of the hub will touch. This will help to hold the point in the center of the blades circle as well as protect the blade circle from being torn by the point. Which will work better - a square or round piece of duct tape? Make a dot with your pencil directly in the center of your duct tape, which is directly in the center of your blade circle.
5. On the blade circle, you will be making 8 blades by cutting from the edge of the circle to the duct tape center. Do NOT cut all the way through your circle to separate each blade, but leave the center whole (the blades are one large piece). Hint: Use a protractor, and make each blade section ⅛ of the circle. Why?
6. You may later want to try a design in which the blades to attach to something that then attaches to the hub.

Evaluating your steam turbine:

1. Before adding the dry ice, students should try to determine the efficiency of the design by finding ways of measuring. For example, is the overall design the most symmetrical? The area and angle of each wing on the milk jug circle can be used. The least difference among the 8 wings could mean the most symmetrical design. Is it the number of times the milk jug circle turns? Ask the class what other criteria could be measured to determine the efficiency of the turbine, then hand out the activity sheets.

2. ***See Instructor Notes (below) for more detail on the evaluation of the turbines.***

Testing your steam turbine:

1. As a class, discuss how to handle dry ice safely.
2. Fill the coffee can about ¾ full with water.
3. Your teacher will give you a spoon and a piece of dry ice in a Styrofoam cup. Carefully add the dry ice to the water. (**See safety instructions below for handling dry ice**.)
4. Secure the coffee can lid on the coffee can. Place the blades' duct tape center mark on the coffee hub point.
5. The blades work better if they are set at an angle. Begin testing what angle will get your steam turbine to spin. Record each time you make an adjustment and the results you obtain from that adjustment in the activity sheet.
6. Remember to share your results with your classmates. By sharing, you will find ideas for improving your design.
7. When you get your blades to spin, what adjustments do you need/want to make to improve the design? Describe your adjustments and your results. Remember to only change one variable at a time.
8. If your dry ice stops sublimating, it is probably encased in water ice or it has completely sublimated. Pour out your water in the sink and refill your coffee can. If you don't get any steam after adding new water, your teacher will give you additional dry ice to continue your experiments.

Class Review

- Evaluate each person's design to determine what are the common factors in an efficient design, and the common factors for a less efficient design.
- Have the class compare and contrast number of turns over a given time period, differences in wing areas, and differences in blade angles.
- As a class, graph the relationships between: a) differences in wing areas and number of turns over the predetermined time frame; and b) differences in blade angles and number of turns over a predetermined time frame.
- What are the common features of the most efficient designs?

Elaboration

- Have students read the Primer References.
- Steam generators use heat to boil water and produce steam. In this exercise, we are using dry ice for safety reasons. Dry ice is cold. Is it a suitable substitute?
- What are some of the pros and cons of using different types of energy to power turbines?

Instructor Notes

- Discuss dry ice safety instructions with the students before dispensing the dry ice.
    - ***************WARNING! ****************
    - *Handle with extreme CAUTION!*
    - *Dry Ice is very cold* −78.5 °C *(-109 ° F).*
    - *Do NOT handle with bare hands.*
    - *Use dry gloves when handling (in this lesson, students do not touch the dry ice, but transport it by a Styrofoam cup and plastic spoon).*

  - *Do NOT ingest dry ice.*
  - *Do NOT seal in glass or other tightly closed containers.*
  - *Do NOT enter poorly ventilated areas where used or stored.*
  - *Do NOT leave children or pets in a vehicle with dry ice.*
  - *Carbon dioxide gas is not poisonous or toxic, but it will NOT support life.*
  - *If transported in a vehicle, leave at least one window open, or otherwise provide for ample fresh air ventilation.*
- This lesson can be done with partners or in small groups.
- Instead of using heat for producing steam, this lesson uses sublimating dry ice in water. Although dry ice can damage skin, it takes longer than using hot steam and the risk of scalding injuries.
- The photographs in this lesson (and the video online) are from a working steam turbine using the following materials:
  - large paperclip for turbine hub
  - aluminum foil for turbine blades
- Guiding students to determine criteria to evaluate turbine design: Symmetry and balance are both important pieces to developing a design that efficiently turns under steam power. Ultimately it would be the number of turns per minute, but how do the students best obtain that result? Suitable criteria, therefore, are the number of turns per minute, the materials used, the blade area, the symmetry of each blade, the mass of the blades, placement of the holes in the coffee can lid, number of blades, and the angle of the blade. The only tricky variable is the symmetry of each blade. Not only does blade area factor into symmetry, but how uniform each blade is to the other also factors in to symmetry. You can use indices to evaluate this component.

Extension and Variations

- Design a steam turbine and generator. How would you build it? Sketch out your blue prints, labeling the materials you would use, and detail how it would work.
- In depth analysis: To analyze the symmetry of each blade, have your students select the length at the midpoint of the longer side (L), the width at the midpoint of the shorter side (W), and the surface area (SA). To easily compare results, develop a formula: (L/W)/SA. Example: L=8.4cm, W=4.0cm, SA=14.8cm^2 or (8.2/4.0)/14.8=0.1385. Each blade would be measured, and the blades then compared by index numbers obtained. Additionally, students can compare different blade designs from all the turbines, regardless of the shape this way.
- Analyzing student selected criteria: Students first need to graph the symmetry index for each blade and find the slope. The most symmetrical blades will be a straight horizontal line (m=0). To evaluate and compare all the turbines, students need to identify the most important component (number of turns per minute). To evaluate the effectiveness of each design, the students need to produce a series of graphs, using the number of turns per minute as the X axis, and then angle, then surface area, and slope of the blade indices graphed. Each datum can then be identified by type of material used (*i.e.* red for milk jug plastic, blue for aluminum, and green for Styrofoam).
- Using the map located at http://www.nrel.gov/gis/geothermal.html, determine if you live in an area that can utilize geothermal energy. After reading the Primer on Geothermal

Energy (3.3) and one or more of the articles linked to below, have a class discussion on how geothermal energy might be used to power a steam turbine:

- "http://coloradoenergynews.com/2011/03/bureau-of-land-management-colorado-partner-on-geothermal-development/" – Colorado Energy News, March 15, 2011
- "http://www.chieftain.com/news/region/geothermal-electricity-a-possibility/article_02db3304-74a2-11e1-a338-0019bb2963f4.html" – The Pueblo Chieftain, March 23, 2012
- "http://www.pagosadailypost.com/news/19789/Significant_Steps_Towards_Geothermal_Greenhouse_Project/" – Pagosa Daily Post, January 19, 2012
- "http://www.cres-energy.org/techbasics/geothermal_div1.html" – An overview of geothermal energy with specifics about Colorado geothermal resources brought to you by CRES, the Colorado Renewable Energy Society

References/For More Information

U.S. Department of Energy
http://www.eere.energy.gov/topics/geothermal.html

Geothermal Power (magazine)
http://www.energyeducation.tx.gov/pdf/51ainv.pdf

Steamin' Ahead

Description of Turbine Design	Number of Blades	Mass of Blades (oz.)	Angle of Turbine Blades (in degrees relative to coffee can)	Area of Largest Wing (cm^2)	Area of Smallest Wing (cm^2)	Difference (cm^2)	Number of Turns Over Given Time (per teacher)

Questions

1. What factors resulted in the turbine working as hoped for?

2. What would improve the efficiency of the turbine design?

3. What would need to be introduced into the turbine in order to generate electricity?

4. How would efficiency be measured for a turbine capable of generating electricity?