Stirling Engine

Overview: The Stirling heat engine is very different from the engine in your car. When Robert Stirling invented the first Stirling engine in 1816, he thought it would be much more efficient than a gasoline or diesel engine. However, these heat engines are used only where quiet engines are required, such as in submarines or in generators for sailboats. You're going to make one out of soda cans and old CDs.

What to Learn: A Stirling engine shows us how energy is converted and used to do work for us.

Materials

- three soda cans
- old inner tube from a bike wheel
- super glue and instant dry
- electrical wire (3- conductor solid wire)
- 3 old CDs
- one balloon
- penny
- nylon bushing (from hardware store)
- small candle or alcohol burner
- fishing line (15lb. test or similar)
- pack of steel wool
- drill with 1/16″ bit
- pliers
- scissors
- razor
- wire cutters
- electrical tape
- push pin
- permanent marker
- Swiss army knife (with can opener option)

Lab Time

1. Open each soda can and empty the soda. Remove the top of one soda can with your can opener. This work most easily by moving along the ridge on the can's lid. Be careful not to cut yourself, so use adult supervision.
2. Take the top off the second can in the same way, and then remove the bottom of the second can completely, about ¾ inch above the bottom. Use a sharp razor.
3. Cut the neck off a balloon to serve as the piston, and fit it over the lid of the can open at the top. Use a rubber band to attach it at the top if needed. Now cut a square out of the inner tube that measures ¾ inch on each side. Glue the tube square on the center of the balloon and push down so it stays. To dry it quickly, spray instant dry on it.
4. Take a pushpin and poke a hole in the center of the tube square. Set the can aside.
5. Take a water bottle cap and mark where we will drill holes. Mark one spot on the side of the cap (about halfway up) and at an equal spot opposite. Also make a mark in the center of the cap. *Drill the holes with adult help*, using pliers and a piece of wood to help make precise holes.
6. Attach the bottle cap to the opposite side of the diaphragm on the soda can (on the bottom), so take the balloon off, and flip it upside down, stretching it over the lid again. The point of the pushpin should point up, so thread it through the hole in the middle of the cap. Secure it with glue, and use instant dry. Set this aside.
7. Grab the other can and prepare it for drilling. Make a mark about 1 inch down from the top of the can, and make a similar mark on the exact opposite side of the can. Drill the holes, using a piece of wood to help support the can if needed. *Remember to use adult supervision!*
8. Use the circular template and tape it in place to cut a viewing hole. You want the template secured so that it is not on the same side as the holes. Mark an outline where you will cut, and use a razor to cut it out.

9. Bend the wire in the shape of the crankshaft according to the template. Use pliers to help, cutting the wire to about 8 inches to ensure a precise fit. Bend it with your fingers to match the template. Make two marks according to the template and make marks on the wire. At this point, you will bend the loop in the crankshaft 90 degrees, using two pairs of pliers this time. Make sure the ends of the crankshaft are as flat and straight as possible. Orient and place the wire inside the can with the viewing hole cut out. Check to make sure it can spin freely. Secure the ends with pieces of tape to stop it from sliding out.
10. To make the displacer, take a 16-inch piece of copper wire, straightening it as much as possible. Use pliers to create a small hook of about ½ inch. Use steel wool to roll the wire up. It should be the diameter of the soda can once rolled up. Check that it fits into the bottom of the soda can with enough clearance to fit in and out fairly easily. Use the pliers to work the copper wire to the height of the can.
11. Take your fishing line and cut off a few inches, tying it onto the loop of the wire in the displacer. Secure it with superglue and instant dry if necessary. Thread the fishing line through the diaphragm. Before you do this, take the diaphragm off and put it back on upside down, and pull the pushpin out, threading the fishing line that the pushpin made. Place some oil around the wire so that it slides more easily. Test it to see that there is no drag when you lift the whole displacer.
12. Nudge the displacer into the top of the soda can with the top cut off. Put the diaphragm over the top of the can, making sure the bottle cap is centered. Test again to make sure the displacer falls freely. If it doesn't add more oil.
13. Take about 8 inches of copper wire and stick it through the holes in the sides of the bottle cap. Bend each side of it with pliers. Make sure it can spin freely, so leave a gap on each side of the cap. Use pliers again to bend the sides of the wires in towards the center of the cap, and then again so that it can fit inside the other can. Both sides of the wire should touch the crankshaft in the can above.
14. Press the top can down around the bottom can gently. Don't crush the can; we only want to ease it down a bit further so that it is secure.
15. Secure the crank to the pushrods by orienting the long part towards the bottom of the can. Make a mark about ½ inch higher than the spot where it rests on the crank. Trim the rods at these marks with wire cutters. Allow the connecting rods to stick out the front, mark them about ¼ inch from the end, and make hooks at these spots. Bend the hooks with pliers so that they stay on the crank. Loop the hooks around the crank so that when spun, the push rods allow the displacer to move up and down. Make sure the crank turns freely. If your balloon wants to push the rods up into the crank too far, simply bend the corners in the push rods more sharply to shorten the rods. Be careful that the fishing line doesn't get caught.
16. Tie the fishing line to the middle of the big loop on the crank. Make sure the knot isn't so tight that it restricts the free movement of the crank as it turns. Tape the two strands of fishing line together, and trim the loose ends of the line with scissors.
17. To make the flywheel, grab 3 old CDs or DVDs (anything by Michael Bay will work). Take your piece of nylon bushing, which should be about ½ in diameter and 1 inch long. It should fit through the center of the CD. Attach the CDs to the bushing (make sure it fits nice and snug).
18. Sand the end of the crankshaft so that it glues more easily. Hot glue this side to the nylon bushing, generously gluing through the center of the bushing. Check to see that the flywheel spinning will crank the engine.
19. Position the crank so that the large crank is facing downward. Attach a penny to the top surface of the CD to serve as a counterweight. This will allow the engine to run more smoothly.
20. To make the engine's base, cut the top and bottom off a can as we did before. Place a burner on the inside at the bottom, and then tape it to the can. Make a hole for air with the razor in the side of the can at about the level of the flame. Cut a few more holes in the side. They should be big enough so that you can light the burner.

21. Assemble the engine on top of the burner base. Now we're ready to test this thing, so remember to put on safety goggles! Use a lighter to light the burner, and keep a hand on the top of the can to keep it steady. If you need to give your engine a jump start, spin the flywheel.
22. Record your observations on the worksheet.

Stirling Engine Observations

1. What happens when you start the engine? What is going on?

2. Grab a cold bottle of water and pour a small amount into the top of the bottle cap. What happens? Why does this happen?

This engine was developed because it was quiet and could use almost anything as a heat source. This kind of heat engine squishes and expands air to do mechanical work. There's a heat source (the candle) that adds energy to your system, and the result is your shaft spins (CD).

This engine converts the expansion and compression of gases into something that moves (the piston) and rotates (the crankshaft). Your car engine uses internal combustion to generate the expansion and compression cycles, whereas this heat engine has an external heat source.

Reading

Here's how a Stirling engine is different from the internal-combustion engine inside your car. For example, the gases inside a Stirling engine never leave the engine because it's an external combustion engine. This heat engine does not have exhaust valves as there are no explosions taking place, which is why Stirling engines are quieter. They use heat sources that are outside the engine, which opens up a wide range of possibilities from candles to solar energy to gasoline to the heat from your hand.

There are lots of different styles of Stirling engines. In this project, we'll learn about the Stirling cycle and see how to build a simple heat engine out of soda cans. The main idea behind the Stirling engine is that a certain volume of gas remains inside the engine and gets heated and cooled, causing the crankshaft to turn. The gases never leave the container (remember – no exhaust valves!), so the gas is constantly changing temperature and pressure to do useful work. When the pressure increases, the temperature also increases. And when the temperature of the gases decreases, the pressure also goes down. (How pressure and temperature are linked together is called the "Ideal Gas Law".)

Some Stirling engines have two pistons where one is heated by an external heat source like a candle and the other is cooled by external cooling like ice. Other displacer-type Stirling engines have one piston and a displacer. The displacer controls when the gas is heated and cooled.

This Stirling engine uses the heat from a coffee cup and the cooling from the ambient air.

In order to work, the heat engine needs a temperature difference between the top and bottom of the cylinder. Some Stirling engines are so sensitive that you can simply use the temperature difference between the air around you and the heat from your hand. Our Stirling engine uses temperature difference between the heat from a candle and ice water.

The balloon at the top of the soda can is actually the "power piston" and is sealed to the can. It bulges up as the gas expands. The displacer is the steel wool in the engine which controls the temperature of the air and allows air to move between the heated and cooled sections of the engine.

When the displacer is near the top of the cylinder, most of the gas inside the engine is heated by the heat source and gas expands (the pressure builds inside the engine, forcing the balloon piston up). When the displacer is near the bottom of the cylinder, most of the gas inside the engine cools and contracts. (The pressure decreases and the balloon piston is allowed to contract.)

Since the heat engine only makes power during the first part of the cycle, there's only two ways to increase the power output: You can either increase the temperature of the gas (by using a hotter heat source), or by cooling the gases further by removing more heat (using something colder than ice).

Since the heat source is outside the cylinder, there's a delay for the engine to respond to an increase or decrease in the heat or cooling source. If you use only water to cool your heat engine and suddenly pop an ice cube in the water, you'll notice that it takes five to fifteen seconds to increase speed. The reason is because it takes time for the additional heat (or removal of heat by cooling) to make it through the cylinder walls and into the gas inside the engine. So Stirling engines can't change the power output quickly. This would be a problem when getting on the freeway!

In recent years, scientists have looked to this engine again as a possibility, as gas and oil prices rise, and exhaust and pollutants are a concern for the environment. Since you can use nearly any heat source, it's easy to pick one that has a low-fume output to power this engine. Scientists and engineers are working on a model that uses a

Stirling engine in conjunction with an internal-combustion engine in a hybrid vehicle… maybe we'll see these on the road someday!

Exercises Answer the questions below:

1. What is the primary input of energy for the Stirling engine?

2. As Pressure increases in a gas, what happens to temperature?
    a. It increases
    b. Nothing
    c. It decreases
    d. It increases, then decreases
3. What is the primary output of the Stirling engine?

Answers to Exercises: Stirling Engine

1. What is the primary input of energy for the Stirling engine? (the candle)
2. As Pressure increases in a gas, what happens to temperature? (It increases.)
3. What is the primary output of the Stirling engine? (the moving piston)