A Stirling Engine Project
by marshon on June 5, 2010

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http://www.instructables.com/id/A-Stirling-Engine-Project/
Intro: A Stirling Engine Project
As part of a longer term project to build an Aluminium Forge blower using a Stirling, I decided to try and build a basic LTD to make sure I could get the damn thing to run.

I had to use whatever I had lying around to try and build it, so my materials list may not be the best, or the right way to do it.

I had a good look at a number of Stirlings on the net before I began. It was obvious to me that the most difficult part of the manufacture would be the sealed piston assembly and the linkages. These were cast using the resin process in one of my other instructables.

I couldn't get the video to embed correctly, so here's a link to the Youtube video:

VIDEO

step 1: Materials

I used the following materials to build this Engine.

Two hard drive platters from a 3 1/2" HDD
3 CD-Rs
A 10p piece
A 2mm steel rod from an HP printer (scrap)
A 2.5mm brass tube (dunno where that came from)
A piece of 22mm (1") copper pipe
A plastic storage container (Tesco's 78p)
A bit of sponge floor tile
Some resin and alginate
Odds and ends from old scrap printers
Various glues, solder etc.

My main goals were to assemble a working engine that looked nice without doing too much machining. Access to a drill press and possibly a small lathe would be an advantage.

Here are my main 'ingredients' from scrap.
step 2: Making the Diffuser Cylinder

I was lucky when I started sourcing materials. The round plastic food container was exactly the same diameter as the 3 1/2" HDD platters. These three would form the main parts of the diffuser cylinder.

The only problem was that the platters have a 1" diameter hole in the middle! The base of the cylinder needs to be sealed so I added a 10p piece to the bottom plate using epoxy resin.

The plastic container was cut down to 25mm high using a Dremel with a slitting saw. If the stroke is made 10mm and the diffuser piston is 12mm thick then there should be about 2.5mm clearance for the piston. At this stage I don't know if that's good or bad. It's a learning curve.

The lower plate was glued on using epoxy glue (Araldite or JB Weld should do the job). It is imperative that the bond forms an airtight seal or the engine won't run! I found out to my cost after struggling to get any kind of performance out of the engine. There was a VERY small leak on the diffuser cylinder!
**step 3: The Upper Plate**

The upper plate for the diffuser cylinder uses the other platter from the 3 1/2" drive. The 1" hole in this one will be sealed using the resin bearing for the diffuser piston con rod. However the platter also needs a hole drilling for the sealed (cold) cylinder arrangement. I was very dubious about drilling through the platter since it may be a glass or ceramic, rather than a metal disk.

Now, trying to mark a centreline on a disk with a great big hole in the centre of it is not easy. The method I used was to carefully mark a line on a piece of card. Having measured the diameter of the disk (95mm exactly) I knew the radius to be 47.5mm so I drew another parallel line that distance from the first. A 6" steel rule was then taped to the lower line and the disk rested against the ruler. The second line MUST bisect the disk (if I measured carefully enough) and a second straight edge laid on the second line MUST describe a line through the centre of the disk. Erm, yes but it's certainly not going to be pinpoint accurate. Hopefully it will be close enough.

I marked and centre punched the position of the sealed cylinder, I was guessing a good location for the cylinder would be halfway across the disk face. This proved to be exactly 30mm from the centre which would give me the position of the crank arm on the crankshaft. If I were to do this again I might use a slightly different positional arrangement. The disk showed a slight deformation where it was punched. Phew, it must be metal otherwise it would have cracked. Then using a set of standard compasses I scribed a 22mm circle using the centre punch mark. This will help me align the cylinder which is 22mm copper pipe.

Because the Stirling is a gas transfer difference engine the hole for the sealed cylinder does not need to be anywhere near the actual diameter of the cylinder (I hope!). I decided that a 6mm hole should be adequate to allow free flow of gases between the two cylinders. I centre drilled the punch mark, then drilled it out to 6mm.

I used a small pipe cutter to cut the copper cylinder 35mm long. It needed carefully cleaning up at the ends and down the bore to ensure smooth running of the piston.
**step 4: The Pistons**

According to various sources, the diffuser piston should be as lightweight as possible. I toyed with an aluminium one using a can, but I didn't have anything anywhere near the size required. I thought of using expanded polystyrene foam, but it didn't seem robust enough. In the end I used some dense closed cell foam floor tile 12mm thick.

I cut a disk around 85mm in diameter leaving a 5mm gap, I dunno if that's going to work either. The disk is light, but also a bit flexible. I think I will give it a couple of thin coats of resin to give it a hard skin which should stop it flopping around.

The piston and the bearing were cast as a couple of resin blanks using the alginate and resin system on one of my other instructables. I cast the bearing 28mm in diameter, then turned down a shoulder to the 25mm fit needed for the HDD platter. A 2mm hole was drilled dead centre and the bearing was glued into the platter using epoxy glue.

The sealed piston was cast using the copper pipe so it would be about 1mm oversize. I then carefully and slowly filed it down while spinning in the drill, and finally polished it for a nice sliding fit. I tested the fit by dropping it into the copper cylinder, it dropped straight down, I then blocked the 6mm gas hole and dropped it in again. This time it took a good 3 seconds to fall the full length of the cylinder. I hope that will be good enough for the seal.

The copper cylinder was then glued on using epoxy glue and the scribed mark as a guide.

Using the Dremel and some grinding disks I made a coupling for the power piston. Drilling it proved a challenge. The coupler will be glued onto the con rod, and another coupler will have to be made for the rod of the diffuser piston.

I painted the diffuser orange once the resin had set, mostly so it will show up when it's moving ........ hopefully.
**step 5: The Crankshaft**

I had a good idea as to how I would make the crankshaft. I didn't want to try and bend one up since my abilities with the pliers would leave something to be desired. I wanted to assemble one instead.

The main shaft is a piece of 2.5mm brass tube. If I had access to solid bar stock I would have used that and made needle point bearings, but I didn't.

The cranks are formed by sliding pre-drilled plates onto the shaft, fixing them in place, then using the Dremel to grind out the original shaft to leave just the cranks. This method has advantages and disadvantages.

The main advantage is that the finished shaft should run true because the entire shaft was in place prior to grinding.

The disadvantage is that whatever method is used to connect the con rods must be in place before the grinding off. This means great care must be used with the fixing method (I wanted to solder the joints), and with the grinding so as not to damage the connectors.

I decided to use double-sided copper clad PCB board I had in the scrap box for the plates, and to make the connectors of resin or aluminium in the vain hope that they wouldn't be damaged by the solder.

If you have access to a small lathe, a better solution would be to use some 10mm brass bar stock. You could then centre drill for the main shaft and off centre drill for the stroke. Then part off 4 individual disks, thus ensuring that all the cranks are identical and giving some counterbalance to the crankshaft.

I didn't have any brass bar stock of the correct size.

I began by marking out and centre punching the copper PCB board. I cut it into a single strip using the Dremel. Then it was attached to a bit of scrap wood using double sided tape to help keep it steady. I then drilled all the holes at 5mm centres. This will give a stroke of 10mm.

I allowed about 1mm of scrap round each arm so they could be cut out and cleaned up.

The arms were then slid onto the crankshaft which I had cut to 120mm to allow some leeway for final assembly. I used a 6mm bit of scrap wood as a jig and soldered the outside of each arm to the main shaft.

I made up two connectors for the con rods from scrap aluminium bar from an old printer, and cut some short lengths of the remaining brass tube as the crank rods. The two connectors were cross drilled and then the rods were slid through the arms and the connectors and soldered on the outside of each arm.

Once it had all cooled down, the original crankshaft between each set of plates were ground away using the Dremel.

That completed the crankshaft.
step 6: The Flywheel

I was intending to use the platter from a 2 1/2" HDD as the basis for my flywheel. However, it's thickness was too small for me to edge glue effectively.

I knew that I didn't just want to use a single CD since a good flywheel carries most of it's weight at the edges. This generates extra centrifugal force increasing flywheel efficiency.

I decided to try and make up a flywheel from 3 CD disks. The main disk would carry the boss, and have spokes to lighten it's centre. The other two disks would be cut to give two rings about 12mm wide. When glued to the outer edges of the main disk this should give a decent flywheel. However, how to cut the CDs accurately without access to a CNC router was going to be interesting. Also marking them up when they have a hole at the centre was going to be a challenge.

I used a similar process to the HDD platters. I made up a simple jig using a piece of good flat wood. The disks are exactly 120mm in diameter, so two parallel lines 60mm apart, with two more at right angles were carefully marked on the wood. Then two known straight edges were taped to the lines. Now when a disk is pushed up against both edges the lines should bisect and mark the centre. It was then simply a matter of using standard compasses to mark the rings and a straight edge to mark out the spokes.

I then made up a little jig out of a nylon washer and bolt head. This was clamped into the machine vice of my drill press and the vice was bolted down to the table. This allows the CD to turn accurately on it's own axis, passing the cutter in perfect arcs.

With the drill on its' highest speed, I put a Dremel high speed cutter in the chuck. The cutter was fed through the CD and then the disk was turned by hand ensuring a perfect circular cut. I left little 'tabs' of material in each cut to stop the bits from flying off. These tabs were cut with a craft knife and tidied up with the Dremel.

Cutting the straight edges of the spokes was more difficult. They didn't end up as straight as I wanted, and I managed to crack the very last cut, probably by using too much force. I super-glued the crack since I wasn't going to go through all that to make another one.

Once cleaned up, the two outer rings were glued on with epoxy, and the boss screwed in.

That completes the flywheel with the exception of balancing later on.
step 7: The Pillars and Crankshaft Bearings

Once the flywheel was completed I made up a coupling for the diffuser piston and a new one from aluminium for the power piston (I broke the resin one when I sat on it!). The two couplings were added and the top plate was glued on with epoxy. Once again, make sure that the joint is a good air-tight seal or the engine won’t run.

I then made up two pillars from brass tube, these were glued into the little tabs on my food container. Two bearings were made of resin and the crankshaft was installed. The flywheel was glued on and a counterweight added to the far end of the shaft.

The con rods were added from 2mm steel rod from an old printer and the engine was ready for testing.
step 8: Adjustments and Refinements

I put the engine on top of a cup of hot water. I was very disappointed to find that it kept trying to run but just wouldn't keep going. Friction seemed to be the problem, the front pillar kept moving slightly and the diffuser piston con rod seemed to be a little juddery.

I decided to change the arrangement of the support pillars. They were cut down and soldered to some double sided PCB strips to give more area for gluing and then stuck directly onto the upper plate. A little drop of oil was placed on the bearings and the coupling on the diffuser was relieved to try and reduce any friction.

The engine still struggled and was obviously not happy. One thing I noticed was the apparent lack of compression in the power piston (or so I thought). The engine turns freely enough, and I have started to balance the system using weights added to the counterbalance at the end of the crankshaft.

I placed an ice cube on the top plate to increase the temperature difference. As the ice melted and dripped down the side of the diffuser piston the problem became very obvious. Little bubbles of air forming at the joint with the base! There was an air leak, and once this was corrected the engine ran well.

I will post a video once the engine is properly balanced.
rimar2000 says:
Very good work, clean and prolix. I think the upper and lower CD must be painted with a black permanent marker, to enhance the heat transfer. It will be better if you remove before the aluminum coating.

marshon says:
Interesting, but there are no upper and lower CDs, they are metal hard drive platters and they don't have an aluminum coating. It would only be worth painting the lower hot plate since black attracts heat, the last thing you want on the upper plate. A better idea would be an ice container on the upper plate to increase the differential temperature.

drorosz says:
Just how big is a “10p” piece??

marshon says:
About an inch in diameter, but any metal disk the right size to seal the hole in the platter will do the job. I just happened to find that a 10p piece fit the hole.

rimar2000 says:
Pardon, as I speak Spanish, not English. I do a superficial reading on the long texts. So, I don't saw the detail of the hard disc plates, only saw the photos. I insist that both sides should be black. A black surface is permeable to heat in both directions, and the Stirling engine, as a thermodynamics application, is not nothing but a converting heat into motion. More heat transfer, more effectiveness.

alienwear says:
He is correct, black heats up quicker, but cools down faster as well. Both plates should be black for maximum efficiency.

dylan young says:
this is cool.....but is there anything i could swap for the resin?????????? 5*

marshon says:
For the power piston you can basically use anything that will give a seal and still run with very little friction. I've seen pistons made from epoxy putty, JB Weld, graphite, nylon and aluminium. I use resin because it's very easy to work and get a good finish. For the bearings, you could use a hard nylon like Delrin, Teflon or acrylic. For the crankshaft you could obviously use real bearings. I'm currently working on another engine using hard drive bearings for the crankshaft.

k2d2 says:
amazing 5*

Phil B says:
This is the best description of a Stirling Engine project I have seen. I would like to try it sometime. Thank you.

marshon says:
If you decide to make one here's what I learned. Don't try to glue the diffuser cylinder together. It would have been far better if I had used a slightly smaller food container or a bit of 3” plastic drainpipe and bolted through the outside with a pair of gasket seals. The glue simply cant keep a seal against the polished surface of the platters, especially once it gets hot. I am constantly patching little leaks that develop.

Phil B says:
Someone gave me a kit for a Stirling engine. I have not had time to finish it, yet. One step had me gluing a brass connecting rod guide to an aluminum disc, but it did not stick. I need to re-engineer that step. Most of the kit is pre-punched cardstock. Thanks.

AndyGadget says:
Whoo - That's quite a project. I bought one of a similar design some time ago. Congratulations on getting the power piston friction low enough and the displacement disc rod seal good enough to work - That must have taken some time. Mine has a glass tube and a graphite piston and bearings.

marshon says:
The resin is quite forgiving as bearings. I just drilled the holes the same diameter as the rods, an sort of forced them through and a bit of spinning beds them in. Very little friction. However I am thinking of another one using HDD bearings.
pilotox says:
Congratulations, it looks very professional!

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