Stirling Engine Display Project

Hugh Currin
October 15, 2007

ABSTRACT

This project is to design and build a small low temperature table top Stirling engine for display. It is to be eye catching and draw people to an OREC or OIT display. The project will also develop an analysis for low temperature Stirling engines and predict performance of the design developed. Tooling will be developed so further engines may be manufactured in small lots.

INTRODUCTION

At fairs, shows and similar events a significant goal is to have people drawn to ones display. At these events there are many similar displays and any unique element which draws people in is advantageous. It is desirable to have an eye catching piece at the center or at least as part of a display. This is true for OIT recruitment as well as OREC outreach. This project is to supply such an eye catching element.

It has been suggested that a low temperature Stirling engine be used. These engines can be designed to use a low temperature heat source. They can be open framed showing their moving parts, be quite elaborate and eye catching. Their size is amenable to table top display. These engines would be ideal as a center piece for a technical school or renewable energy display.

The Stirling engine, commonly known as a hot air engine, was first developed by Dr. Robert Stirling. It was developed to overcome the dangers of steam engines used at the time. Steam engines require a boiler for operation, which under the right circumstances, can explode. This posed a great danger not only to the operators, but bystanders as well. During the 1930's, advances in electrical and internal combustion engines made the Stirling Engine somewhat obsolete in most applications. However, development of the Stirling Engine continues throughout WWII up until the present day, with advances occurring mostly in efficiency. New materials promoted less friction and better seals. The Stirling Engine was, and still is, used to generate power from waste heat of other engines and manufacturing processes.

Although Stirling engines aren't common research and development are ongoing. ReGen Power Systems of Stanford, ME (ref) is building a 100 megawatt Stirling type engine to run off of process heat generated at industrial plants. This engine is for electrical production.

NASA	http://www.grc.nasa.gov/WWW/tmsb/stirling.html
Lund University	http://www.vok.lth.se/~ce/Research/stirling/stirling_en.htm
US DOE	http://www1.eere.energy.gov/solar/csp.html
Univ or Canterbury	http://www.mech.canterbury.ac.nz/research/stirlingcycle.shtml
Estero	http://www.uidaho.edu/engr/ME/sr_des/hev/stir/
Quiet Revolution	http://www.qrmc.com/model2animation.htm
American Stirling Co	http://www.stirlingengine.com/FullPower.adp
etcetera	

Note, of interest
Univ of Idaho http://www.uidaho.edu/engr/ME/sr_des/hev/stir/

There are several applications currently used for Sterling engines. Combined heat and power engines, along with solar power generators are both currently produced for electricity generation. Cryocoolers have been around since the 1950's in cryogenics, but there counter part, heat pumps, have had limited commercial success. Sterling engines have been used as an alternative to nuclear powered military submarines and even trickling into commercial submarines. Nuclear power plants have replaced the steam generators with sterling engines. NASA and Ford each developed an automotive Sterling engine, but haven't moved passed the test phase. Low temperature difference engines are used for toy and demonstrations and are available commercially. Stovetop sterling engine fans are also available. [references]

There are a good number of hobby or demonstration Stirling engines available. These include ready made engines, kits and plans. Ready made demonstration engines range in price from around $100 to several thousand. [Only one site referenced ???]

A good number of Stirling engine kits and plans are likewise available. These range greatly in sophistication and required effort in construction. Darryl Boyd's Internet site offers free plans (ref http://www.boydhouse.com/stirling/). This design is a bit crude but does demonstrate engine operation. Koichi Hirata's web page (ref http://www.bekkoame.ne.jp/~khirata/english/make.htm) provides free plans for several Stirling engines types. The resulting engines vary from crude to quite sophisticated for hobby class engines. Another site, from Ronald Steele (ref http://www.sesusa.org/steele/steele.htm) offers a set of plans for $25. These result in a compact Stirling engine for higher temperature heat source use. Jerry Howell (ref http://www.jerry-howell.com/Menu-1.html) offers plans for several Stirling engines with plans costing around $20. These require more construction and machining than the others but the results have a very polished but industrial look. Though construction of these is more time consuming, and thus expensive, the results are very eye catching. His "Miser" engine is particularly interesting as a low heat source engine, ideal for a display setting.

CRITERIA

There are three objectives identified for this project. First, to develop a low temperature Stirling engine as part of a table top display. Its purpose is to draw attention to to OIT and/or OREC and their respective displays. Second, to analyze the selected low temperature Stirling engine in enough detail to predict and improve upon that design. And third, to develop and construct the tooling necessary to build small production runs of the selected Stirling engine.

The specific outcomes for the project to be a success are:

- The engine will operate (run unloaded at 500+ rpm) using the temperature difference between room temperature, 70 degrees F, and a human palm.

- The engine will easily sit on ones hand, thus being no larger than 6" diameter and 10" high.

- The engine will weigh less than 5 pounds.

- The engine will “look cool”, be eye catching, and attract people to the overall display.

- Heat transfer and thermodynamic analysis will be completed showing performance of the engine and lead to a more efficient design. The analysis should predict unloaded performance within 100 rpm.

- Processes and tooling will be developed to manufacture additional engines, in lots of 5 or more, is less than 2 hours each.

- The material and parts to manufacture each engine, in lost of 5 or more, will not exceed a cost of $75.

- The engine should run for 500+ hours without maintenance.

PROPOSED SOLUTION

There are several Stirling engines available, both ready made and kit form, which would meet the display goal of this project. For display it is suggested that a Stirling engine be built at OIT rather than purchased. There are two reasons for this. First finely built ready made engines are quite expensive, and second an engine built at OIT will better show off the hands on skills of OIT. This further justifies the Criteria that the engine be manufactured at OIT in small lots.

It is suggested that existing plans be used for the basic design. The analysis called for in the project will be used to fine tune this basic design. Likewise, the basic design may be modified for a better look and/or easier manufacture. In making modifications the criteria of an eye catching “cool” engine will be paramount. Trade offs will favor eye catching characteristics and engine function over ease of manufacture, to a reasonable point.

Further study of existing plans is needed before final plans are selected. From preliminary study the “Miser” Stirling engine from Jerry Howell seems to meet our needs. Figure 1 shows this engine.

The Miser is a low temperature Stirling engine which appears to meet our Criteria. It has a mix of modern design mixed with old fashioned turn of the century styling. It should be quite eye catching as the center of a display.

Obviously if plans are used the author of the plans must approve their use for our purposes. This may require a licensing agreement. If no reasonable licensing agreement is available other plans will be used or an OIT design will be developed.

Manufacturing will use existing OIT facilities are much as possible. CNC lathes and mills are anticipated to be the primary tools. It is anticipated that some processes will have to be jobbed out.

Processes such as finishing and anodizing would fit into this category.

Analysis will focus on performance predictions and improving function of the engine. It is anticipated this will involve thermodynamic and heat transfer analysis.

FIGURE 1 : Miser Stirling Engine from Jerry Howell

WORK BREAKDOWN

Select Base Planset:

1. Further Internet research (3 hrs)
   Identify "all" plans which may be of use.
   Outcome: List of existing plans fitting our Criteria.

2. Narrow List of Existing Plans (3 hrs)
   Review plans in detail determining 2 to 4 which best meet the Criteria.
   Outcome: List of 2 to 4 plans for further consideration.

3. Licensing (6 hrs)
   Contact authors of plans to obtain permission to use plans and/or cost of licensing plans.
   Outcome: Licensing status and cost of Plan List.

4. Purchase Plans on Plans List (3 hrs)
   Outcome: Plans in hand for detailed study.

5. Select Base Plan(s) for Use (6 hrs)
   Study the purchased plan(s) for the best one, or select two with the best combination of features.
   Outcome: Basic Plan Set

Modify Basic Plan Set

6. Changes for better Visual Impact (4 hrs)
   Consider the Basic Plan Set for possible modifications to make it more eye catching.
   Outcome: Proposed modifications to Basic Plan Set for Pizzaz.

7. Changes for Easier Manufacturability (6 hrs)
   Preliminary look at stock and operations needed to manufacture Basic Plan Set. For each part in Basic Plan Set consider modifications which would make the part easier to manufacture. Also look at engine assembly with consideration of modifications to simplify assmbly.
   Outcome: Proposaed modifications to Basic Plan Set for Manufacturability.

8. Prototype Plan Set (10 hrs)
   Determine which modifications from 6 and 7 to incoporate. Develop a solid model(s) representing the final engine design.
   Outcome: Solid Model of Prototype Engine.

9. Prototype Drawing Set (20 hrs)
   Develop two dimensional detailed and assembly drawings. Incorporate these into a Prototype Drawing Set.
   Outcome: Prototype Drawing Set

Performance Analysis

10. Research Low Temperature Stirling Engine Thermodynamic Cycles (5 hrs)
    Library research into Stirling cycles and analysis. This concentrated on low temperature difference engines. Evaluate analysis methods and determine the best for our use. Our goal here is to predict performance of the Prototype engine.
    Outcome: Thermodynamic analysis procedure.

11. Analysis of Prototype Engine (15 hrs)
    The purpose of this thermodynamic and heat transfer analysis will be to predict the performance of the Prototype engine.
    Outcome: Performance prediction of Prototype engine and process for this analysis.

12. Prototype Analysis to Improve Performance (15 hrs)
    Apply the analysis develped in 11 to investigate changes to Prototype. Changes investigated should not adversly affect the engines Pizzaz or Manufacturability.
    Outcome: Modifications to Prototype Design to increase performance.

Manufacture

13. Operations Lists (6 hrs)
    Develop Operations lists to manufacture each Prototype part.
    Outcome: Operations Lists

14. Determine Tooling (15 hrs)
    Determine the tooling necessary for each part. This will grow from the Operations Lists and take into account the number of parts to be manufactured. For this consider runs of 10 units. This includes design of any specialty jigs and fixtures.
    Outcome: Tooling List, Design of Specialty Jigs and Fixtures.

Build Tooling and Prototype

15. Order Tooling (2 hrs)
    Order or obtain required tooling. Order materials for jigs and fixtures.
    Outcome: Tooling and tooling material obtained.

16. Order Prototype Materials (2 hrs)
    Order the stock and standard parts for prototype manufacture. Order material for manufacture of three (3) prototypes.
    Outcome: Material obtained for three Prototypes.

17. Build Jigs and Fixtures (30 hrs)
    Build the Jigs and Fixtures identified and designed in 14 above.
    Outcome: Jigs and Fixtures for production run built.

18. CNC Coding (15 hrs)
    Write CNC code for each part requiring CNC operations.
    Outcome: G-code for each part as appropriate, post processed for appropriate machine.

19. Build Prototype (5 hrs)
    Build a single prototype using production tooling. This includes assembly.
    Outcome: Prototype Engine.

Prototype Evaluation

20. Verify Function of Prototype (4 hrs)
    Deterimen temperature differential necessary for engine operation. Also test for a speed versus termperature differential curve.
    Outcome: Evaluation of Prototype Engine

21. Verify Longevity of Prototype (2 hrs)
    Operate Prototype Engine over a longer period of time. This testing will be for 48 hours of operation. Verify function for this period. Document degradation or improvement in performance.
    Outcome: Evaluation of “long” term operation.

Document Project and Prototype Engine

22. Final Report (25 hrs)

Final Report of Project will include information on the project itself and on the development of the Prototype engine. It will also include detailed documentation of the manufacturing process so the client can effectively use the tooling to produce additional engines. A Drawing Set will be included.
Outcome: Final Report