Air Engine Design for Machining Class

Hugh Currin
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ABSTRACT

This proposal is for the design of a small compressed air engine to be used in introductory machining classes.

INTRODUCTION

It would be desirable for students in introductory machining classes to combine their efforts during the class into an overall product. This will give students a sense of accomplishment and illustrate the concepts of assemblies.

The idea is to use lathe and mill exercises to machine parts of a small engine which will run on compressed air. The main result is to have an engine which will function, turning freely without load. However, a competition for the "best" engine (speed, power, etc.) could be held at the end of the course.

CRITERIA

The specific criteria for this project to succeed are as follows:

- The air engine should be very simple. The number of parts needs to be small and the complexity of machining needs to be kept down.
- The materials used should be easy to machine but give students a good idea of basic machining.
- Construction will be completed using a lathe, mill and hand tools. Machining time should be kept to 8-10 hours for an experienced machinist. This will translate into 20-30 hours of student machining time.
- The cost of materials should be kept to $15.
- The finished engine should fit within a 6"x6"x6" envelope.
- The engine should run on compressed air of not more than 50 psi and use not more than 2 cfm.

- The design should allow connection to a load for evaluation of power output.

PROPOSED SOLUTION

After consideration of several possibilities, two proposed air engines were thought to meet the criteria. Turbine/vane and a piston/cylinder configurations were evaluated. It was decided to pursue the piston/cylinder configuration due to the complexity of building the turbine rotor/vane wheel.

Figure 1 shows the proposed air engine configuration. The piston and connecting rod are one solid piece. Thus, as the crank turns, the cylinder pivots back and forth. This movement opens a pressure port on the power stroke and an exhaust port otherwise.

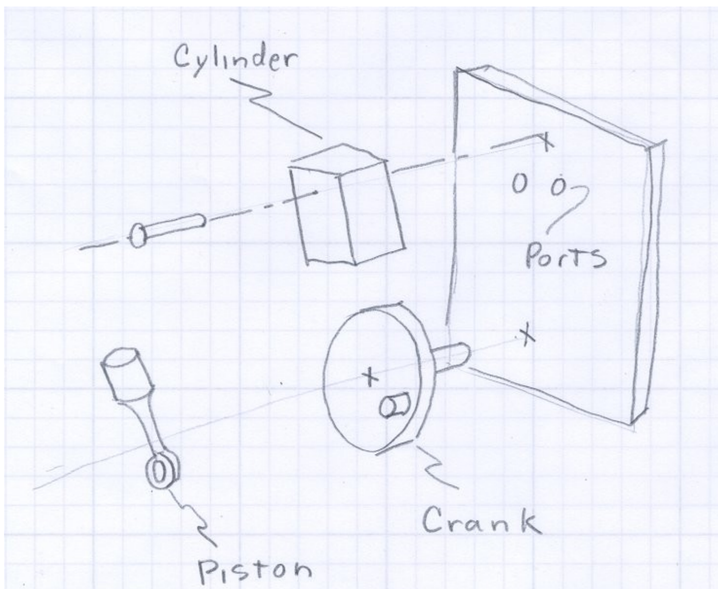

FIGURE 1 – Air Engine Configuration

The conceptual engine has only five parts. It is anticipated that the number of parts will increase in the final design but should still result in a very simple air engine. Some of these parts may well be stock and require no machining.

The materials used will be steel, aluminum and possibly brass. Mild steel will be included as the students need experience machining this material. Aluminum is readily machined and relatively inexpensive. Brass is easily machined and is an excellent bushing material for sliding fits. The particular uses of these materials will be determined through the design phase.

WORK BREAKDOWN / TASKS

To complete this design the necessary work has been broken down into tasks. Each task below describes the work to be done, the expected outcome, and a time estimate. The time estimate is for "billable" hours, not elapsed time.

1. Library Research – Review library resources for similar compressed air engine designs. The outcome will be references identifying existing designs having been used for such engines. The time for this task will be limited to a total of two hours. [2 hrs]

2. Internet Research – Search the Internet for similar air engines. The outcome will be the number of similar designs, if any, and web sites references to these. The time for this task will be limited to a total of four hours. [4 hrs]

3. Research Existing Analysis Methods – This research will be looking in the library, through technical papers, and on the Internet for analysis techniques used for similar air engines. This research may include fluid dynamic analysis, materials, and tolerance analysis specific to air engines. The outcome will be reference material in these areas, or a report that no reference materials were found. The time for this task will be limited to a total of four hours. [4 hrs]

4. Machining Course – Consider the introductory machining course at OIT. This knowledge will be applied though the design effort to assure the machining of the air engine will cover the techniques required in the course. The project should include the mix of lathe, mill and hand work currently used. Expected tolerances should also be taken into account. The tooling used will also be considered. The outcome will be the techniques expected of students, machine tools used, and tooling now used in the course. [2 hrs]

5. Initial Design – Determine initial layout of the engine. Determine the approximate size, air port configuration and orientation, crank size, etc. The result of this task will be the critical engine dimensions. [8 hrs]

6. Initial Engine Layout – Create an initial solid model of the engine. This model will be a first cut at a solid model layout based on the dimensions of task 5. The result will be a rough solid model. [3 hrs]

7. Engine Analysis – Analyze the preliminary engine design from task 6. This will include application of appropriate analysis methods defined from task 3. Analysis performed will center on hand calculations, no FEA or CFD computer codes. Outcome of the task will be cylinder and crank sizing. [8 hrs]

8. Materials Selection – Select the Initial Layout and size of the engine, including

the materials selected for each component. [2 hrs]

9. Stress Analysis – Use a hand stress calculation to determine safety factors for each component. First do simple calculations to calculate the loads anticipated. Then check critical areas for stress. The result will confirm the dimensions of the engine part sizing as found in tasks 6 and 7 and the material selections from task 8. [4 hrs]

10. Detailed Solid Model – Refine the Layout from task 6. Select small parts on hand and purchase other small parts as needed. This tasks anticipates several intermediate designs and refinements. The result will be a solid model of the final product, the design of the air engine. [10 hrs]

11. Drawing Set – Produce a detailed drawing set. This will include a 2D detail drawing for each part, assembly drawings and associated documentation. Also suppliers for materials and small parts will be identified. [6 hrs]

12. Order Materials and Parts – Order and obtain materials and parts for two prototypes. Also obtain any necessary tooling.[2 hrs]

13. Machine Prototype – Machine and assemble the parts of the air engine. The outcome will be a complete prototype. [10 hrs]

14. Quality Control – Check tolerances on each machined part. [1 hr]

15. Free Run Prototype – Connect the engine to a compressed air source and verify function. Measure RPM with a strobe tachometer. [3 hrs]

16. Power Test Prototype – Connect the engine to a small DC motor. Connect the electric motor to a variable resistor as an adjustable load. Estimate the power produced by measuring the output of the motors voltage and current. Test enough operation points to generate a power curve. The outcome will be a power curve estimate for the prototype air engine. [5 hrs]

17. Final Report – Compile the final report of design. This will include the design and analysis done. Also an appendix will contain a short construction manual and A size drawings to be used in the machining course. The outcome will be a Final Technical Report containing drawings and a construction manual. [15 hrs]

PROJECT SCHEDULE