A take on Robert Stirling's Stirling Engine

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Project Summary

For our final project in the course Materials and Manufacturing I, we worked as a team of 4 to create a Stirling engine. The Stirling engine is a demonstration of a closed-cycle regenerative engine and was designed to use a heat differential to create pressure, moving a set of pistons to create rotational energy.

Our main goal was to practice prototyping, achieve tight tolerances, compactness, and stability in our model, aiming to have a majority of our pieces modeled using computer aided design. We considered material types for each part, taking into consideration the density, heat transfer, and machining limitations for each.

Ultimately, we were unable to make the engine run on its own using boiling water and ice. Despite this, many of our goals were met, with tight tolerances within the piston junctions and ample prototypes to refine our process.

Figure 1. Images of Completed Artifact

Design Process

Our initial design was modeled off of common toy stirling engine designs, from which a CAD assembly was created, pictured in *Figure 2* to the left. This assembly featured a displacer piston with a transparent body and an aluminum top and bottom plate , with a foam displacer to move the hot air. Additionally, this design features a transparent power piston casing and an aluminum piston.

After initial prototyping, the design was revised heavily. The positioning of the support arms, the weight and material of the flywheel, piston positioning on the top plate, and regenerative material choice all went through many iterations.

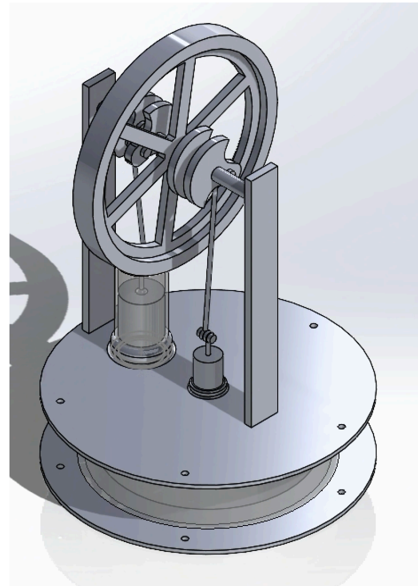

Figure 2: Initial Cad Design

Fabrication

Working with the materials accessible within the Tufts Bray machine shop helped refine the final design process. The CAD was initially created only specifying metal and nonmetal, but we refined this in fabrication, selecting aluminum as our primary material due to its heat conductivity, abundance, and machinability. For the rods of the pistons, steel sheet and wire was used due to its stiffness.

many pieces of the Stirling engine were not pre-planned; initial strategies were tested in the machine shop and continuously revised. For example, the counterweights were initially going to be amorphously shaped, but a circular shape was more straightforward and effective. Similarly, new design iterations for the plates, rods, and casings were created in CAD.

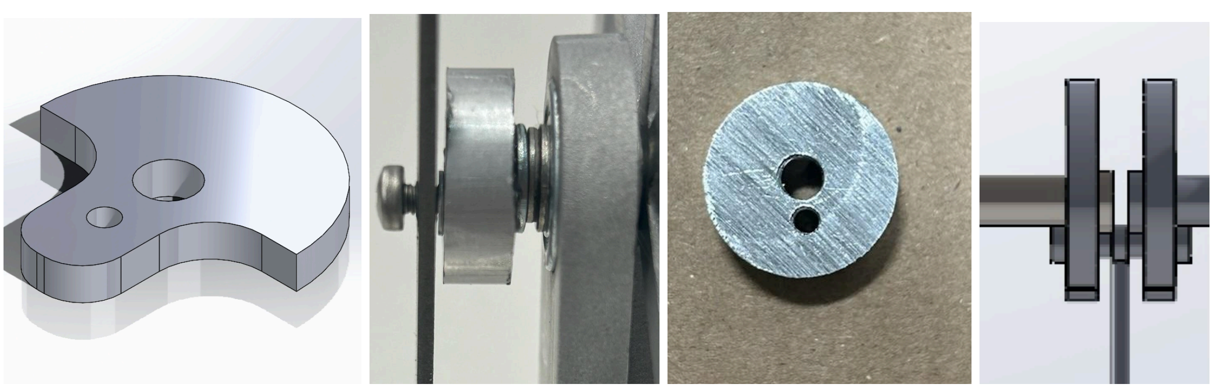

Figure 3: CAD vs manufactured counterweight and counterweight system

Challenges

The discussion of executing tight tolerances was most relevant in securing an airtight attachment between the piston and displacer rod to the top plate. The initial prototype was designed and constructed for an aluminum brazing attachment method. However, aluminum brazing proved ineffective in securing an airtight attachment, so experimentation produced a screw and gasket method as the finalized procedure. The alignment in piece size between the drill press, screw, holes in the top aluminum plate, and thread had to be executed with minimal room for error.

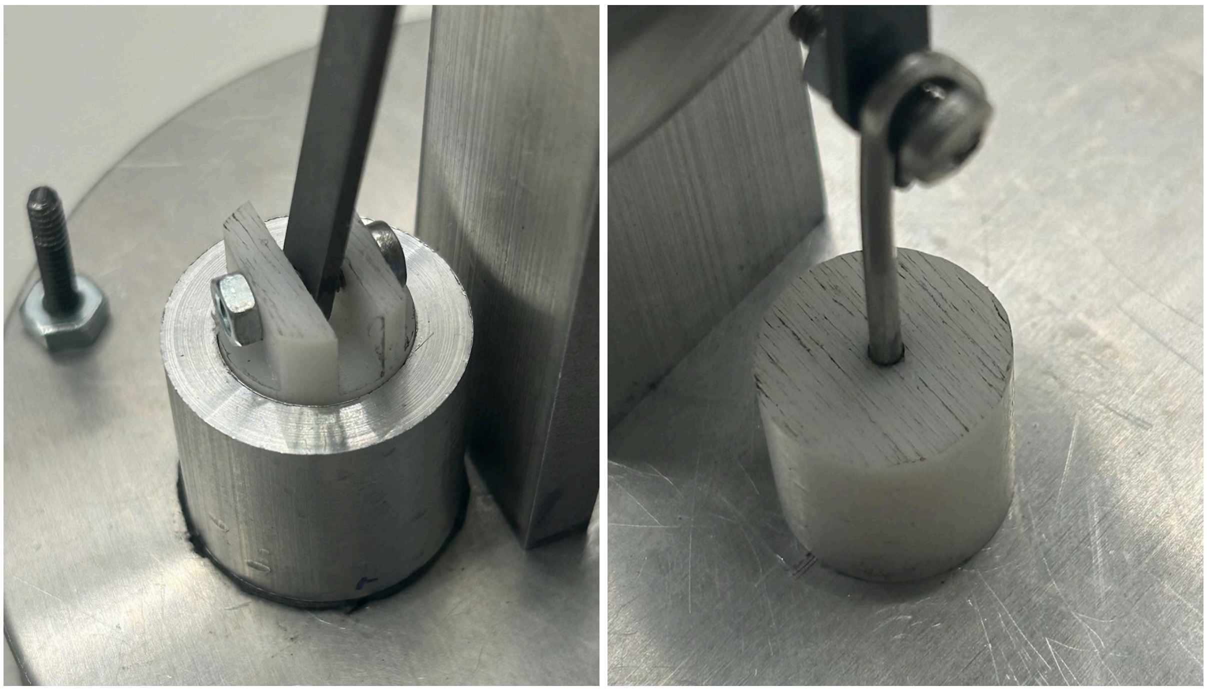

Figure 4. Piston mechanisms

Another locus of the tight tolerances discussion was attaching a tapped rod to two counterweights, a flywheel, and the displacer and piston arms. The displacer and piston arms had to rotate with the counterweights around the rod in reaction to the piston and displacer's movement. Execution of these goals required tapping the counterweights in alignment with the primary rod, drilling fitted holes in the arms, and connecting the rods to PVC pipe, all in a lateral alignment with the support stand..

Figure 6. Side view of the stirling engine

Results

The Stirling engine looks excellent but does not effectively spin when subjected to a significant temperature gradient. The most significant factors inhibiting effective spin behavior in the flywheel are friction generated in the PVC pipe of the displacer and piston rods and in the connecting rod between the counterweights and flywheel. The friction generated in these spaces causes energy to be lost. Another hypothesis is the flywheel's large mass. The flywheel has to be heavy enough to spin but not too heavy, to avoid drag. Due to the flywheel's ability to spin but its inability to continue spinning, it is most likely too heavy.

Given these hypotheses, the Stirling engine can be improved by tinkering with the flywheel weight, displacer thickness, and minimizing friction with the displacer and piston rods. Upon reflection of the design and brainstorming process, constructing another prototype earlier in the engineering process would have helped avoid the design flaws described above.