Sage Model Notes

SplitCycleCooler.stl

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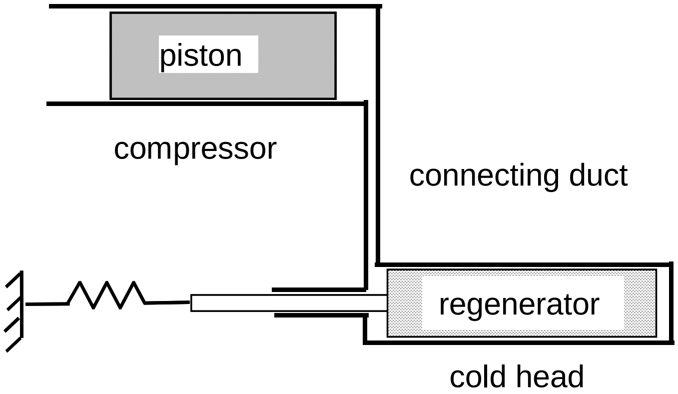
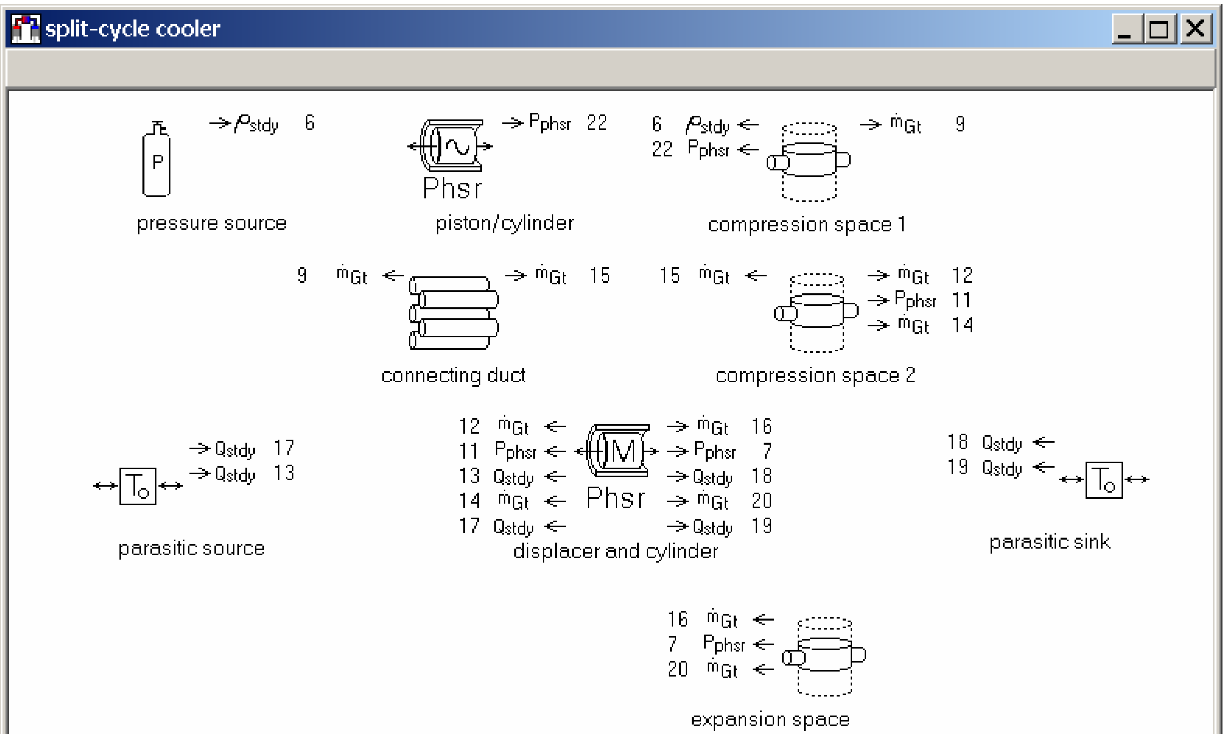
A model for a split-cycle stirling cooler that might be represented schematically like this:



The Sage model consists of the compressor, connecting duct and cold-head components all within the top level model:



Compressor

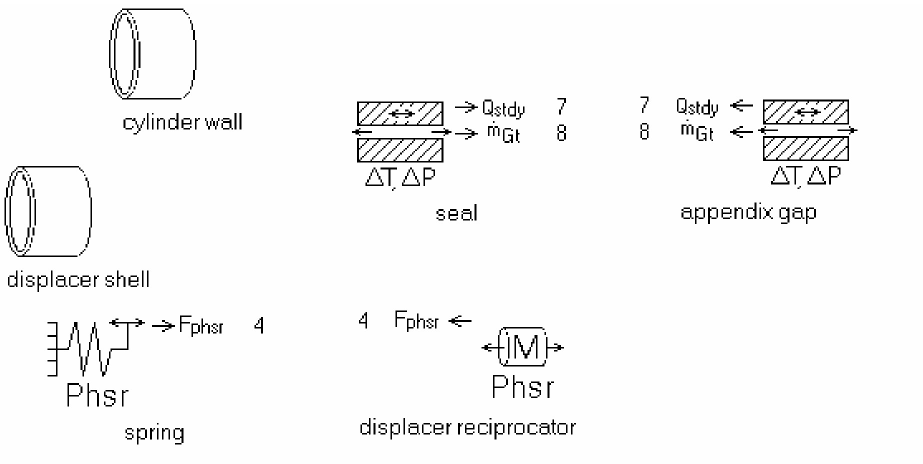
In the above view the compressor consists of a single constrained *piston* within the *piston/cylinder* component with an area attachment connected to the compression space. That area *A* is an independent input by default but in this case recast to 0.25*Pi*Sqr(Dshell) so it automatically adjusts to the piston diameter Dshell input of the *piston/cylinder*.

Connecting Duct

The *connecting duct* is a single circular tube between the two compression spaces. The tube walls are modeled as isothermal surfaces so the duct acts as both an aftercooler for the compressor and a heat rejector for the stirling cycle of the cold head.

Cold Head

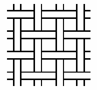
The cold head of the above model consists of the *compression space 2*, the *displacer and cylinder* and the *expansion space*. Here are the components inside the displacer and cylinder:



The *cylinder wall* and *displacer shell* represent the material and wall thicknesses of the fixed pressure wall and moving displacer body. The seal models an annular clearance seal between the compression space and the *appendix gap*. It has an isothermal solid surface temperature inherited from input *Tinit* of the parent component. The *appendix* models the annular gas gap between the *displacer shell* and *cylinder wall*, including the combined conduction of the two walls and the shuttle heat transfer mechanism produced by the thermal interaction between them as they move relative to each other. The positive (right) end of the appendix gap connects to (gas flows to) the expansion space. The conductive surface within the *appendix* (not shown) gets wall thickness and material information from the built-in *cylinder wall* and *displacer shell* components in order to implement a combined wall conduction model.

The *displacer reciprocator* models a free displacer with inputs for the reciprocating mass and frontal areas exposed to the *compression space 2* and *expansion space*. The difference between these two areas is the area of the drive rod, except there is no drive rod area attachment in the model since it is presumed to see a constant pressure space and therefore has no effect on the phasor solution of the free displacer. But the difference between the two frontal areas does drive the displacer in the sense that it delivers net PV power to the displacer. Another displacer drive force is supplied by the *spring* attached to the displacer. The combination of differential-area force and spring are what makes the displacer run at the desired phase relative to the piston. You can use the optimizer to adjust the area facing the compression space and the *spring* stiffness to achieve a desired displacer motion, thought the current model does not do that.

The regenerator matrix is located within the displacer shell and inherits its diameter from the internal diameter of the shell:



The *parasitic source* and *parasitic sink* components anchor the warm and cold ends of the thermal conduction paths within the *displacer and cylinder* component. The wall and shell conduction plus shuttle heat transfer.

Cold Temperature

The file is currently set up for a cold-end temperature of 90K. To change cold-end temperature change the *T* input for the *parasitic sink* and the *Tinit* input for the *expansion space*. Because this is a small cooler model there is no specific cold heat exchanger between the regenerator and the *expansion space*. The *expansion space* gas sees an isothermal surface from which it accepts heat. That temperature is inherited from the parent *expansion space Tinit* input. Also, you might want to change *Tinit* at the positive end of the *displacer and cylinder* component. This change is not strictly necessary because the temperatures of the components inside are solved, with Tinit only providing initial values.

Bottom-Line Outputs

Net cooling power is available in the root level user-defined variable *Qlift*. Included in *Qlift* are the heat flows absorbed by the helium in the *expansion space*, less the conduction losses down the pressure wall, displacer shell and shuttle heat transfer.

Compressor PV power input is available in user variable *Wpv* i. There is no model of the motor driving the compressor piston so electrical power input is not available.

Optimization

The model contains a rudimentary optimization specification. The objective is to maximize het cooling power *Qlift*, subject to compressor PV power equal to 10 W (*Wpv* = 10).

Optimized variables are compressor piston amplitude *Xamp*, displacer *spring* stiffness *K* and *negative-facing area attachment A* (facing *compression space 2*) .

This optimization is intended as a starting point for more serious design optimizations.