Sage Model Notes

RegenerativeDisplacer-Cylinder.scfn

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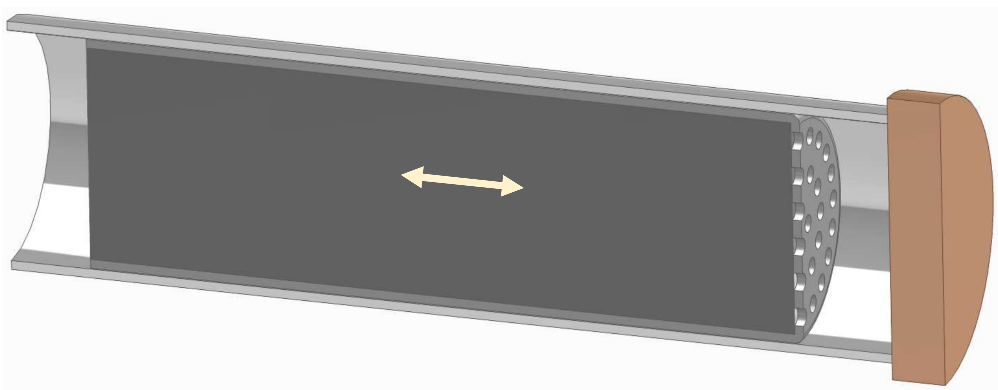
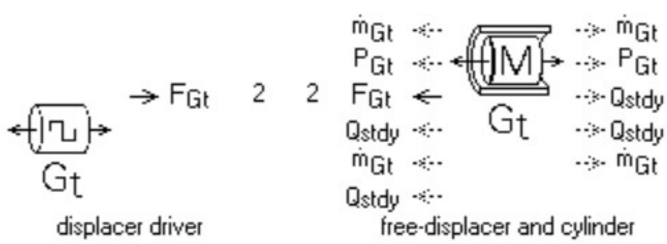
In stirling-cycle cryocoolers the regenerator is often housed inside a moving displacer instead of packaged within a separate canister, as illustrated in the rendering below.

In effect the moving regenerator displaces the same volume, produces the same flow through the matrix and does the same PV work on the expansion-space gas volume as an impermeable displacer with the same motion and frontal area driving flow through an identical stationary regenerator in parallel. Provided, that is, that the inertial pressure drop acting on the moving regenerator gas is negligible. More on this later.



This model is similar to the HollowDisplacer-Cylinder.scfn sample model, except for the regenerator matrix inside the *displacer shell* component. For all other aspects of the model see the documentation for HollowDisplacer-Cylinder.scfn.

In Sage, the top-level model looks like this:

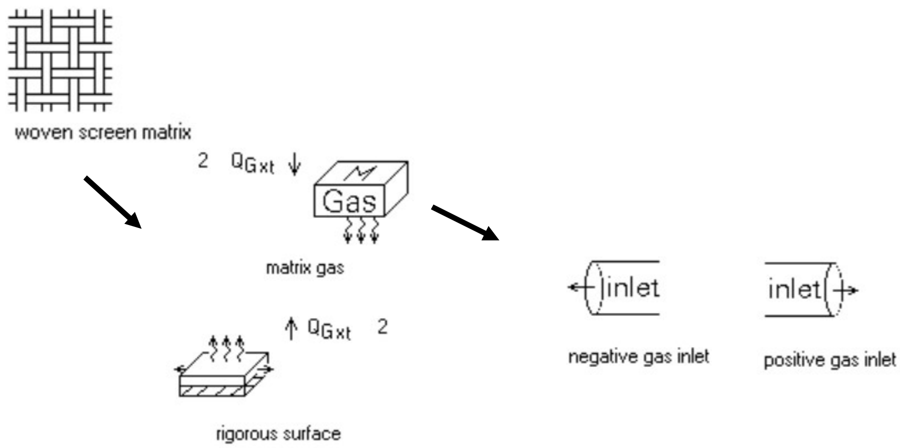


To make this model fully functional it must be copied into another model containing two *generic cylinder* (AKA variable volume space) components (representing stirling-cycle compression and expansion spaces) with mating P_{Gt} connectors to connect to those emerging from the *free-displacer and cylinder*. Also required are some available mating $\dot{m}_{Gt}$ gas flow connectors and Q_{stdy} heat-flow connectors from heat exchangers and point temperature sources or sinks. The model is configured so that all negative directed Q_{stdy} connectors (left side) provide ambient temperature boundary conditions and all positive directed connectors (right) side provide cold-end (in case of a cooler) or hot-end (in case of an engine) boundary conditions.

Compared to the hollow-displacer model there is an extra set of $\dot{m}_{Gt}$ connectors (second row from top) that emerge from the regenerator within for connection to heat-rejecting and heat accepting heat exchangers of a larger model. In a hollow-displacer model the regenerator would be an independent component.

The holes at the right end of the regenerator canister in the above rendering are not part of this model. They can be modeled with separate *turbulator* holes, as discussed in sample model HeatExchanger-JetImpingement.scfn.

Inside the *displacer shell* component within the free-displacer and cylinder is a woven-screen regenerator matrix from the *Matrices* page of the component Palette with the usual gas, surface (matrix solid part) and gas inlets inside:



The top-level $\dot{m}_{Gt}$ connectors have been bumped up from the two inlets.

Its all relative

Effectively the regenerator matrix is modeled as a parallel gas-flow path, even though it is physically within the displacer shell, and as if driven by an impermeable displacer with the same frontal area. Some people find this confusing and argue that the effective frontal area of a moving regenerator should be smaller than the full canister frontal area, according to some factor depending on the porosity. Not true!

Thought Experiment: Imagine the same rendering as above except look at it in two ways:

Way 1 - The inner regenerator is moving and the outer cylinder stationary.

Way 2 - The outer cylinder is moving and the inner regenerator stationary.

If the relative motion between regenerator and cylinder is the same in each case and fluid inertial pressure drop is negligible, then there is no essential physical difference between the cases regarding flow through the matrix, pressure drops or anything else. To say that the effective expansion-space volume displacement is different for the two cases means the expansion-space pressure fluctuation, flow through the matrix, and even cooling power itself in an actual cryocooler must also depend on whether one component or the other is held stationary. That makes no sense. QED