A Flow Network, Heat Exchanger and Turbomachinery Component Library for MSC.EASY5

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Abstract

A Flow Network, Heat Exchanger and Turbomachinery Component Library for MSC.EASY5

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A library of flow network, heat exchanger and turbomachinery component macros has been developed for use in MSC.EASY5. The component macros can be used to simulate fluid systems which include ducts, valves, heat exchangers and turbomachinery. Dynamic models can be built of an entire flow network system or cycle or a subsystem or a single component. The key purpose of building a dynamic model of such a system is to define the schedule for the valves to follow so that the system will start from no flow and no rotating pumps to full power operation quickly and safely without damaging any hardware. The types of components in the library include: volumes, flow elements, valves, centrifugal pumps, hydraulic turbines, gas turbines, heat exchangers and heat sinks. A database of fluid properties for gases, cryogenic liquids and room temperature liquids is imbedded within the library. Closed loop control is simulated using MSC.EASY5 controller components from the GP library.

Keywords: MSC.EASY5, transient, turbomachinery, start, control

Why do transient simulations?

Transient modeling of turbomachinery flow networks

- Simulate starts, power level changes and stops
  - Nominal
  - Off-nominal
  - To guide:
    - Development of safe, reliable & robust valve sequences
    - Definition of critical failure modes
- Prevent hardware damage

Transient Analysis Progression

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MSC.EASY5
GUI, sophisticated integration methods

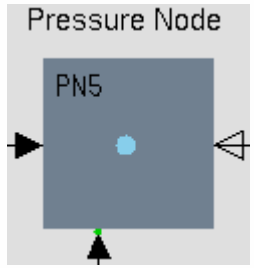
Modular FORTRAN code
no debugging, slow

Custom FORTRAN code
application specific, debugging

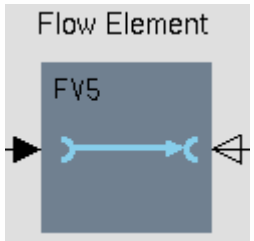
The Library

Flow Network Components

- Pressure Node (Storage type)
  - Mass and Energy States



- Flow element with optional valve (Resistive type)
  - Flow state (liquid only) - using inertance



- Also - Imbedded fluid properties database

The Library

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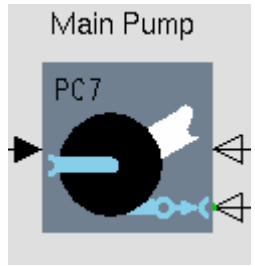
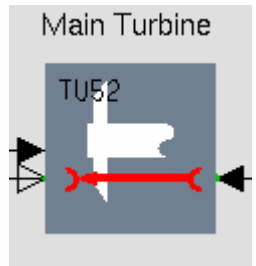
Turbomachinery Components

- Centrifugal Pump (Storage & Resistive type)
  - Discharge Pressure and Flow States
  - Pressure rise and required torque maps



- Turbine (Resistive type)
  - Flow state (if hydraulic)
  - Efficiency and flow parameter maps



The Library

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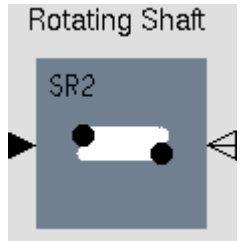
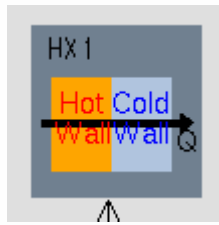
Other Components

- Rotating Shaft (Storage type)
  - Shaft speed state
  - Connects pump and turbine to define a turbopump



- Heat Exchanger (Storage & Resistive type)
  - Wall temperature states



Structure of a Macro

<u>Initialization</u>

- Propagate fluid identification and phase throughout network
- Calculate characteristic parameters from operating point
  - Allow for overrides of parameter values
  - Uses information from neighboring components
- Initialize needed states and freeze unneeded states

Initialization passes - Component calculations required

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Pass	Downwind Initialization	Upwind Initialization
Component		
Pressure node	★	
Flow element	★	★
Heat Exchanger		★
Centrifugal Pump	★	★
Turbine	★	★
Rotating shaft	★	

Structure of a Macro

<u>Simulation & Steady-State Phase</u>

- All calculations performed in 6 passes
  - Minimum number of source code sort blocks
  - Easiest for MSC.EASY5 to rearrange sort blocks of source code when building model executables
- Passes include: 1- fluid properties, 2 – flows and flow derivatives, 3 – pump & turbine performance, 4 – torque balance & heat transfer, 5 – heat load pass-thru through flow elements, 6 – mass and energy derivatives

Computational passes - Component activity required

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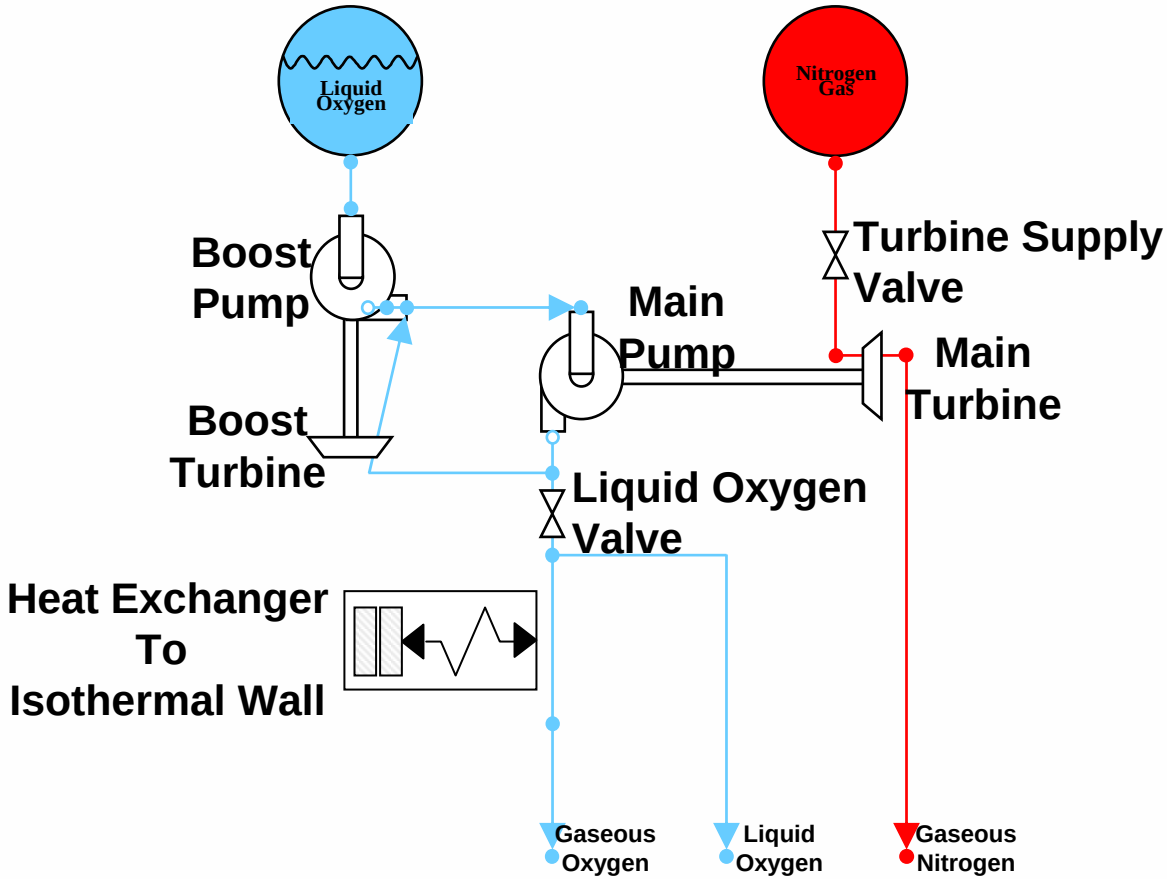
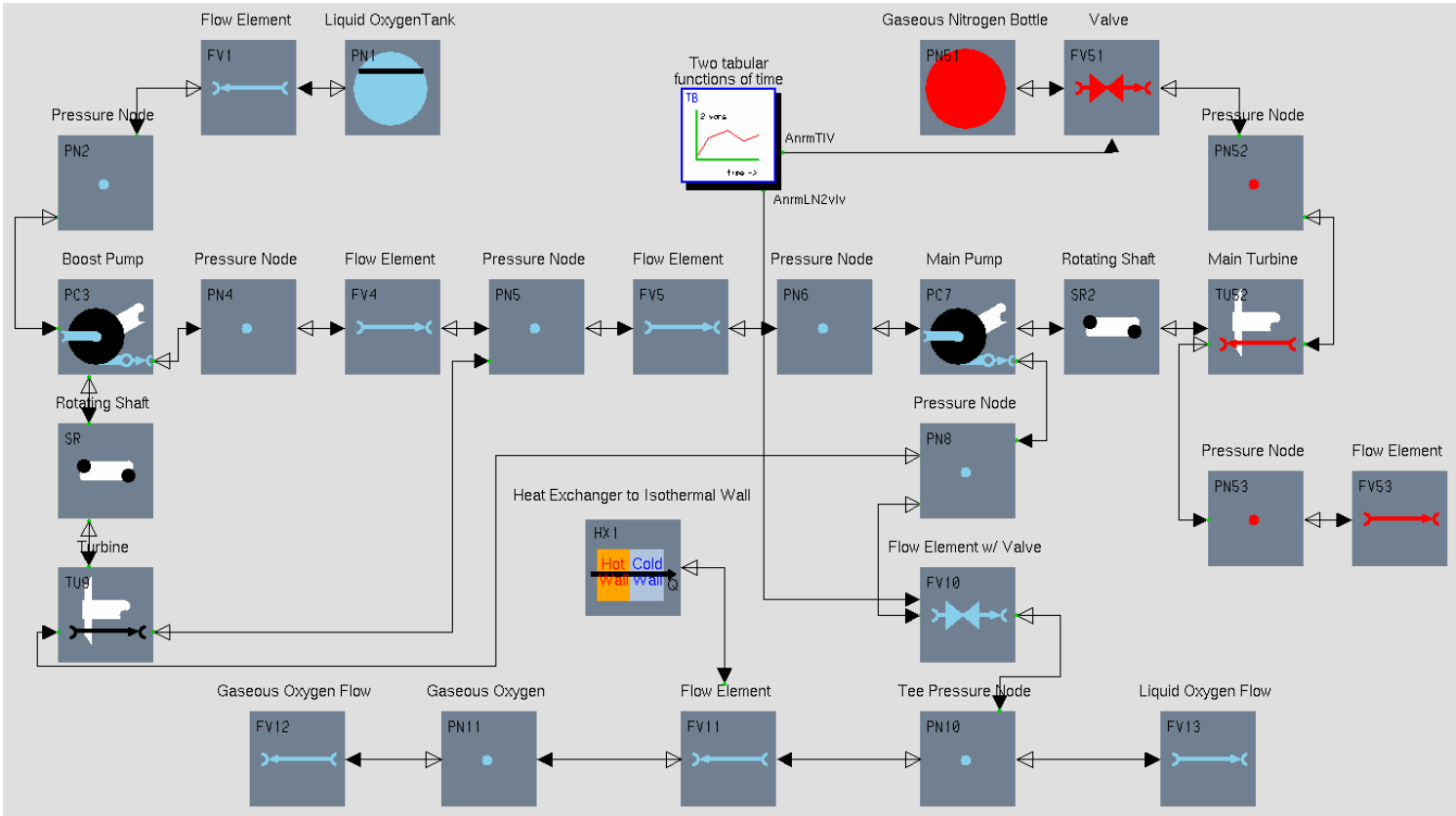
Pass number	1	2	3	4	5	6
Component						
Pressure node	★					★
Flow element		★			★	
Heat Exchanger				★		
Centrifugal Pump			★			
Turbine			★			
Rotating shaft	★			★		

Example Model - schematic



Example Model – MSC.EASY5



Future Work

More components

- Jet pump, Compressor

Improve components

- Ported connection from flow element to heat exchanger components in the thermal hydraulic, multi-phase fluids or gas dynamics MSC.EASY5 delivered libraries

New Analyses

- Valve sequence optimization

Conclusions

MSC.EASY5 is logical next step in model tool maturation

- Ability to build large models
- Shorter cycle time to build a model than existing modular FORTRAN
- Macro code sorted into “passes” for best model building and compiling
- Expect to be able to run parametric analyses, optimization analyses with MSC.EASY5
- Ability to leverage capabilities in the future