Agenda

- Introduction
- Cooling System Model Development
- Lubrication System Model Development
  - High Fidelity Model
  - Fast Running Model
- Model Integration – Overview
- Modular Cooling Model
- Modular Lube Model
- Integrated Model
- Summary
- Longer Term Vision
Introduction

As model based product development advances, there is a desire for increased leverage of 1D models early in the development process. The need to create and maintain significantly more modeling capability, without a corresponding increase in resources required, is leading to a more modular approach to model architecture.

- Internal architecture
- Module interfacing
- Modules of differing fidelity
Cooling System Model Development

Model includes EngCylStrucCond cylinder object. Calculates heat transfer from cylinder to both coolant and oil.
Initial lube system model development focused on high fidelity models.

- Open loop
- Angle resolved, explicit solver
- Hydro-mechanical valve models
- No thermal predictive capability
- Typically consider full load only
Lubrication Model Development – Fast Running Model (FRM)

More recent development of lube system FRM from high fidelity model.

- Closed loop
- Mean value bearings
- Implicit solver – close to real time
- Includes thermal behavior
  - Some sources of heat transfer to oil provided as boundary conditions from cooling model
- Boundary conditions over full operating map
Model Integration - Overview

Disadvantages to standalone models:
- Circular boundary condition references
- Missing subsystem interactions
- Transient phenomena

Decision to use the lube FRM to integrate with cooling system:
- Integration of thermal analysis

General approach to model integration:
- Parallel convergent development of the two models
Modular Cooling Model

- Identify oil and gas flows in model.
- Separate them into individual subassemblies.
- Heat exchangers are split between subassemblies.
Modular Cooling Model

- Coolant functional module contains only coolant fluid and contains all of it.
- Splitting heat exchangers allows coolant reference objects and initial state to be defined in one place.
- Block/head internal subassembly absorbed on to main canvas to allow external subassembly connections.
Modular Cooling Model

- Oil and engine boundary condition (BC) modules each contain a single fluid.

- RLT dependency reference objects (lookups vs. engine speed, load) moved to the boundary condition subassemblies.
Modular Cooling Model

- Convection connections remain on canvas of master model.
- Engine speed and torque defined on main canvas.
- Each module has self contained RLT reference parts – more robust.
Modular Lube Model

Handling of heat transfer references must be changed:
- Original model uses RLT reference to actuate heat input to piston spray jet oil flow directly.
- Modular approach uses same RLT reference to apply heat transfer to thermal mass, with thermal connection to oil flow.
Modular Lube Model

Lube master model requires only functional lube and BC cooling modules.
Modular Lube Model

HOWEVER - It is desired to converge the lube and cooling models. A common main model canvas is needed.

- Redundant engine BC module must be included on lube master model canvas.
- Cooling BC module must contain redundant parts to satisfy main canvas connections.
Modular Lube Model

Final lube master model looks functionally identical to coolant master model.
Fully Integrated Model

Final convergence step - resolve remaining differences between functional and BC modules, e.g.
- Case Setup parameter names
- Names of referenced parts

Set up selection of module type with super parameter.

Similar results confirmed for all configurations.
Summary

- Lube / cooling model interface architecture provides easy method for integrated running, or standalone running of either module.
- First step to future integration with functional engine module and other subsystems.
- Connectivity limitations required connection parts on main canvas that “belong” within a module.
- Connectivity requirements resulted in redundant parts in the lube model configuration, affecting run time.
- For convenience, high fidelity lube model should be converted to similar architecture.

- Extending the methodology to all other subsystems results in further complexity:
  - Master model would need every subsystem module to be present on the canvas.
Longer Term Vision

Engine BC module

- EGRc gas flow
- In-cylinder gas conditions
- Torque
- Etc.

Cranktrain functional module

or

Engine BC module

- EGRc gas flow
- In-cylinder gas conditions
- Torque
- Etc.

Cooling functional module