Development of physics based re-usable building blocks for quick system level performance prediction and optimization

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Agenda

Problem statement
Solution
Basic component
Business Impact
Problem statement

• System level models are developed in various domains – Mechanical, Hydraulic, Electrical for performance analysis
• Increased lead time in plant model development process due to lack of knowledge management and lot of redundancy on legacy models across Eaton.
Solution

A centralized plant model library of basic components that are specific to Eaton is created to enable re-use and faster execution of modeling. These models can be quickly customized and can be re-used for specific applications.
Customizable basic component model

Governing equations for Steady-State Flow Forces

Steady State:

Initially,
Velocity of spool \( \bar{u}_s = \bar{0} \)
Velocity of fluid \( \bar{u}_f = \bar{0} \)

After the spool moves allowing fluid flow,
Velocity of spool \( \bar{V}_s \)
Velocity of fluid \( \bar{V}_f = V_f (\sin \theta \ j + \cos \theta \ i) \)

Conservation of linear momentum along \( i \)

\[ m_s \bar{V}_s + m_f \bar{V}_f \cos \theta \ i = \bar{V}_s = -\frac{m_f}{m_s} V_f \cos \theta \ i \]

Force (Steady state) acting on spool = Rate of change of momentum

\[ F_{ss} = \frac{d(m_s \bar{V}_s)}{dt} = m_s \frac{d\bar{V}_s}{dt} = -m_f V_f \cos \theta \ i \]

\[ m_f = \rho Q \]

\[ Q = \bar{V}_f \cdot A_c = V_f A_c \cos \phi \]

Since \( \phi = 180^0 \),
\[ Q = -V_f A_c \]

\[ F_{ss} = -(\rho Q) \left( \frac{-Q}{A_c} \right) \cos \theta \ i \]

\[ F_{ss} = \frac{\rho Q^2}{A_c} \cos \theta \ i = \frac{\rho Q^2}{C_c A_f} \cos \theta \ i \]

Substituting \( C_d A_f \sqrt{\frac{\Delta P}{\rho}} \) and \( C_d = C_c C_v \), where in the equation for steady state flow force we get

\[ F_{ss} = 2C_d C_v A_f \Delta P \cos \theta \]
Customizable basic component model

SIMULINK Model for Flow-Forces

User has provision to quickly customize the blocks as required
Customizable basic component model

User can get help on inputs and outputs from the block itself.
Business Impact

- ~30-40% Time is Saved in Modeling by using the models in the repository

- Model development and analysis of nose wheel steering system was completed in a week, as against 6 months previously. This helped business to win the bid for the particular program by quickly sizing the components

- Apart from significant reduction in model development time the user has freedom to test new design concepts (non-standard geometries) by modifying these basic components with the help of the documentation provided.