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 $\vec{u}_s = \vec{0}$
Velocity of fluid $\vec{u}_f = \vec{0}$

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

Conservation of linear momentum along $\hat{i}$

$\Rightarrow m_s \vec{V}_s + m_f \vec{V}_f \cos \theta \hat{i}$
$\Rightarrow \vec{V}_s = -\frac{m_f}{m_s} V_f \cos \theta \hat{i}$

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

$F_{ss} = \frac{d(m_s \vec{V}_s)}{dt} = m_s \frac{d\vec{V}_s}{dt} = -m_f V_f \cos \theta \hat{i}$

$m_f = \rho Q$

$Q = \vec{V}_f \cdot \vec{A}_c = V_f A_c \cos \phi$

Since $\phi = 180^\circ$, $Q = -V_f A_c$

$\Rightarrow F_{ss} = -\left(\rho Q \left(\frac{-Q}{A_c}\right)\right) \cos \theta \hat{i}$

$\Rightarrow F_{ss} = \frac{\rho Q^2}{A_c} \cos \theta \hat{i} = \frac{\rho Q^2}{C_v A_f} \cos \theta \hat{i}$

Substituting $= C_d A_f \sqrt{\frac{2 \Delta P}{\rho}}$ and $C_d = C_v C_v$, 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.