



# Development of A Virtual Prototype of Piston Pump For Hydrostatic Transmission

Lewis Kasper

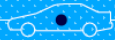
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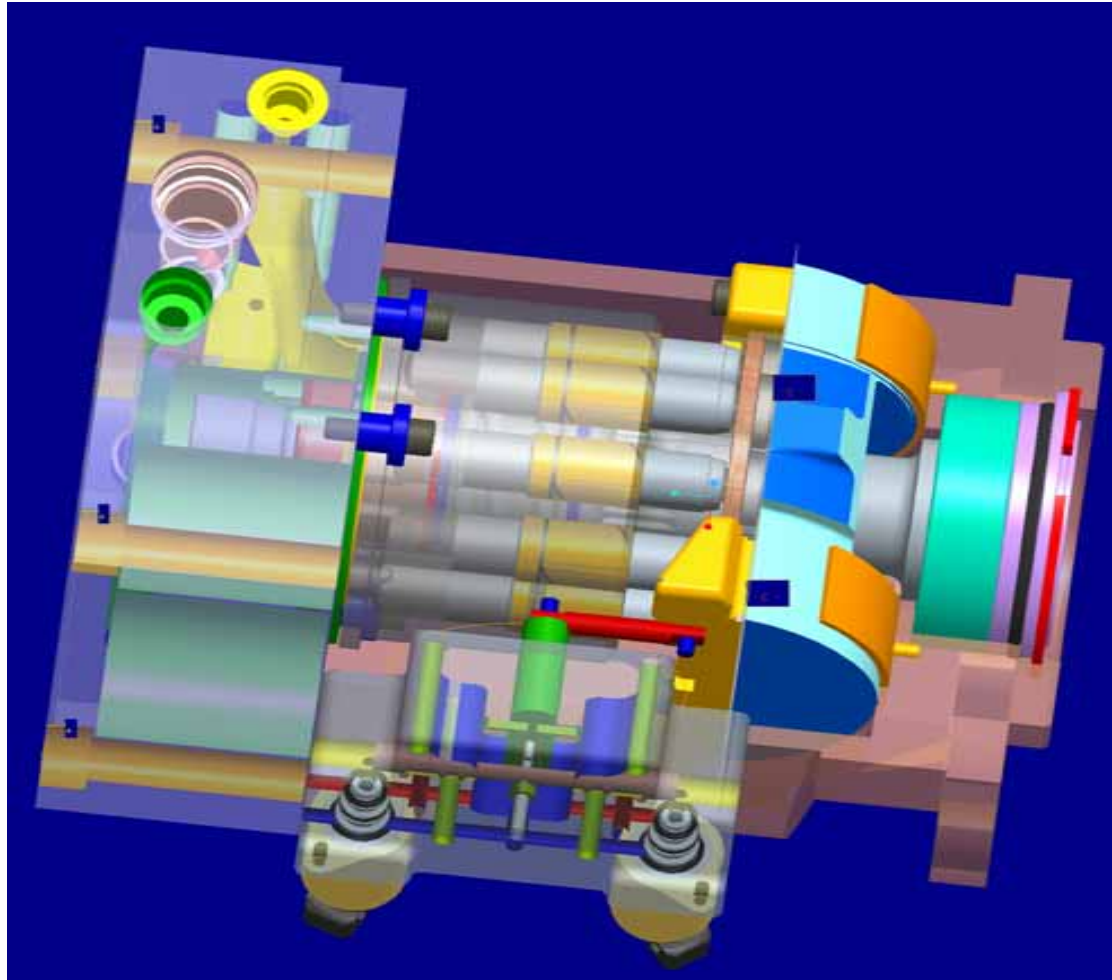
Parker Hannifin Corp.

MSC.Software Corp.



# Piston Pump Structure

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Possible.™



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# Modeling Strategy

## ❖ Rigid Body Dynamics

- Understand the capability and limitation of design concept/mechanism.
- Provide guidelines for component and structure design (loads, motion)

## ❖ Flex Body Simulation

- Assess the impact of piston deflection, shaft deflection, and barrel tipping to pump dynamic loading and performance.
- Guarantee components integrity and reliability (stress, durability).

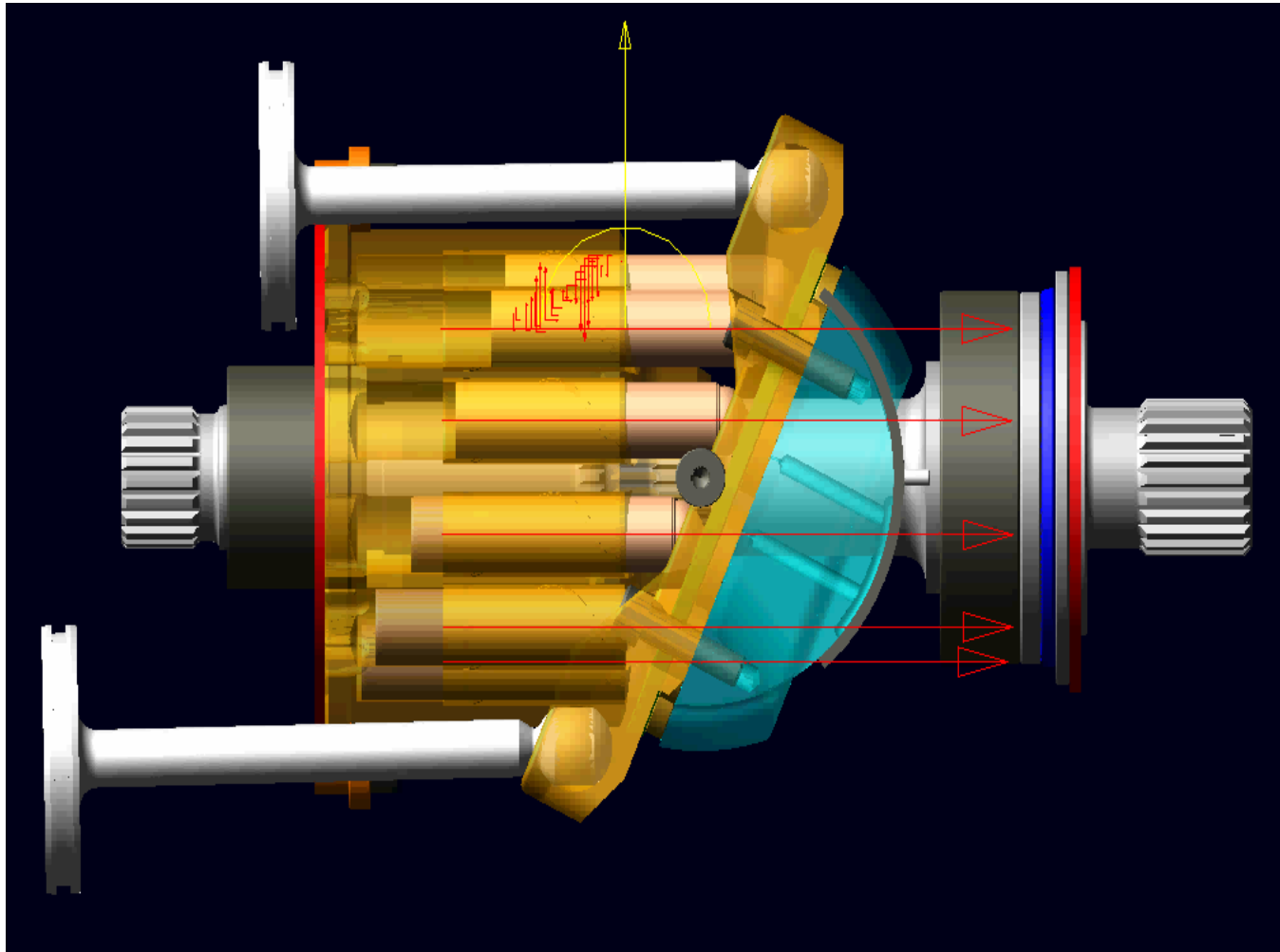
## ❖ Integrated System Modeling

- Conduct integrated system (structural, hydraulic, and control) simulation.
- Create mapping of virtual prototype and the physical pump dynamic characteristics (efficiency, response, stability).
- Reduce physical prototyping cost and testing cycles.



# Piston Pump Rotating Group

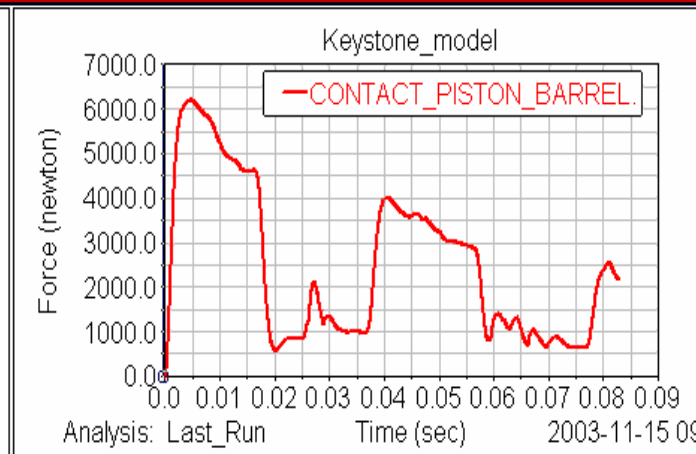
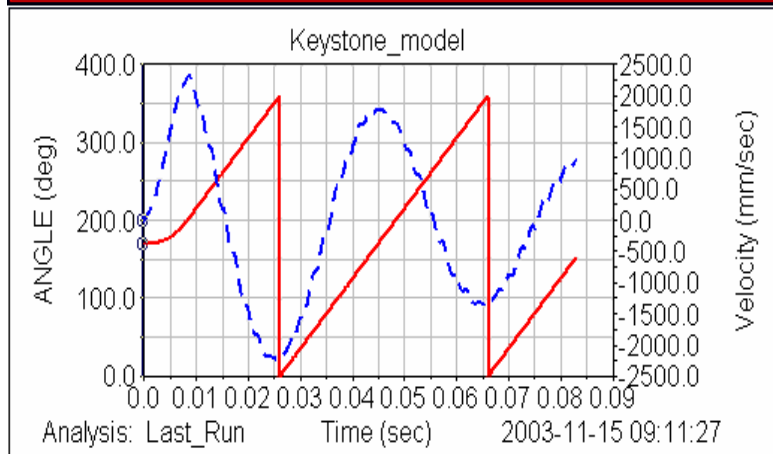
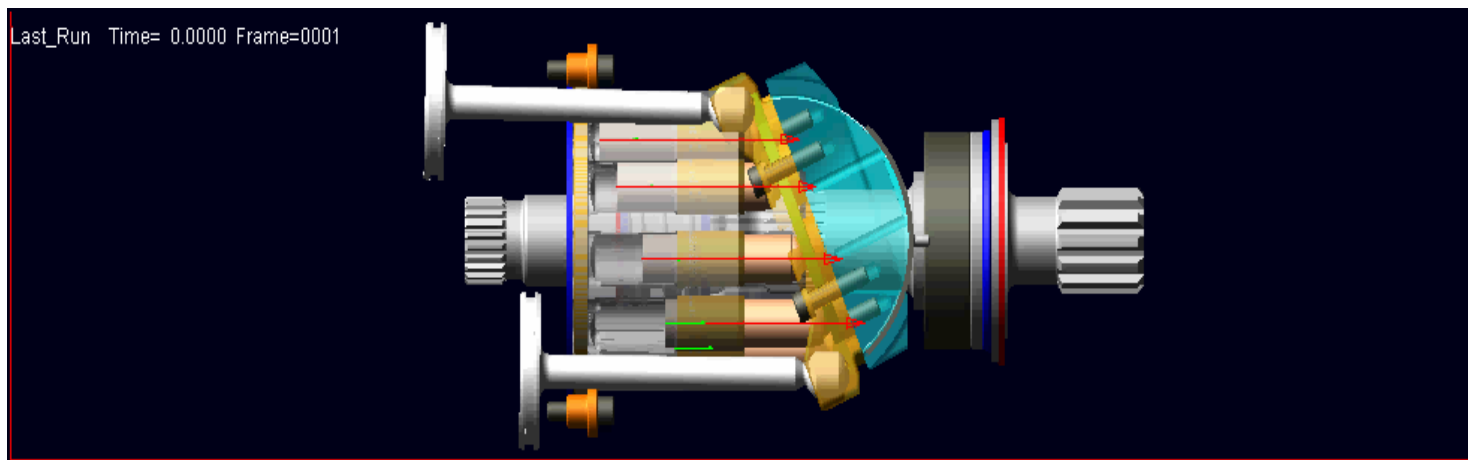
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# Modeling Approach: Virtual Prototyping

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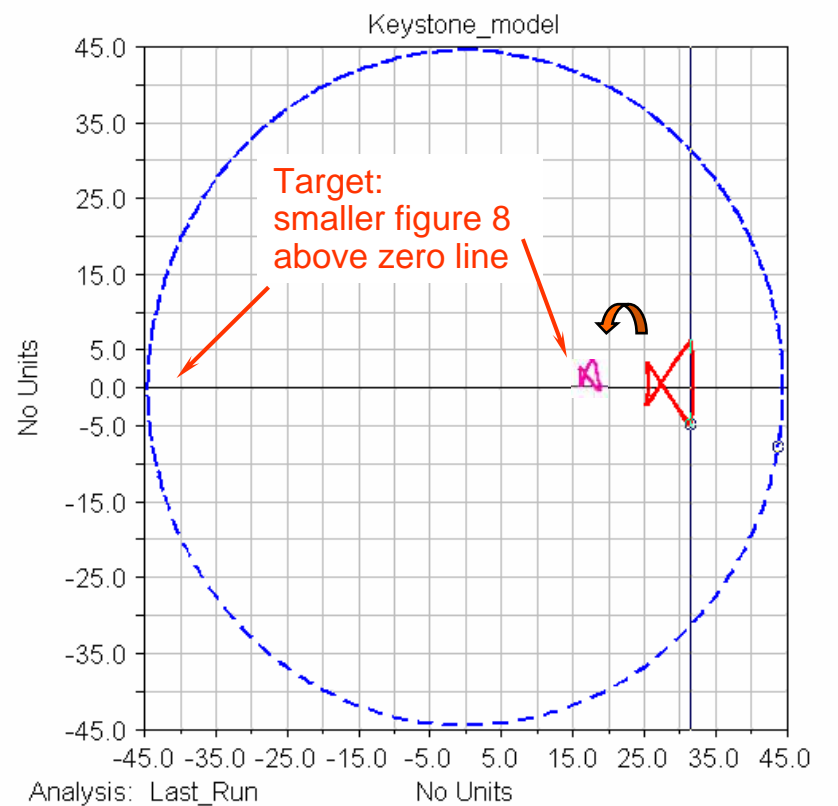
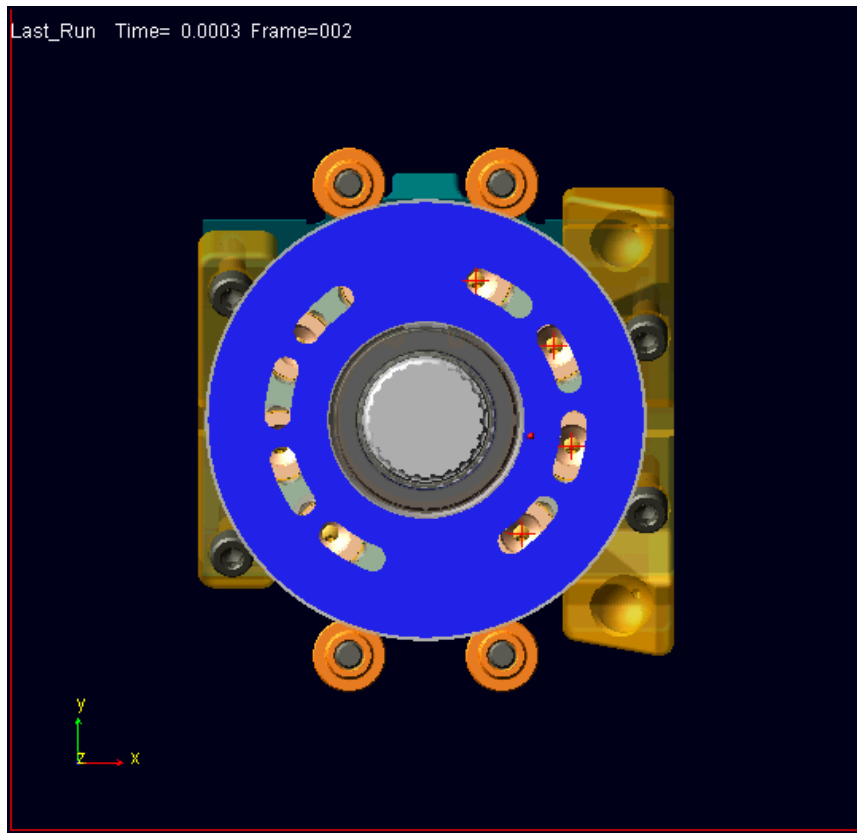




# Modeling Approach: Force Optimization

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- Provide guidance for displacement control/actuation design

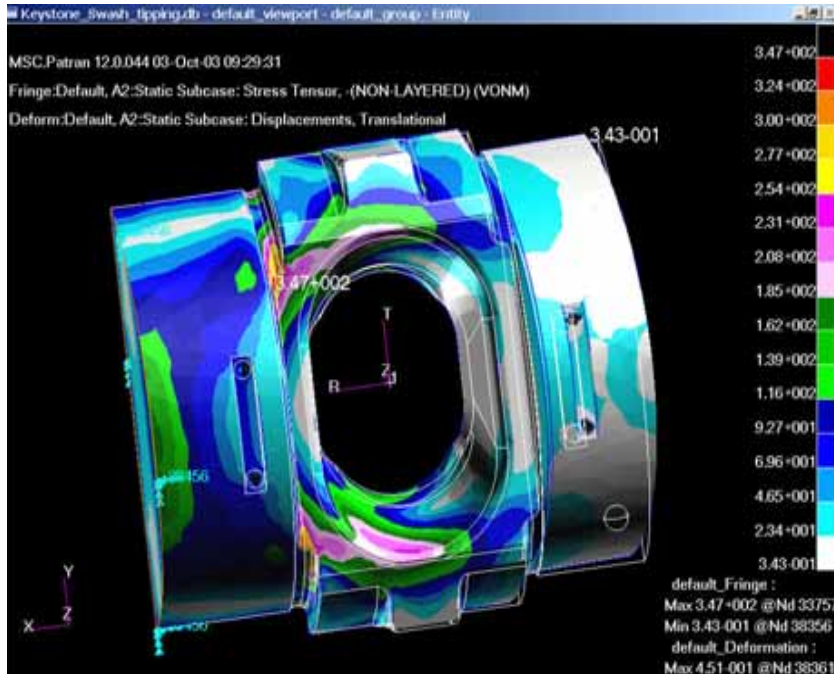




# Modeling Approach: Structure Integrity

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Before



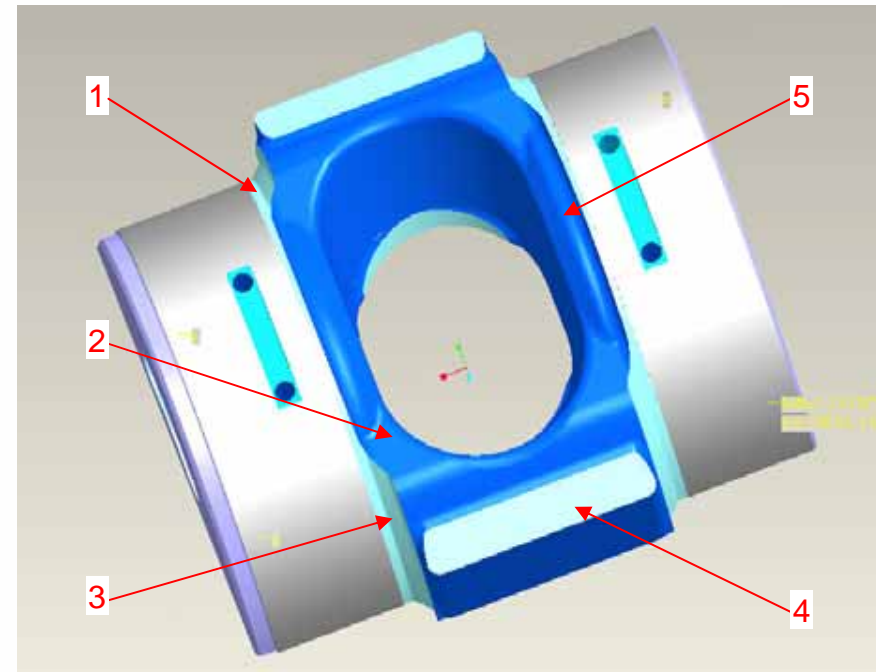
Issues:

Stress hot spot

Fatigue weak area

High swash deflection

After

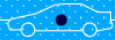


Solution:

Remove stress concentration (undercut)

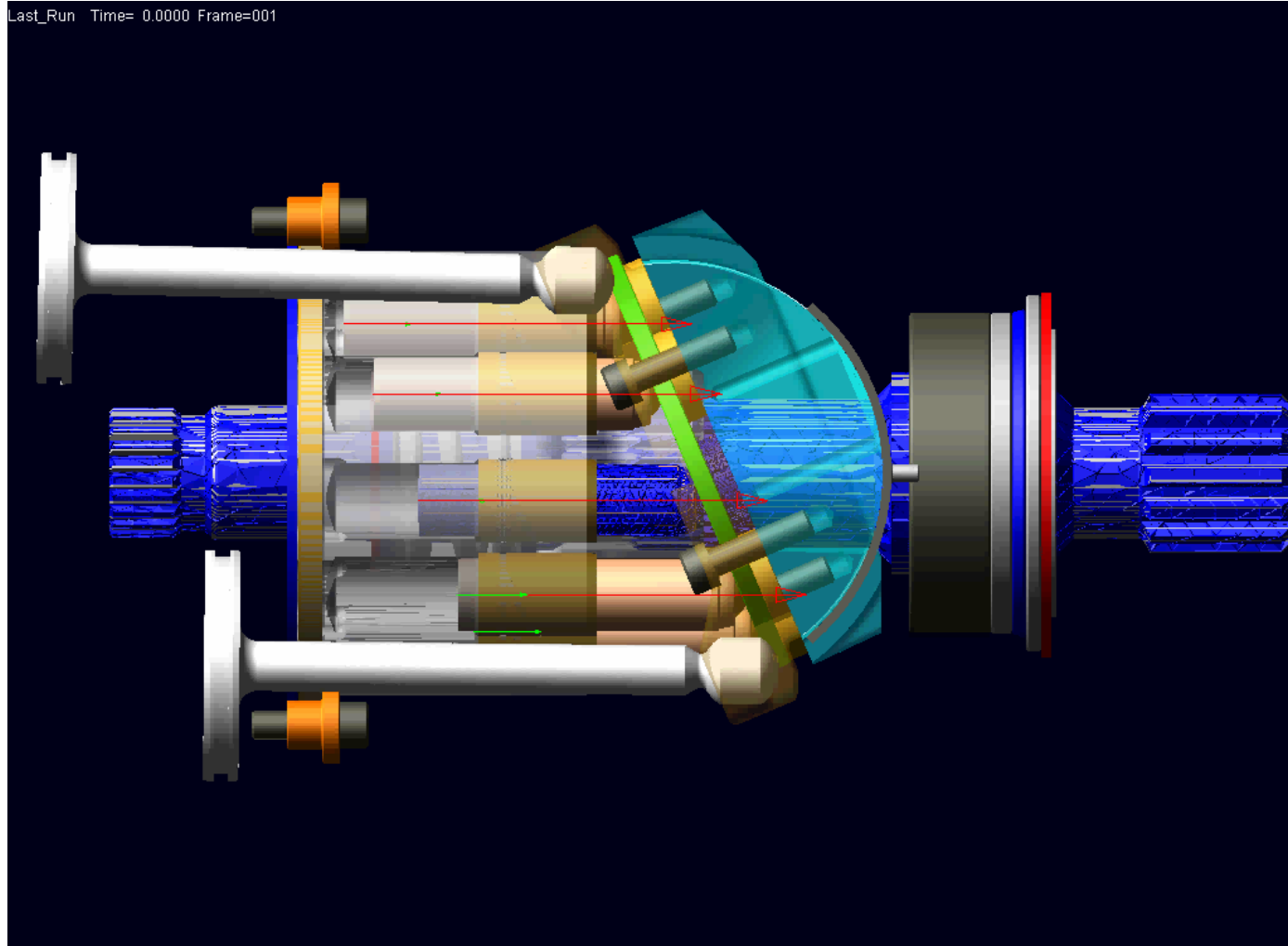
Thicken weak area (beefing)

Stiffen swash structure (ribs, shoulders)



# Piston Stress Analysis (Flexbody)

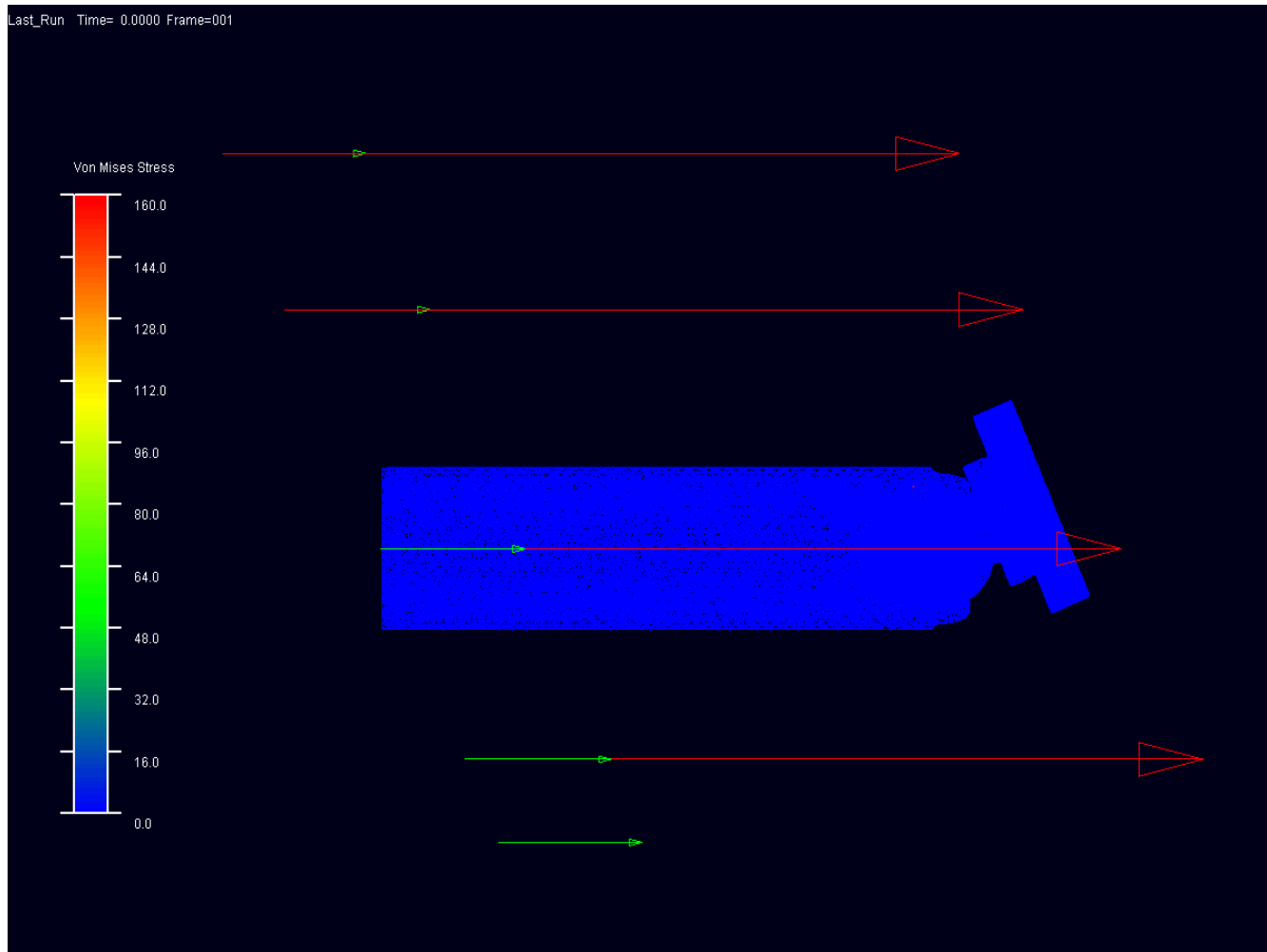
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# Piston Stress Analysis (Flexbody)

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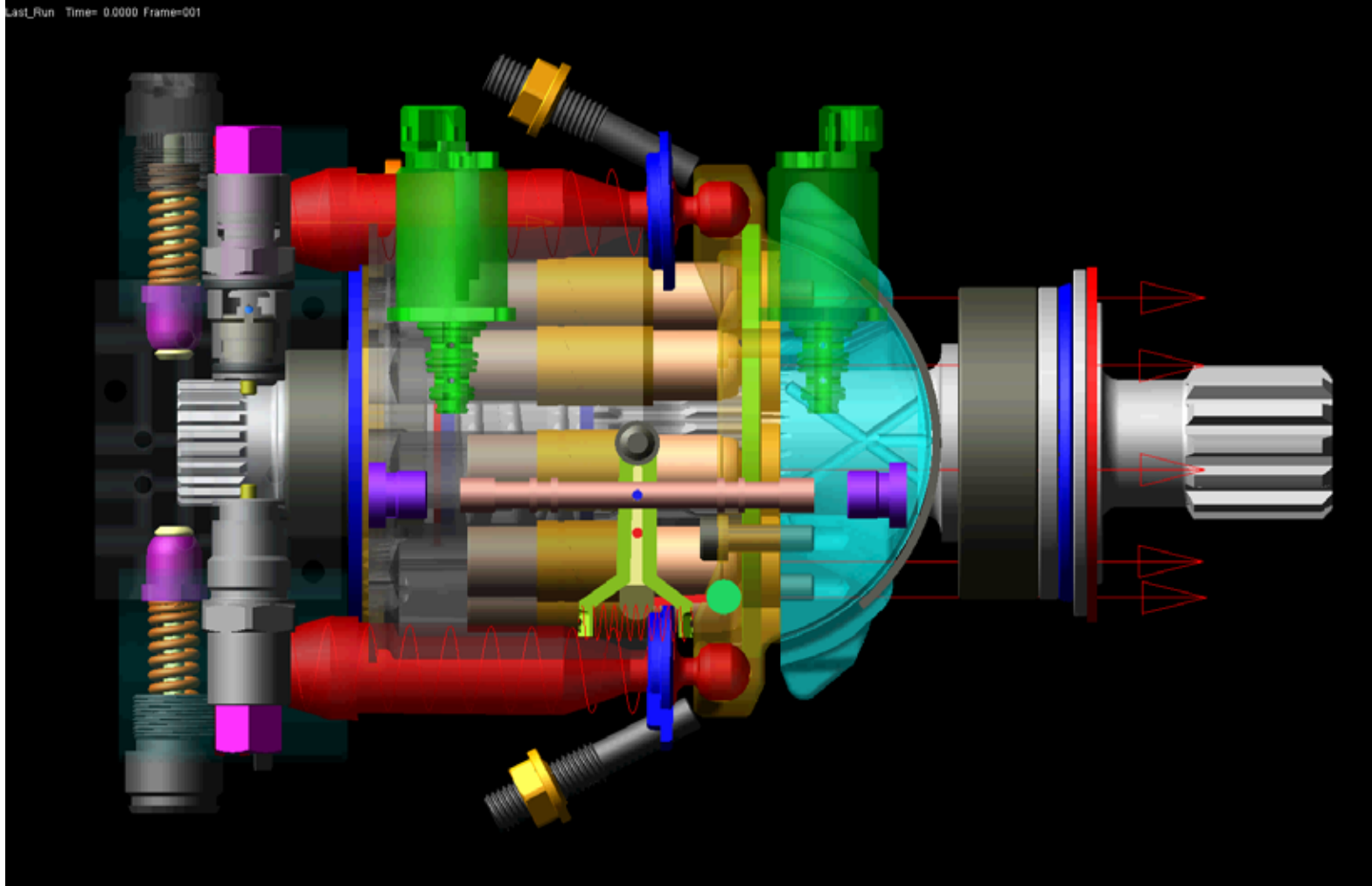


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# Integrated Model: MSC.ADAMS Mechanism

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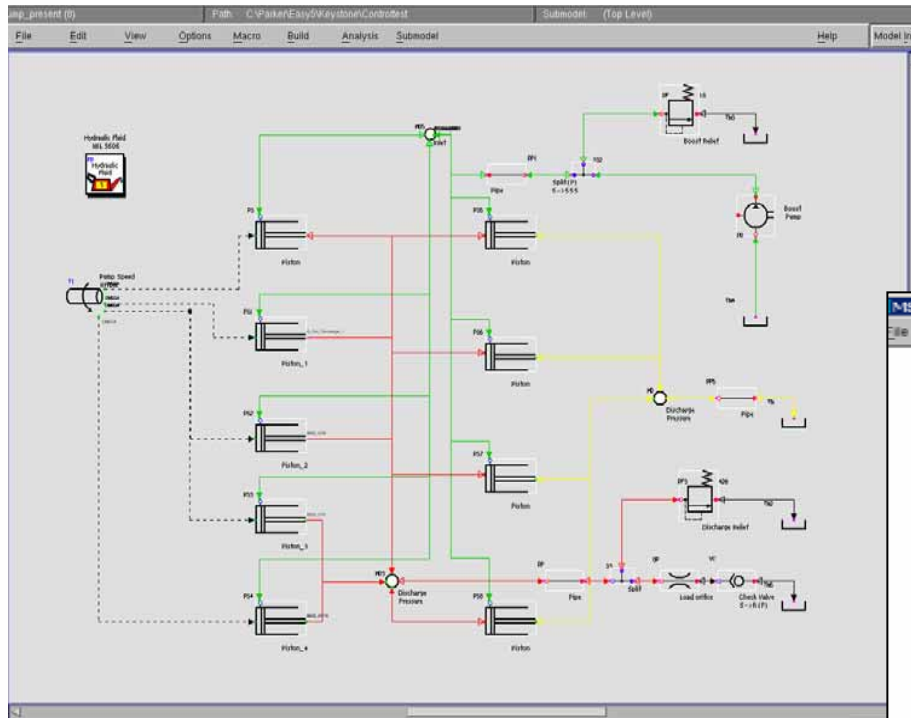


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# Hydraulics Simulation (MSC.Easy5)

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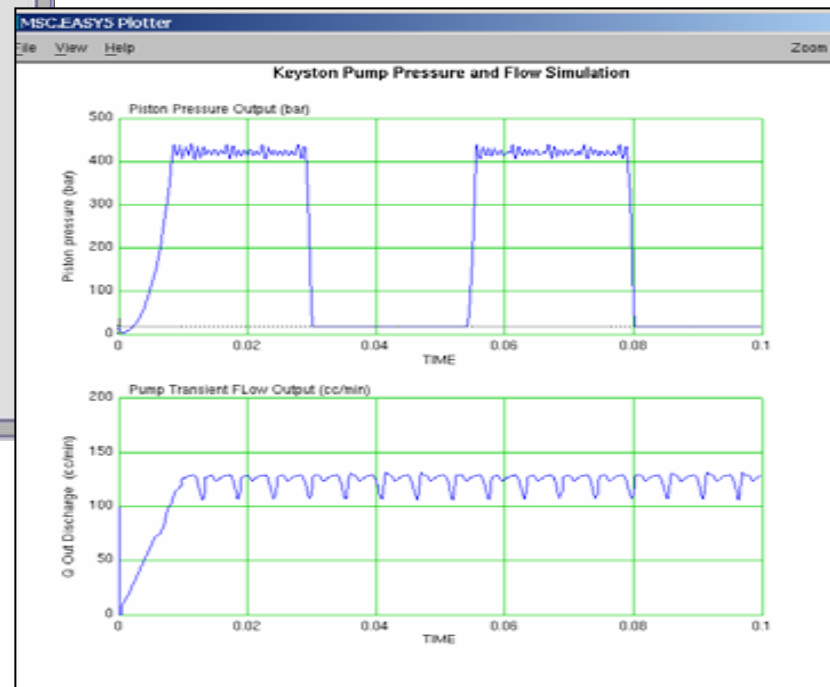


Outcome:

Pump pressure profile

Pump flow ripple prediction

Feedback to ADAMS for co-simulation



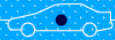
Features:

Complete pump model

Predict dynamic pressure and flow

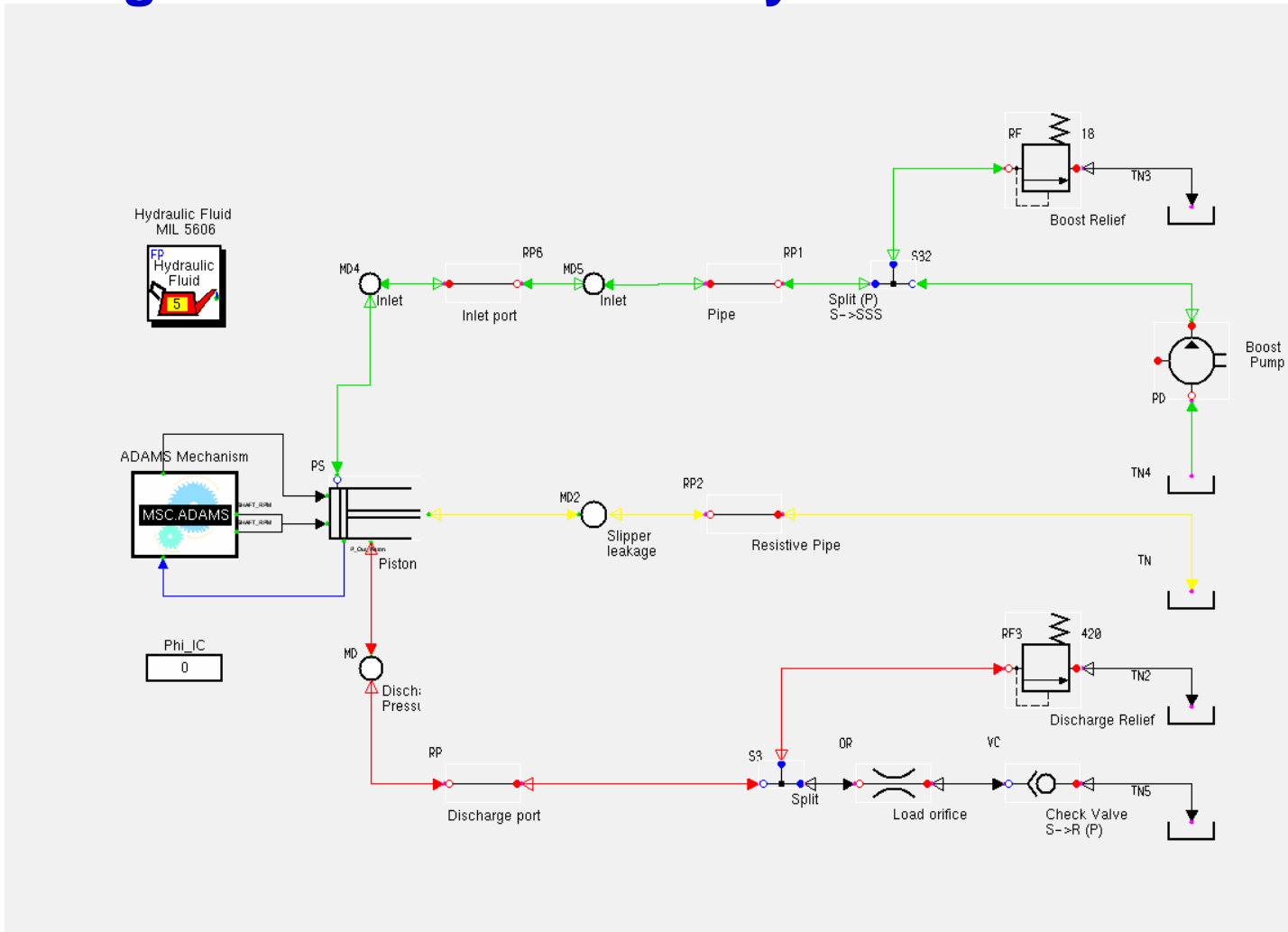
Assist flow ripple reduction and noise attenuation

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# Integrated Model: MSC.Easy5 Interface

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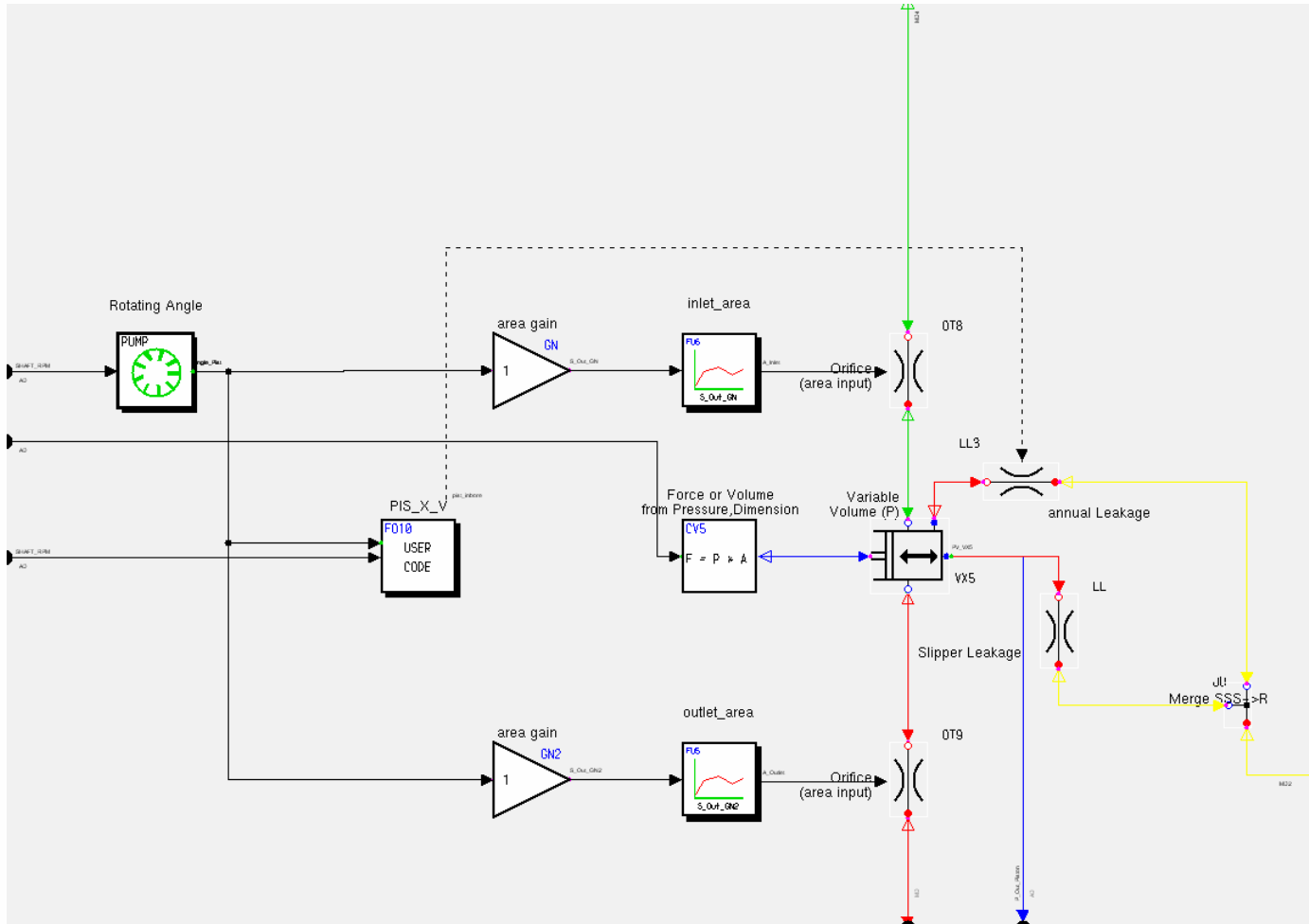


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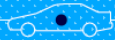


# MSC.Easy5 Interface: Pumping Piston Model

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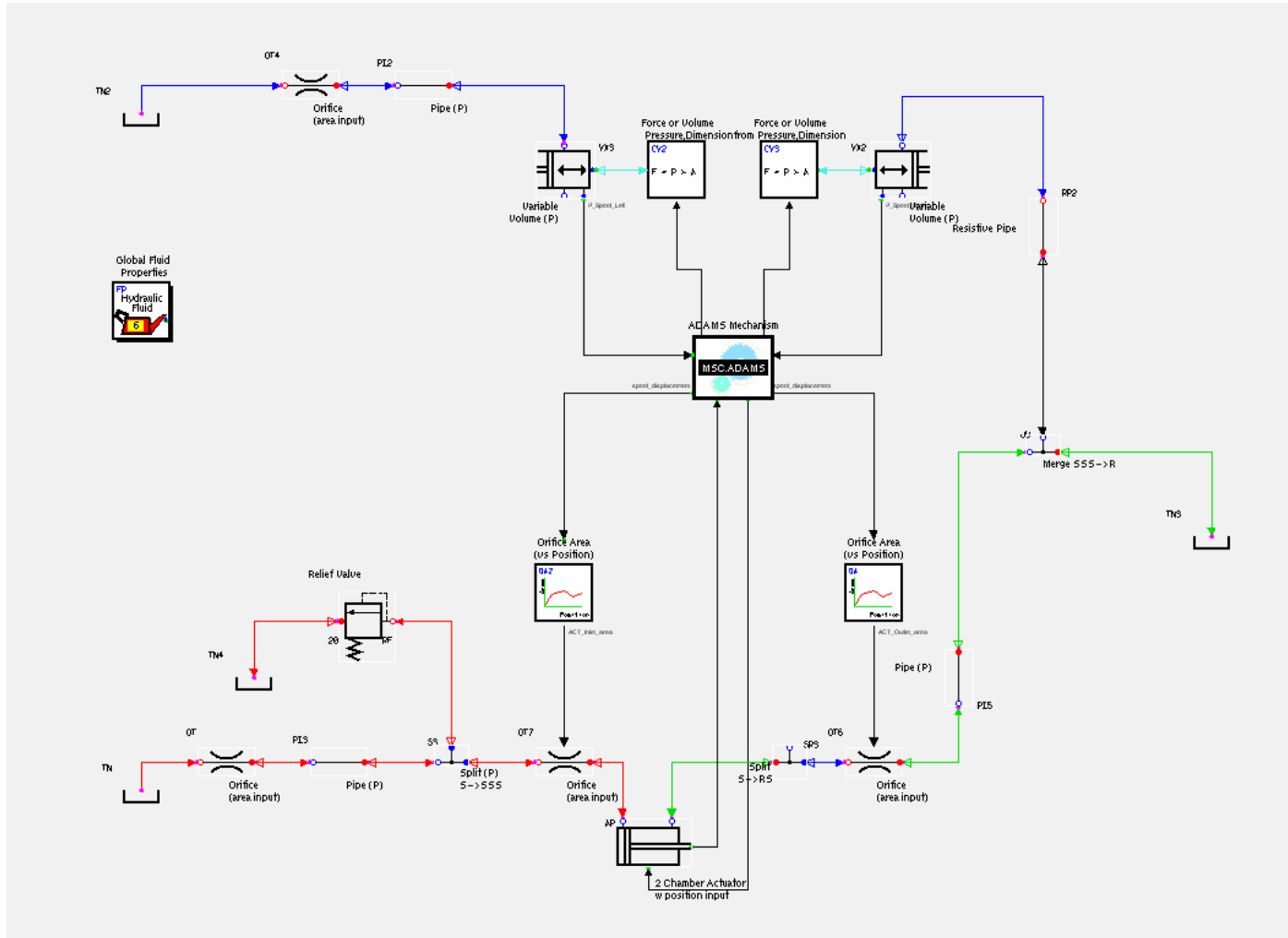


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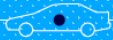


# MSC.Easy5 Interface: Control Actuator Model

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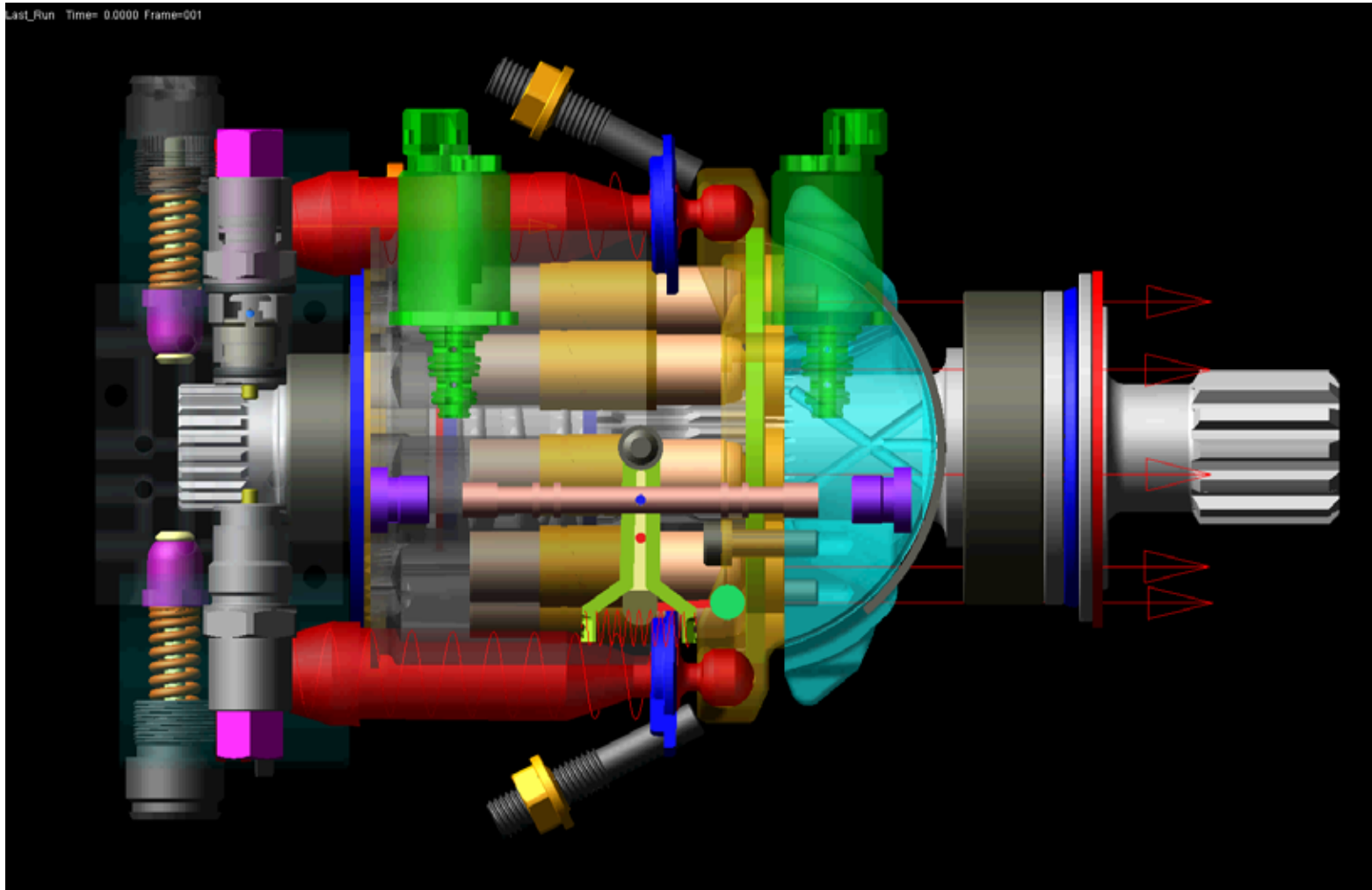


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# Co-simulation: Structure and Hydraulics

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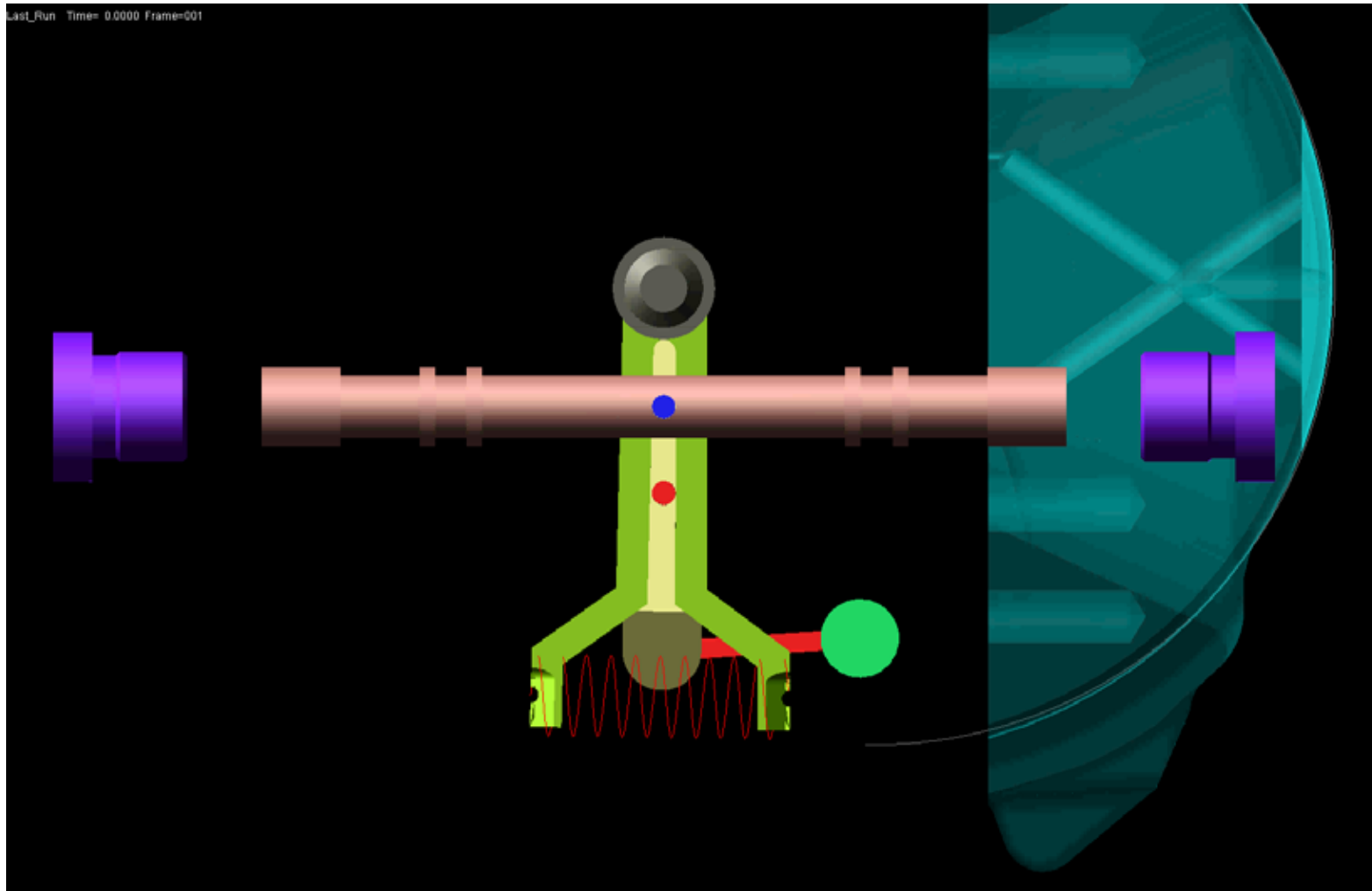


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# Co-simulation: Swash Control Mechanism

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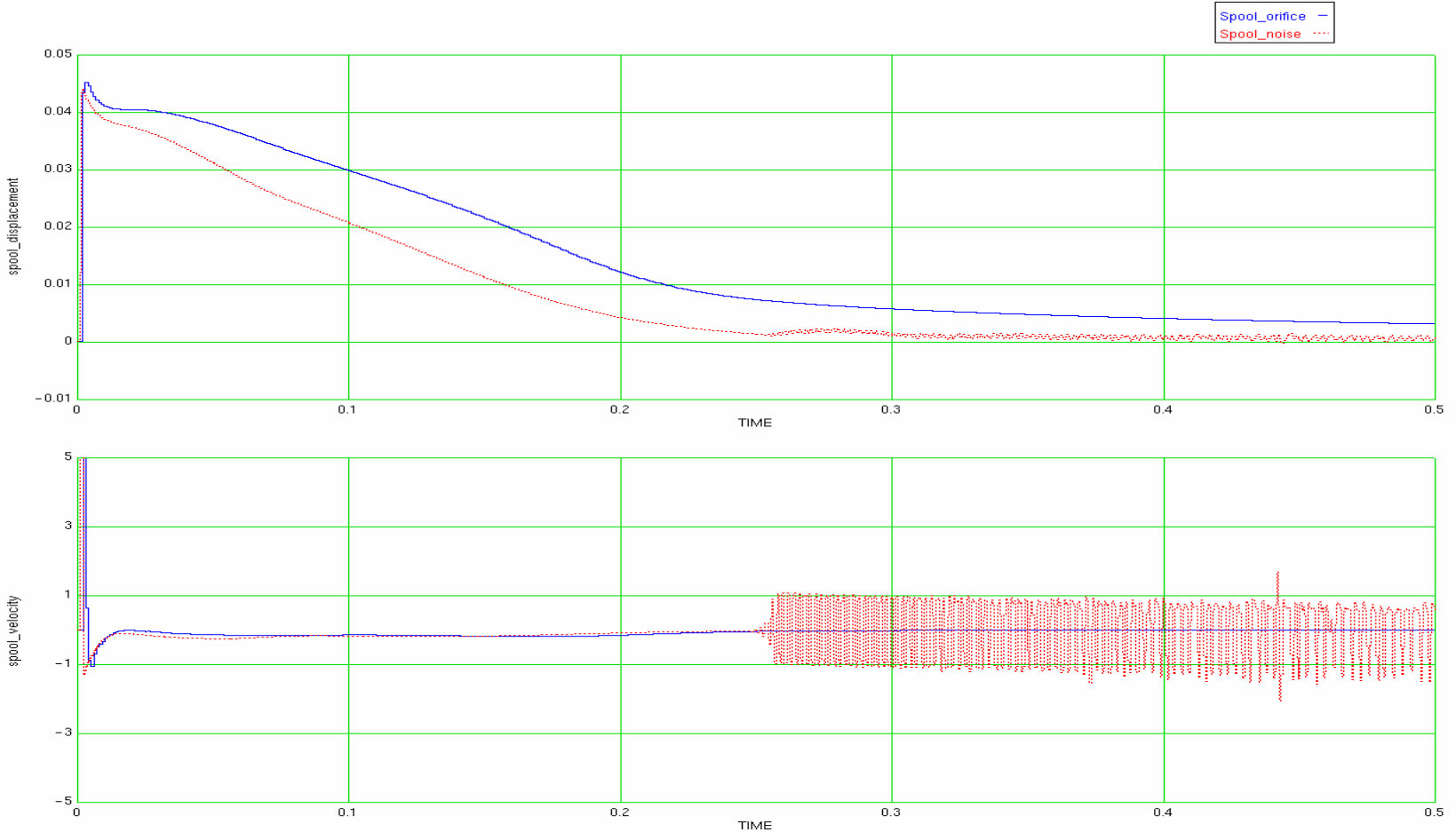
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# Integrated Simulation: Control Response

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1: spool\_displacement, spool\_displacement, spool\_velocity vs TIME



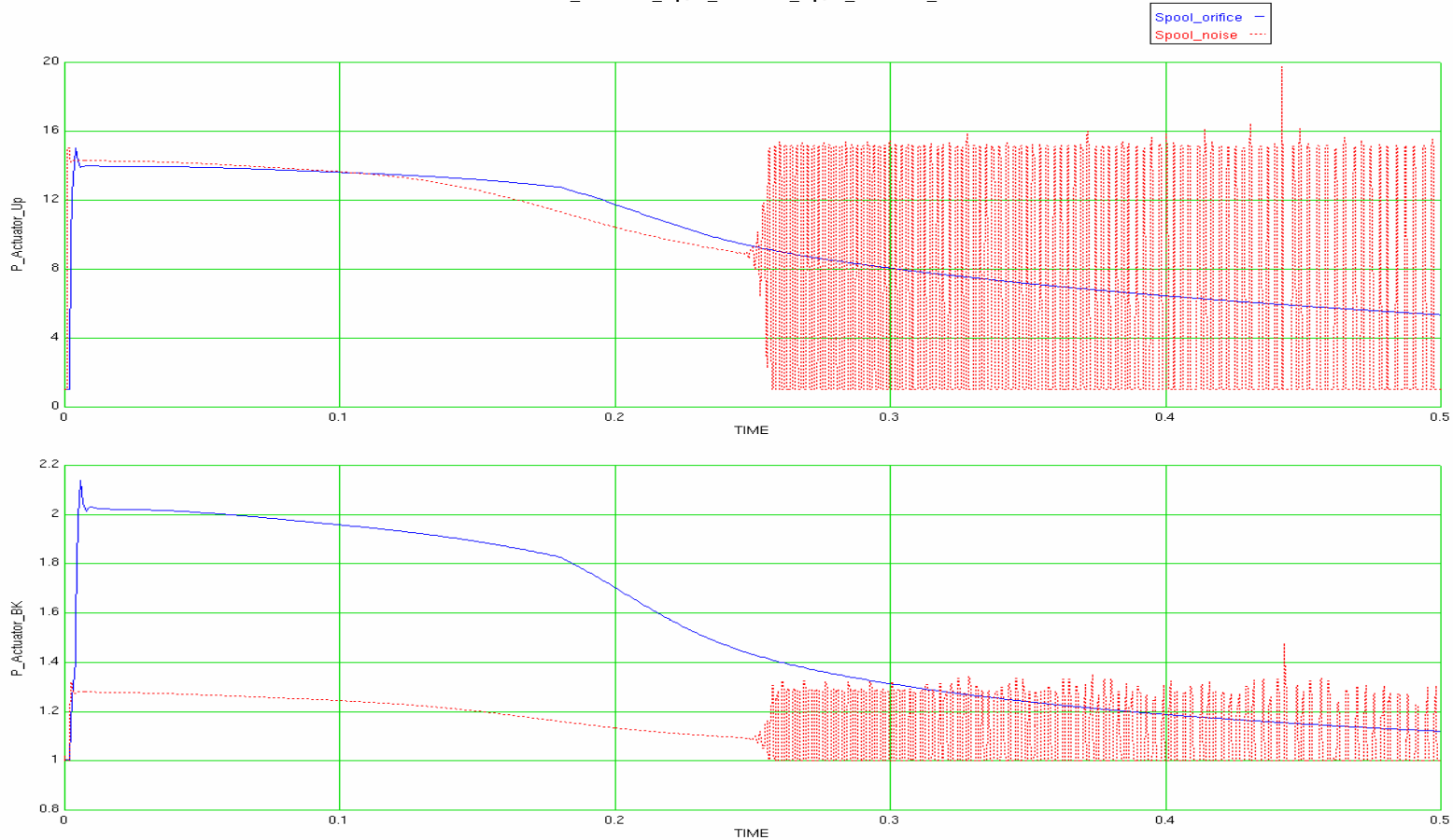
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# Integrated Simulation: Actuator Pressures

6: P\_Actuator\_Up, P\_Actuator\_Up, P\_Actuator\_BK vs TIME



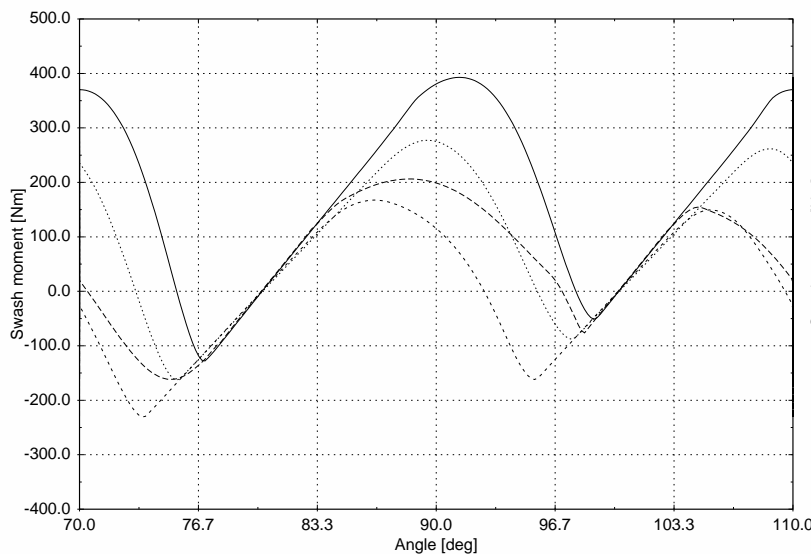
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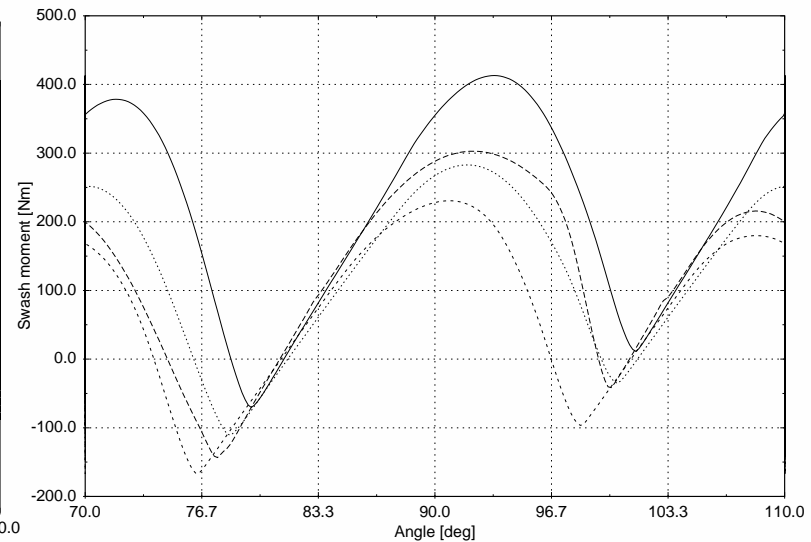
# Swash moment variations

- Swash plate moment vary with pump swash angle, pressure, and speed
- Positive mean value indicate a de-stroke ( return to zero) torque
- Swash control actuator may need to overcome swash torque beyond the mean value under dynamic conditions

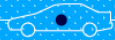
Swash plate moment under various operating pressures



Pump speed = 1000 rpm



Pump speed = 2500 rpm



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## Summary

### ❖ Advantages of Co-simulation

- Utilize MSC.ADAMS structure modeling power, interfacing with MSC.Easy5, to model complicated structure and fluid interaction.
- Quickly evaluate various design concepts; optimize pump displacement control response and stability.
- Perform parametric study under varying pump speed and pressure conditions to reduce pressure ripple and control actuator force.

### ❖ Benefit of The Integrated System Analysis

- Create mapping of virtual prototype and the physical pump dynamic characteristics (efficiency, response, stability).
- Reduce physical prototyping cost and testing cycles (structure, load, and performance optimized on virtual prototype).