CCEFP Summit at Purdue in Honor of Monika Ivantysynova

Analysis of Power Distribution in a Mid-Size Agricultural Tractor through Modeling

Xin Tian, Josias Cruz [Presenter]

Advisor: Andrea Vacca

MAHA Fluid Power Research Center

June 5th, 2019

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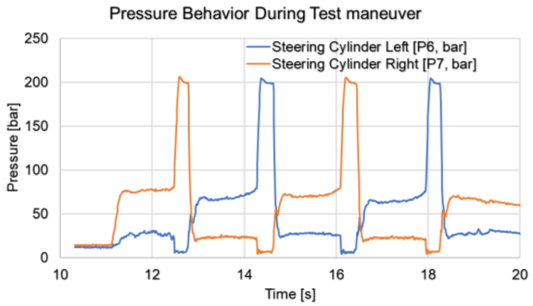
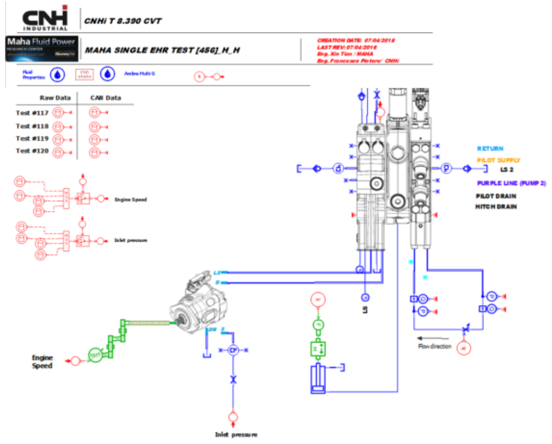
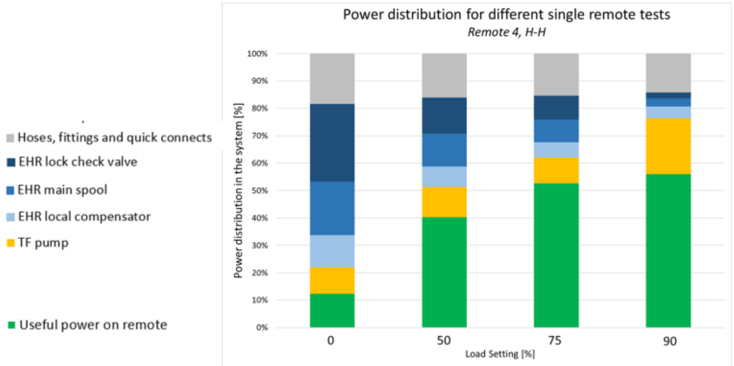


Pressure Behavior During Test maneuver
Steering Cylinder Left [P6, bar]
Steering Cylinder Right [P7, bar]
Pressure [bar]
250
200
150
100
50
0
10
12
14
16
18
20
Time [s]



CNH INDUSTRIAL
Maha Fluid Power
Raw Data
CAN Data
Engine Speed



Power distribution for different single remote tests
Remote 4, H-H
Hoses, fittings and quick connects
EHR lock check valve
EHR main spool
EHR local compensator
TF pump
Useful power on remote
Power distribution in the system [%]
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
50
75
90
Load Setting [%]

Research motivation

Auxiliary hydraulic functions

Traveling service

Steering

Power beyond

Braking

Ag. Tractor Standards

Guarantee

State of The Art Architectures

Load Sensing

Competitive Machine Operation

How to know?

Optimal Behavior

All working maneuvers?

Research goal

We know: Different sources of power loss existing [load sensing]

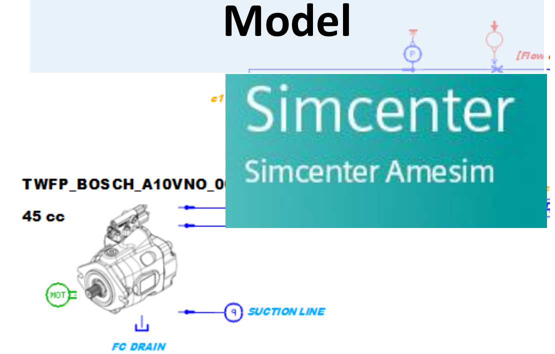
↓

- Feasible and cost-effective solutions for significant increase of energy efficiency of such system to improve overall system efficiency.

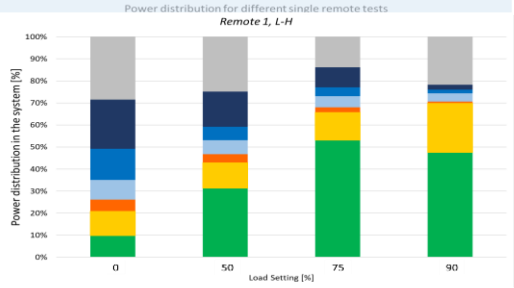
Research approach

Experimental Characterization

Validated AMESim Model



Classification of Energy Losses



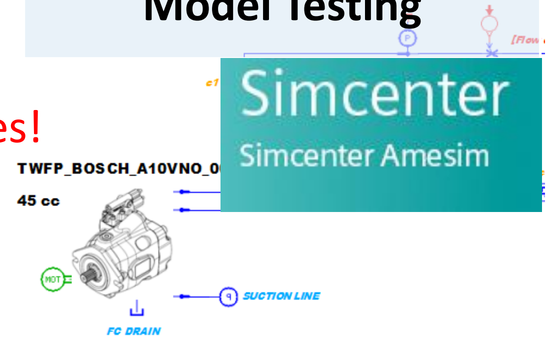
Machine Instrumentation → Steady State Testing → Dynamic Testing (Real Drive Cycles)

Solution Proposal

Research approach

Experimental Characterization

Validated AMESim Model Testing



Improved? Yes!

No

Solution Proposal

Steady State Testing

Dynamic Testing (Real Drive Cycles)

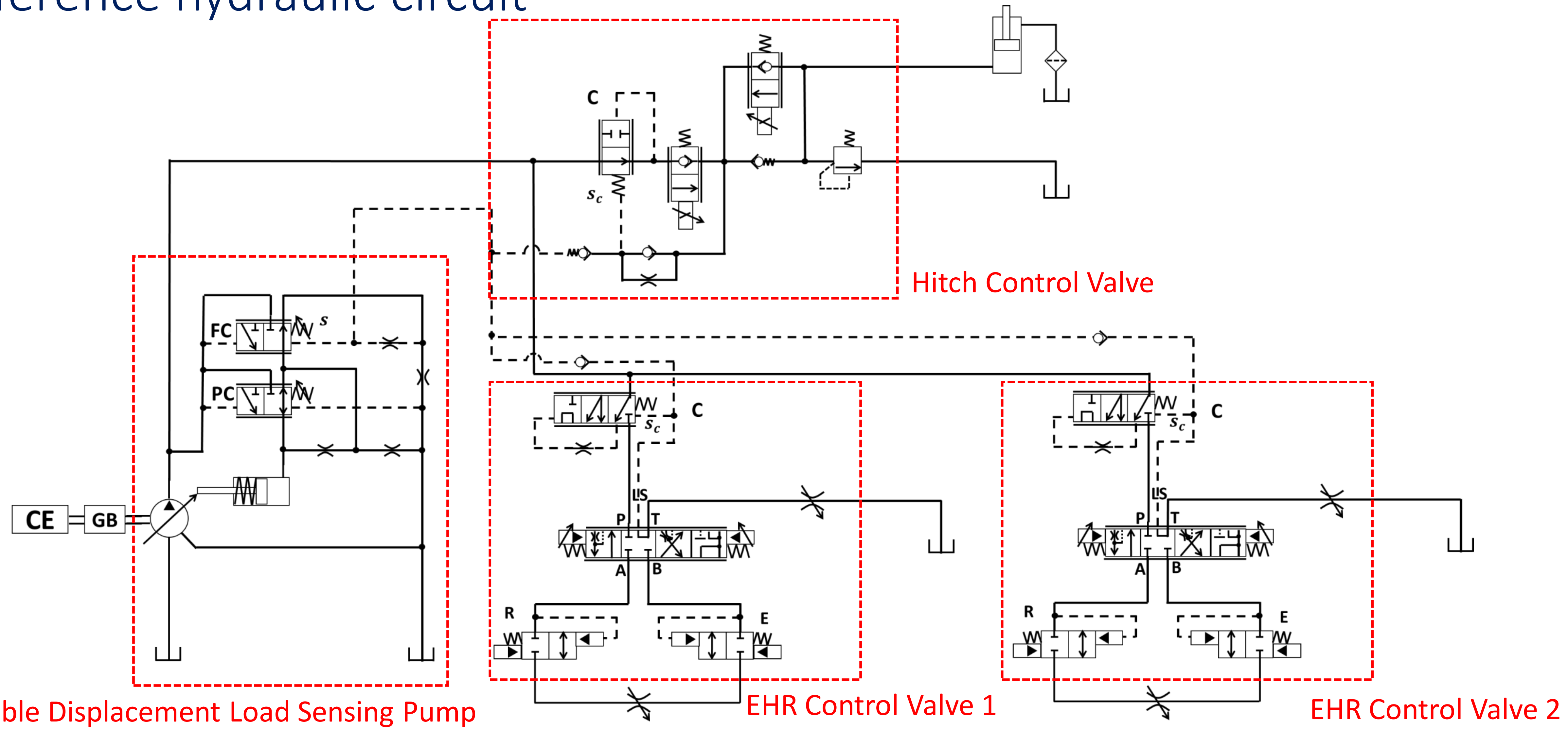
Improved?

No

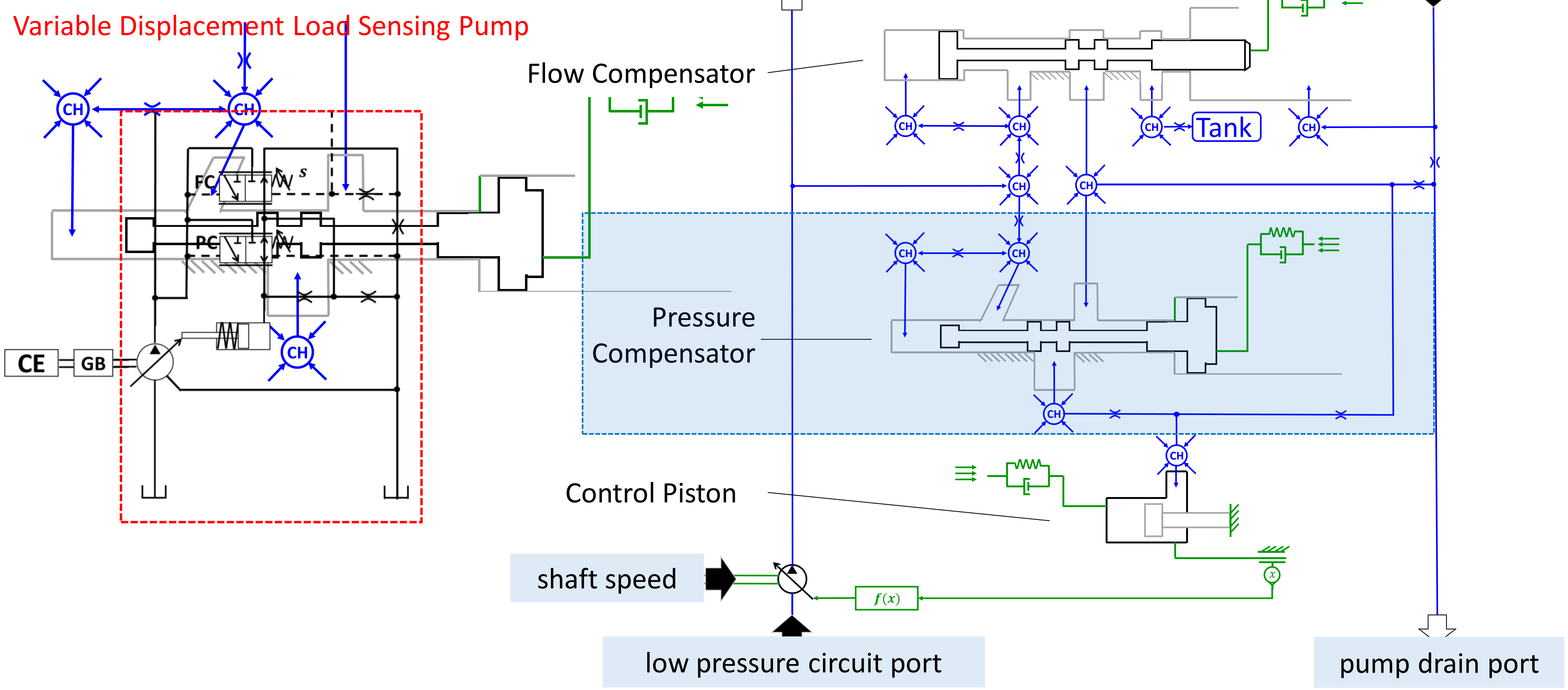
Yes!

Deliver

Reference hydraulic circuit

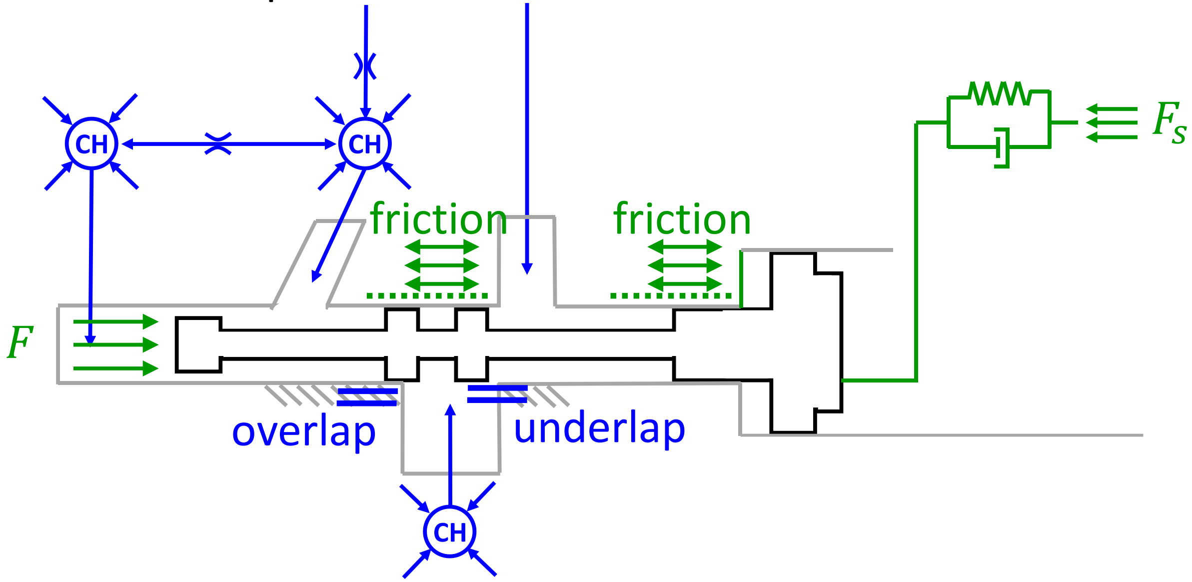


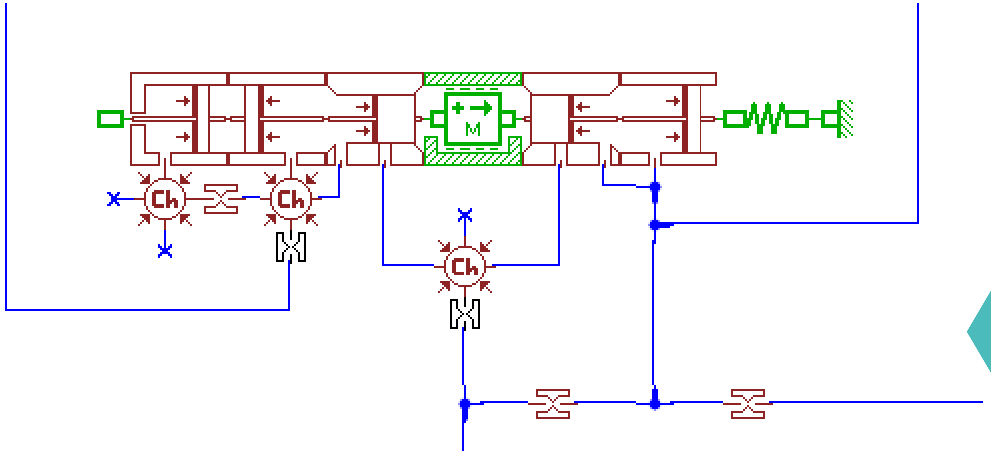
System modeling



System modeling

Pressure Compensator





Simcenter
Simcenter Amesim

Orifice equation: $Q = c_q \cdot A \cdot \sqrt{\frac{2|\Delta p|}{\rho}} \cdot sign(\Delta p)$

CH Internal volumes: $\frac{dp}{dt} = \frac{B(p) \cdot Q(p)}{V(p)}$

F_s Spool equilibrium: $F = F_s + F_{jet}$

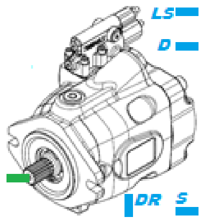
friction Viscous friction force: $f = -b \cdot v$

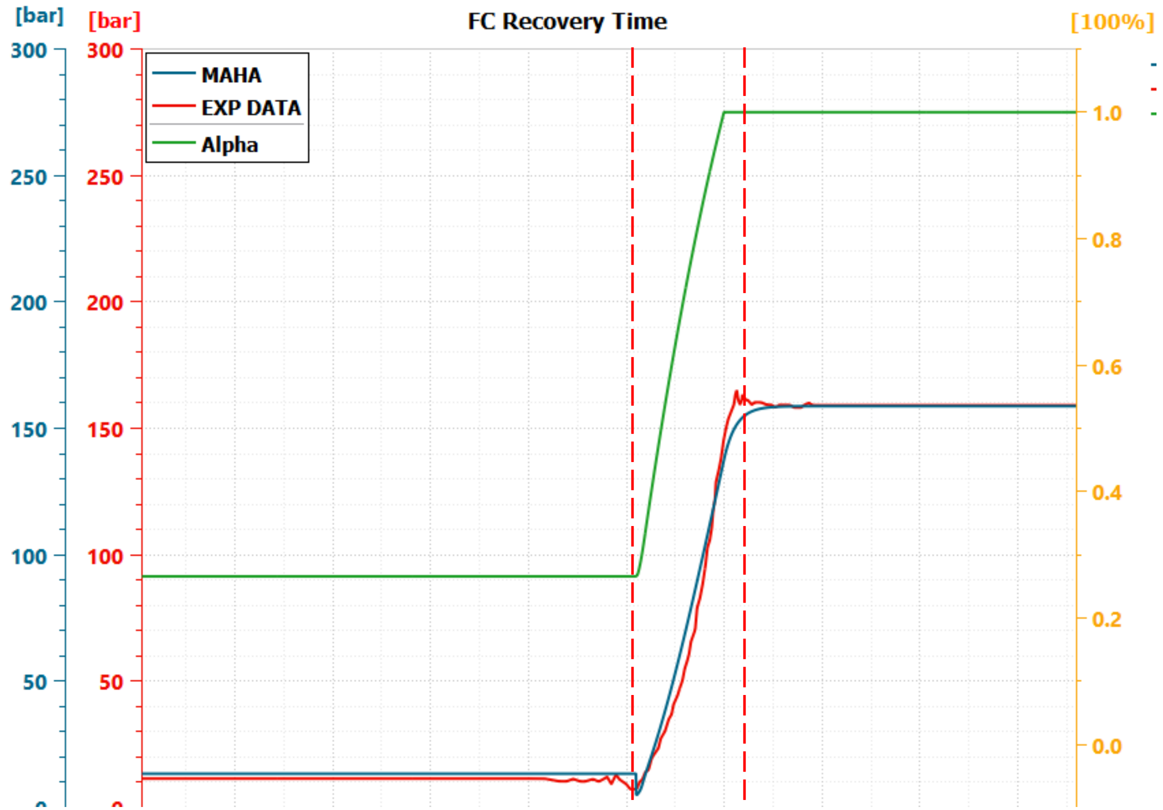
overlap underlap Jet forces: $F_{jet} = K \cdot 2 \cdot c_q \cdot A \cdot \Delta p \cdot cos\theta$

$$K = k_{jet} \cdot \frac{1}{2}\left[\tanh\left(\frac{2(x_{lap} - x_{min})}{x_{min}}\right) + 1\right]$$

Model validation

- Pressure-flow compensator dynamic test: SAE STANDARD J745 JUN2009



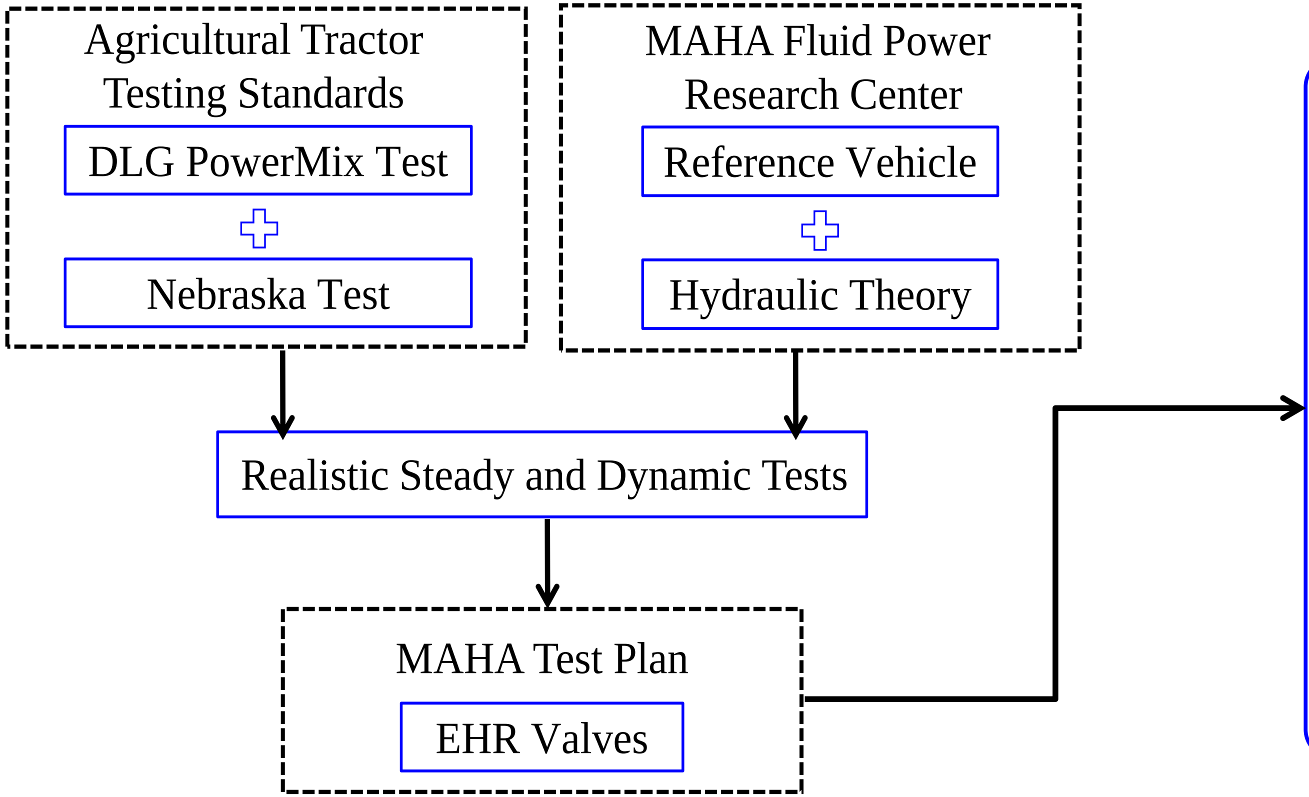


	Load Pressure	Deadhead Pressure
Pressure Compensator	95.08	99.29

	Load Pressure	Standby Pressure
Flow Compensator	99.79	83.22

Load Pressure:	Standby Pressure:
Model = 158.77 bar	13.43 bar
Experiment = 159.11 bar	11.50 bar

Experimental tests set up

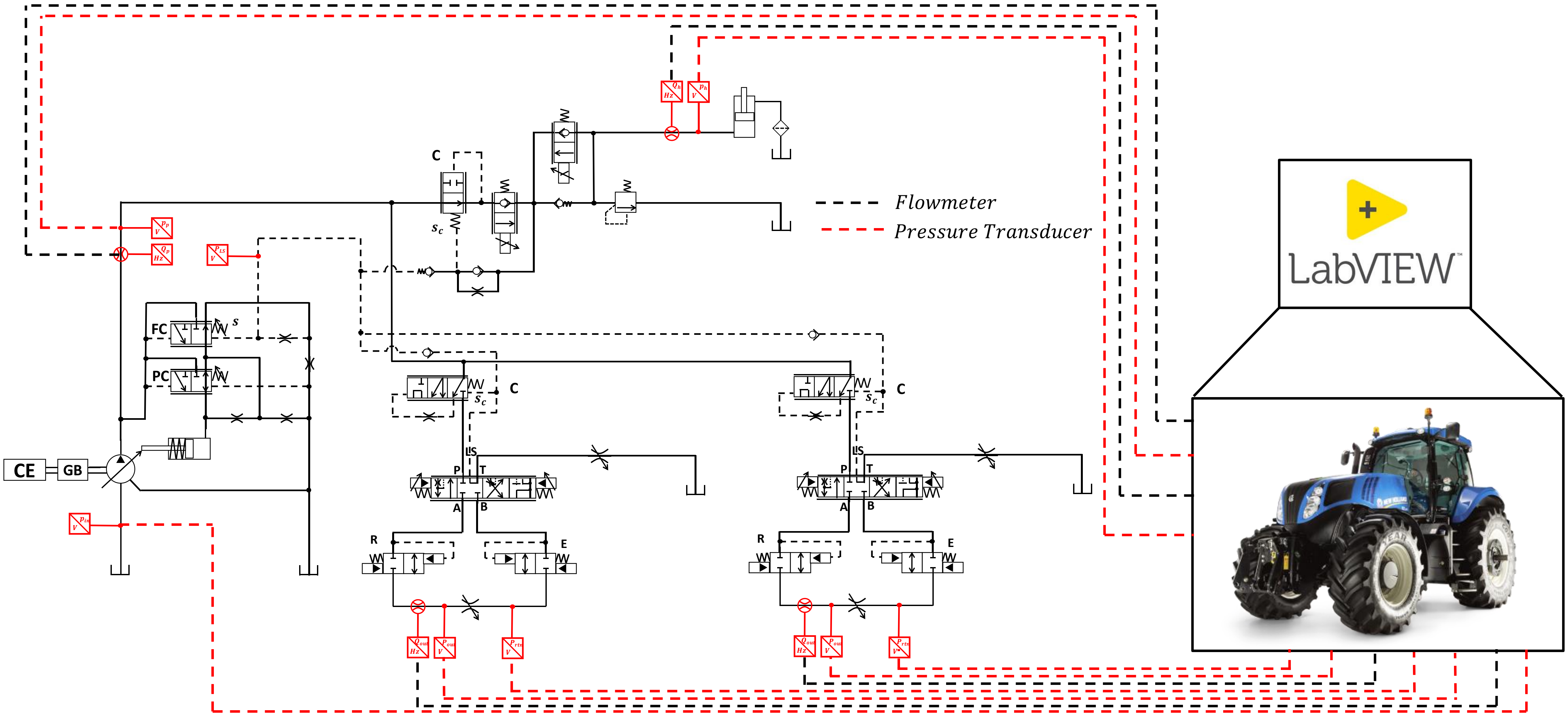


- Maha Test plan:
  - Based on real tractor testing standards.
  - Contains specific modifications for energy consumption analysis
  - Versatile & easily adjustable to larger or smaller size tractors.

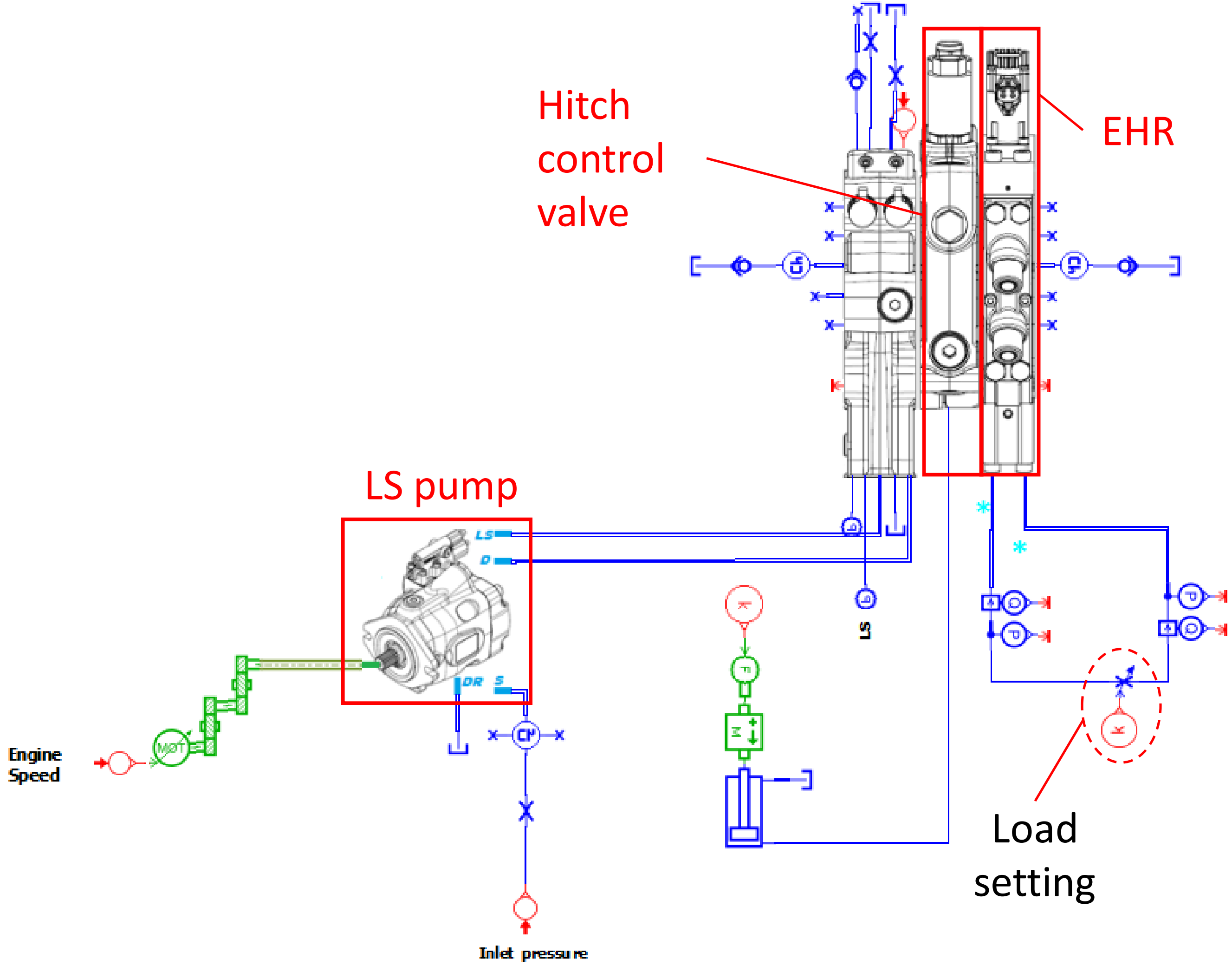
EHR Test Summary

	Number of Tests
Single Remote	224
Multiple Remotes	48
TOTAL	272

Experimental tests set up



System Model Tests



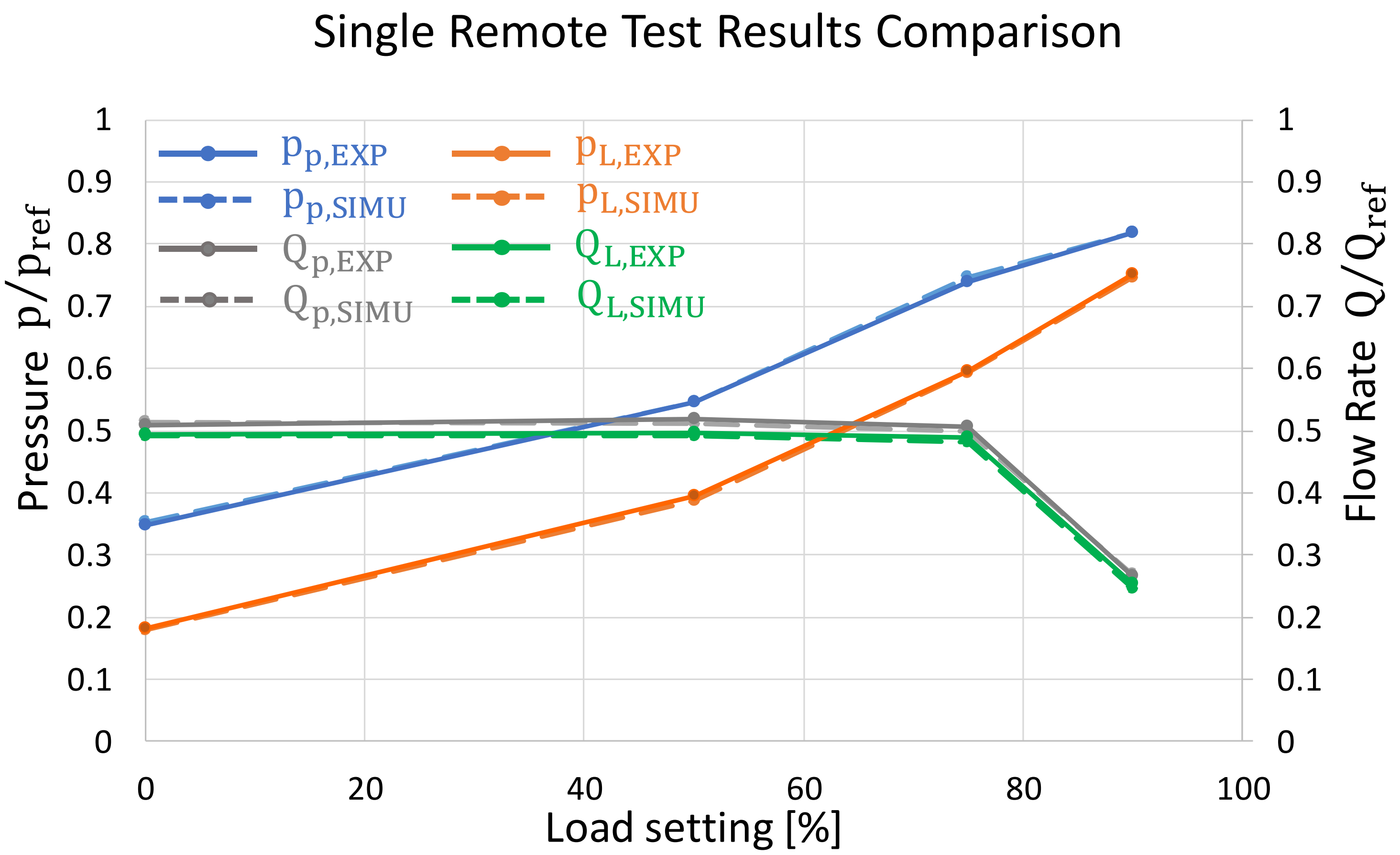
Test Plan for EHR and Hitch

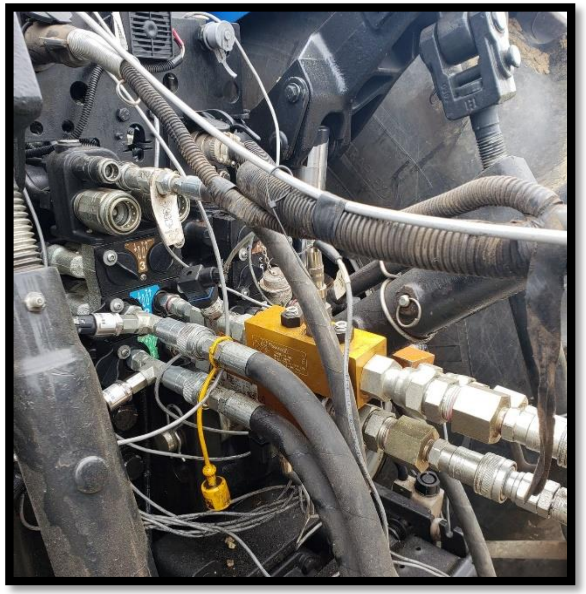
100% Flow Command EHR: (Retraction/Extension, High/Low T_{oil}) HITCH: (Rising, High/Low T_{oil})			
0% Load	50% Load	75% Load	90% Load

90% Load EHR: (Retraction/Extension, High/Low T_{oil}) HITCH: (Rising, High/Low T_{oil})		
25% Flow command	50% Flow Command	75% Flow Command

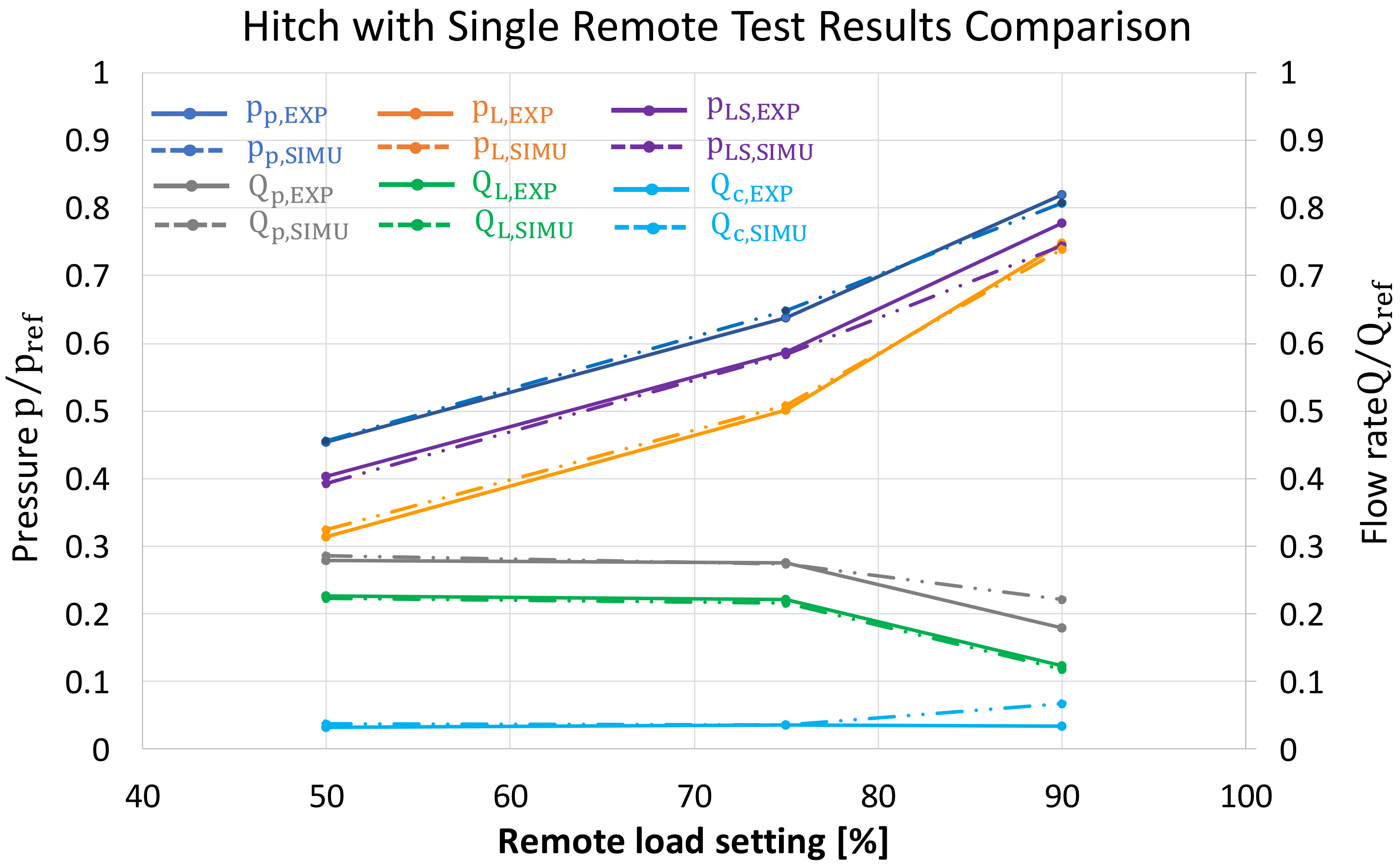
System model validation results

- Different load settings
- Full command
- Retraction
- High T_{oil}
- High RPM

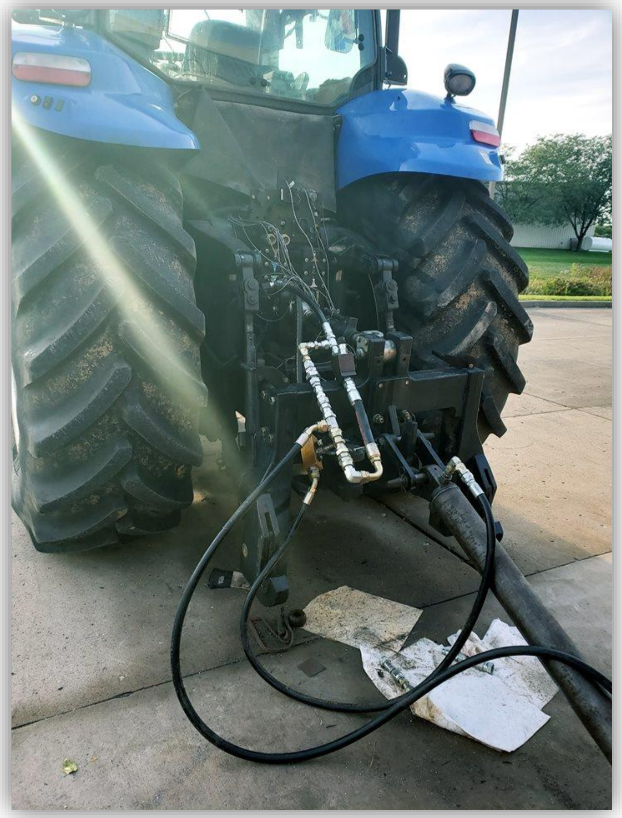




System model validation results



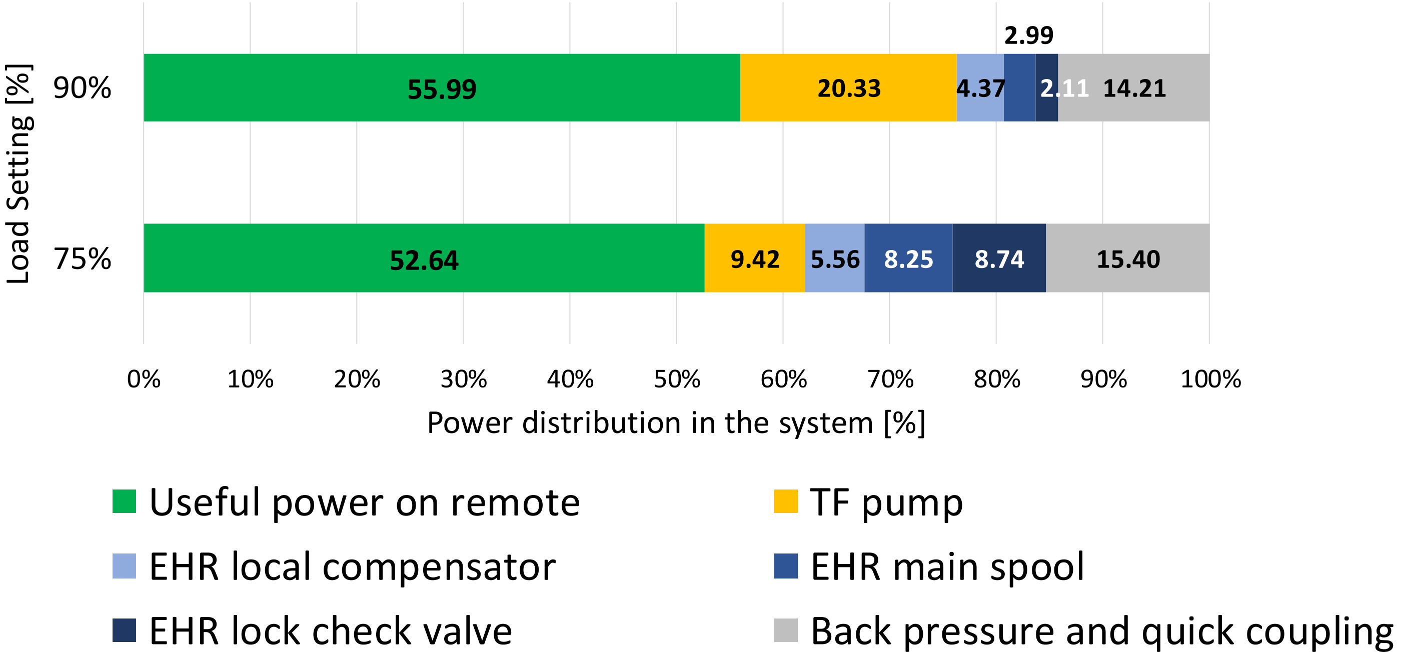
- Different load settings on remote
- Hitch cylinder raising
- Full command
- Extension
- High T_{oil}
- High RPM



System power distribution

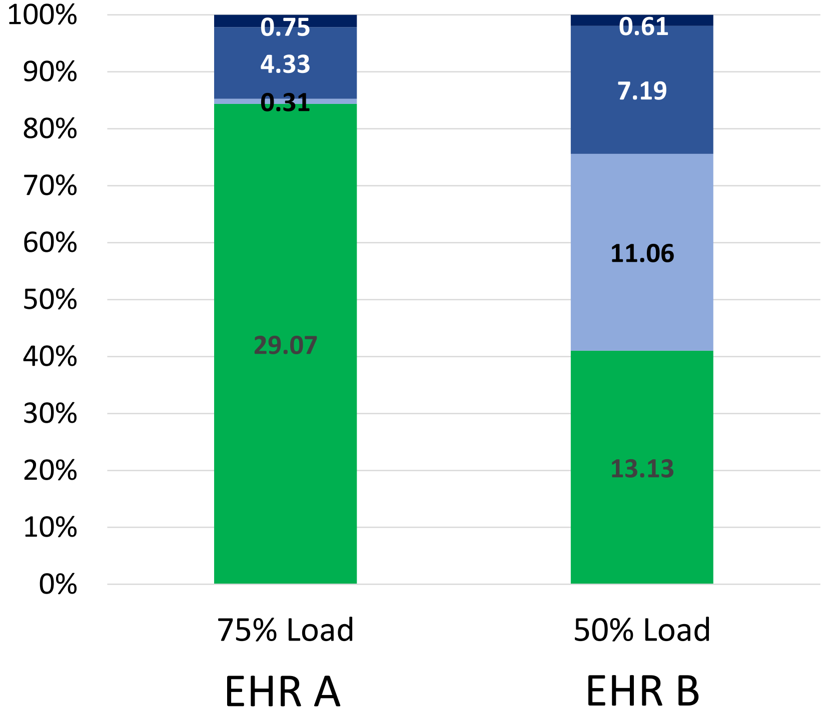
Power Distribution Comparison Between Different Loads for Single Remote Test

Full command, Retraction, High RPM, High oil temperature

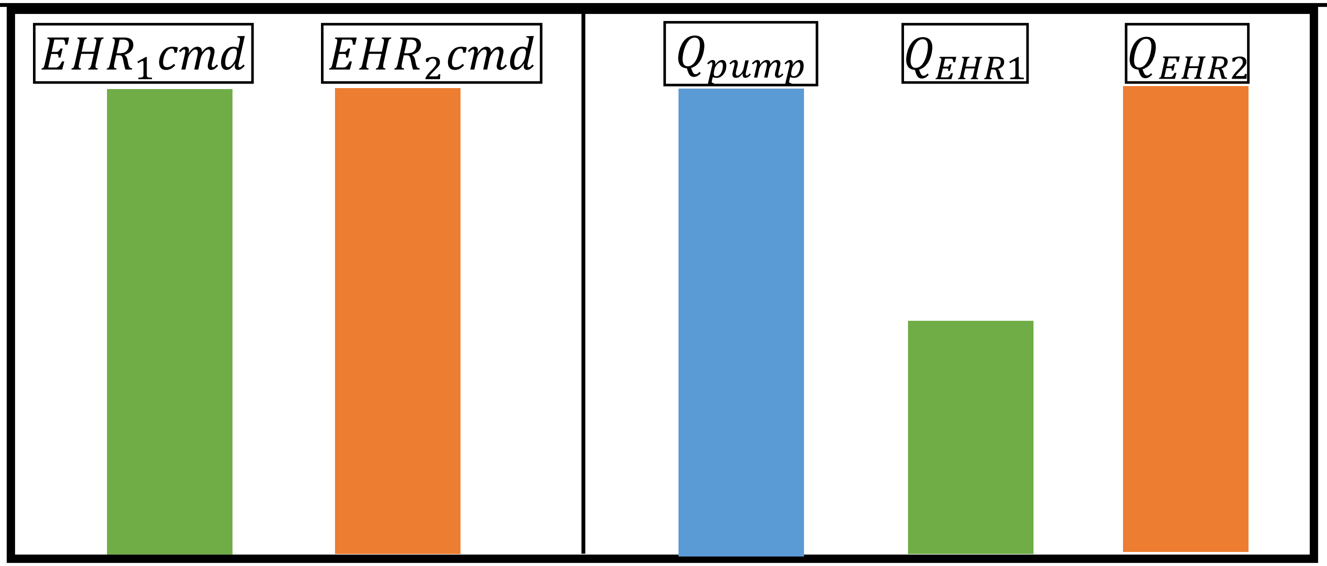


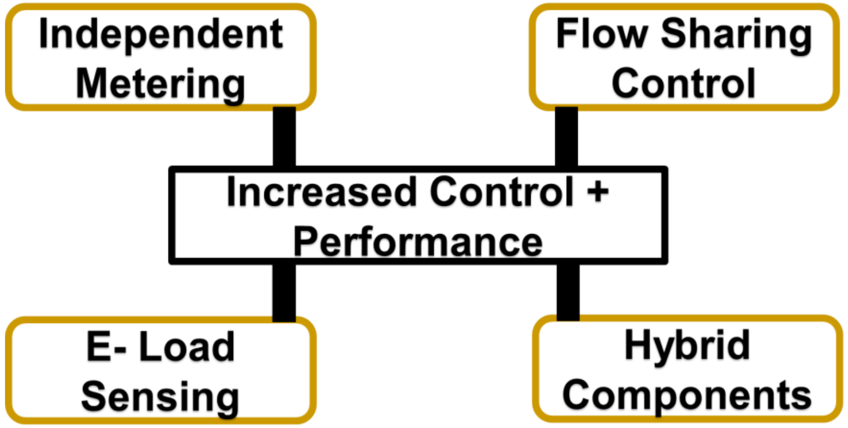
Power Distribution Comparison Between Different Loads for Dual Remotes Test

Full command, Retraction, High RPM, High oil temperature




Auxiliary hydraulic functions
Travelling service
Steering
Power beyond
Braking


$EHR_1 cmd$
$EHR_2 cmd$
Q_{pump}
Q_{EHR1}
Q_{EHR2}


Independent Metering
Flow Sharing Control
Increased Control + Performance
E- Load Sensing
Hybrid Components

Conclusion

Rationale &

&

Validation

Experimental

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on

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Improvements

Maha Fluid Power RESEARCH CENTER
PURDUE UNIVERSITY

Thank you
for your attention!

Xin Tian, Josias Cruz [Presenter]

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MAHA Fluid Power Research Center

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