Giuseppe Pellizzi Prize

METHODS TO REDUCE ENERGY CONSUMPTION IN THE HYDRAULIC SYSTEM TOWARD THE NEXT GENERATION OF GREEN, HIGH-EFFICIENT AGRICULTURAL TRACTORS

Dissertation presented to Purdue University, West Lafayette, Indiana, USA

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1 Introduction

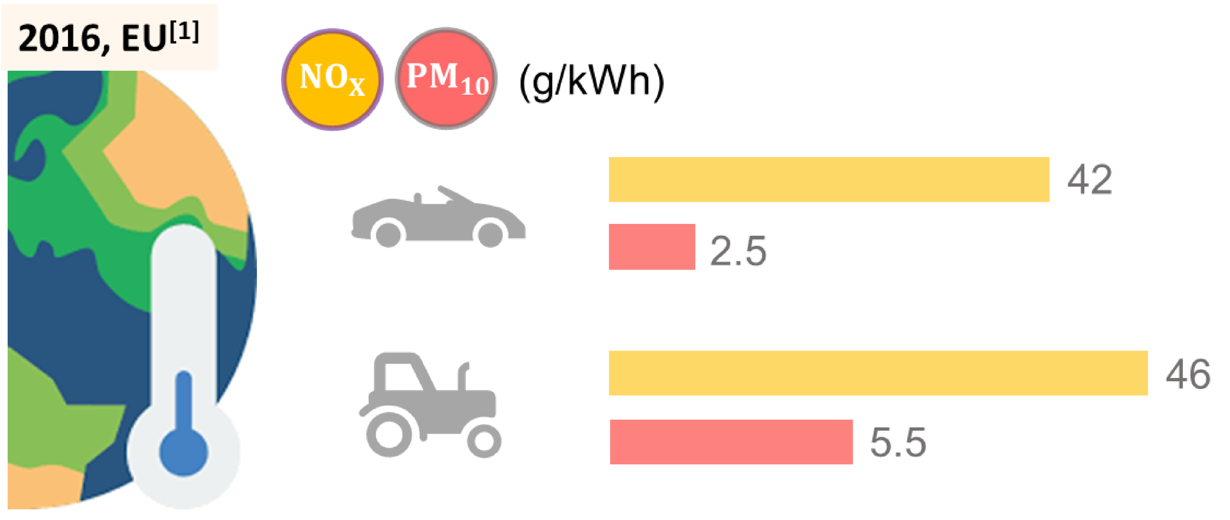
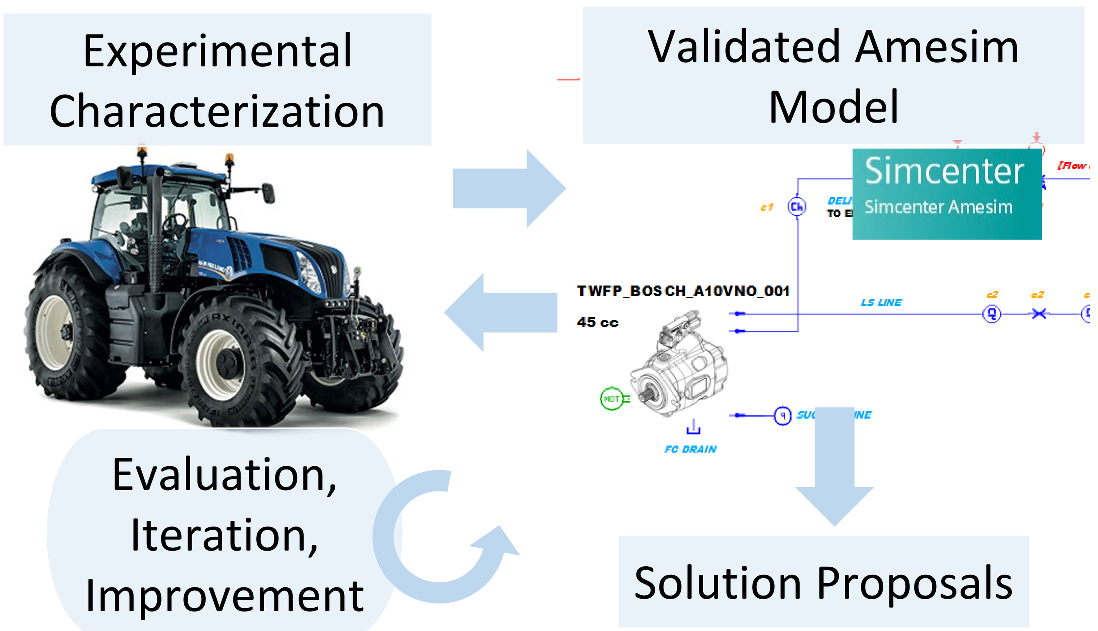


Fig. 1 Emission Comparison: On-Road vs. Off-Road Vehicles

Main Objective: To propose and experimentally demonstrate strategic solutions, and to provide insights of partial electrification potential on the auxiliary tractor hydraulic circuit to reduce fuel consumption and possibly lower the manufacturing cost for the next generation of green, high-efficient agricultural tractors.

Approach: Combined analytical, numerical analysis and experimentation



2 Modeling and Validation

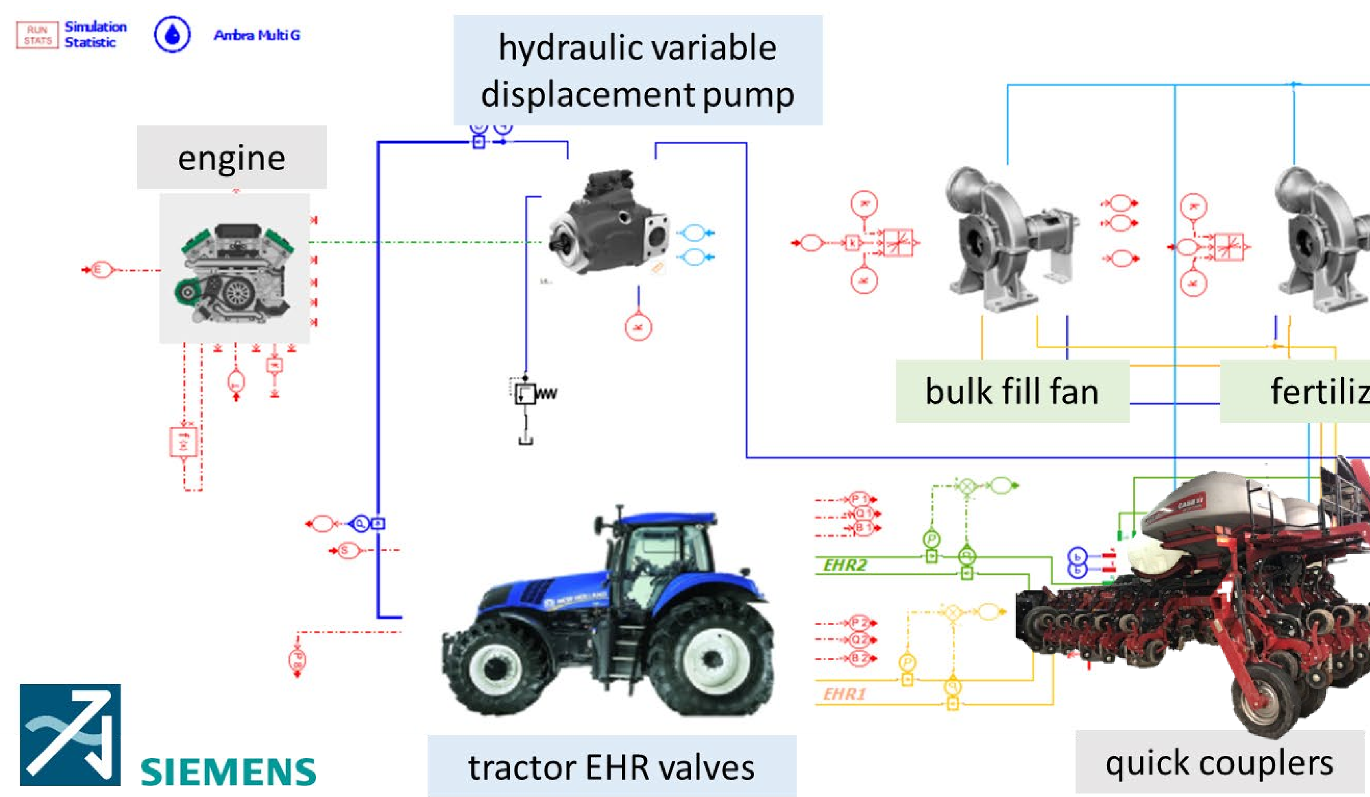


Fig. 2 Reference System High-fidelity Model

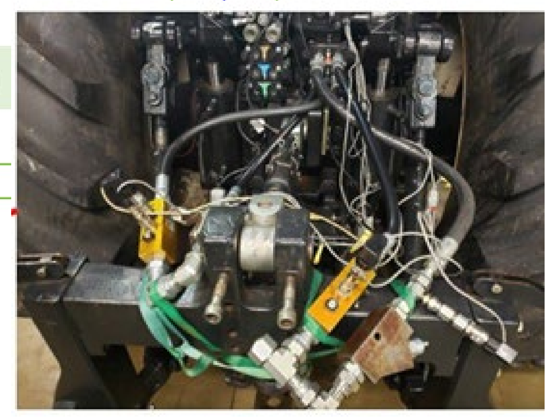


Fig. 3 Tractor Rear Remote Valve Sensor Setup

- **Reference machines** being the most common size vehicles in Midwest US market :
  CNH (CCH) T.8.390 New Holland tractor
  Case IH Early Riser 2150 16 Row planter
- **Model Development:** A high-fidelity model inclusive of engine – hydraulic control system developed following a lumped-parameter approach for both vehicles.
- **Model Validation:** The model has been validated against in-lab stationary tests with over 95% average accuracy under different operating conditions.
- **Power Flow Analysis**: With the validated model, the detailed system power loss distribution shows that the remote control valves are responsible for up to 25% of power loss in the system. This points the direction of new solutions to be proposed.

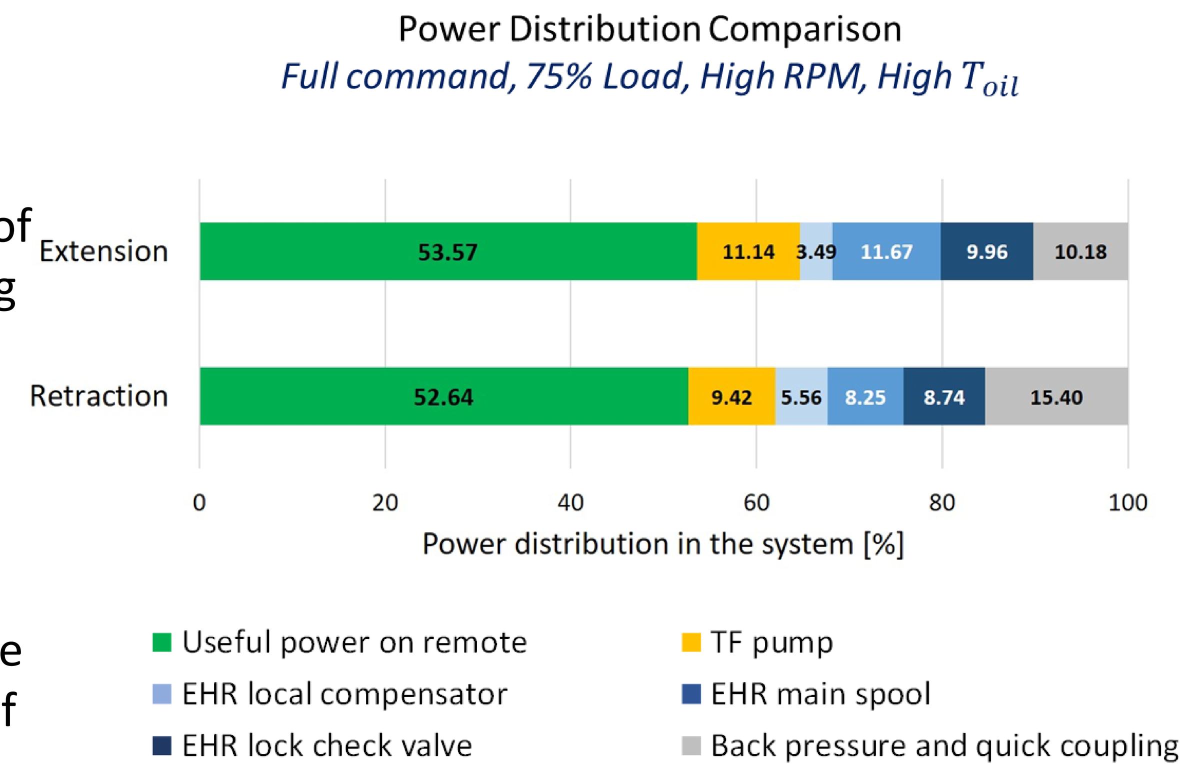


Fig. 4 Tractor Supply Power Distribution

3 Proposed Solutions

- The work proposed 7 solutions including:
  - **2 tractor solutions** (reduce power loss when tractor is operating alone)
  - **3 tractor-planter solutions** (when tractor is connected to implements)
  - **2 electrification solutions** (electrified rotary/linear functions & e-pump supply)
- Two most commercially valuable solutions are provided here.

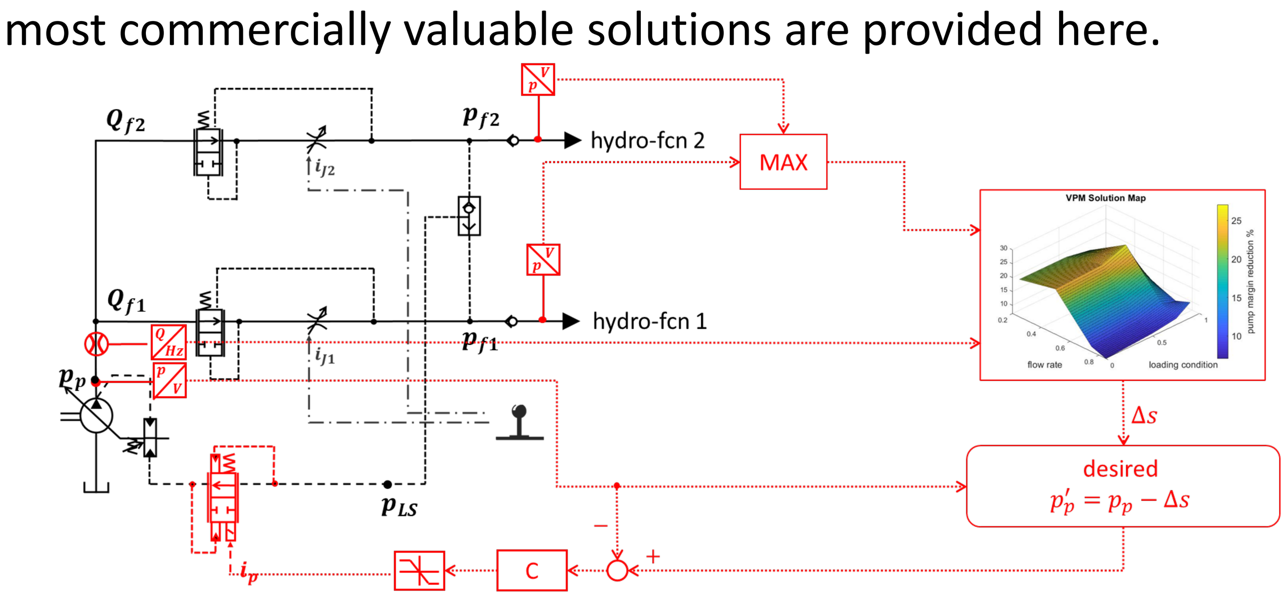


Fig. 5 Tractor Solution: Variable Pump Margin (VPM)

- **VPM Highlight:** uses an electro-hydraulic pressure reduction valve to lower the pump pressure margin to reduce system power supply.

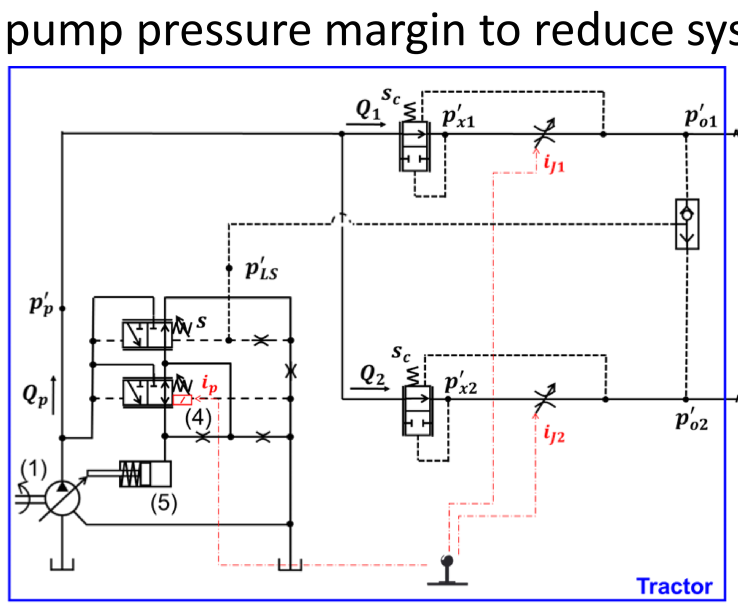


Fig. 6 Tractor-Planter Solution: Intelligent Pressure Saturation Control (IPSC)

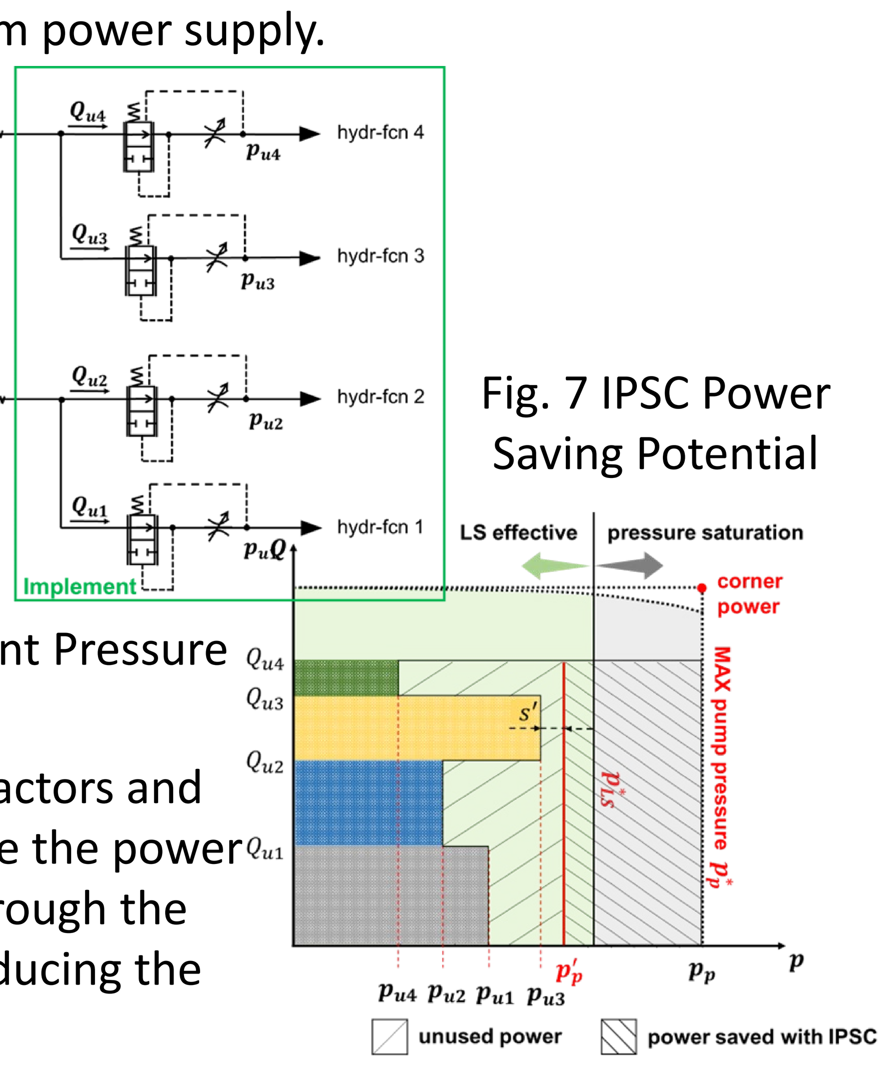


Fig. 7 IPSC Power Saving Potential

- **IPSC Highlight:** better integration of tractors and implements controls, effectively reduce the power loss introduced by the throttling oil through the second set of hydraulic valves, thus reducing the heating of the oil through the system.

4 Results

Fig. 8 Field Tests of the Solutions on the Purdue Farm

Take-aways:

- HVM stands out as the best in-tractor solutions hitting up to 15.6% power saving from both simulation and stationary in-lab tests.
- IPSC solutions serves as the highest saving for tractor-planter solution with minimum system configuration change and still can save up to 34% from the in-field test result.

Final Remarks: The solutions explored in this work have a wide range of adoption easiness for agricultural OEMs. From incorporating the use of electro-hydraulic components, to reconfigure the tractor-planter hydraulic circuit for ease of control and better fuel efficiency.

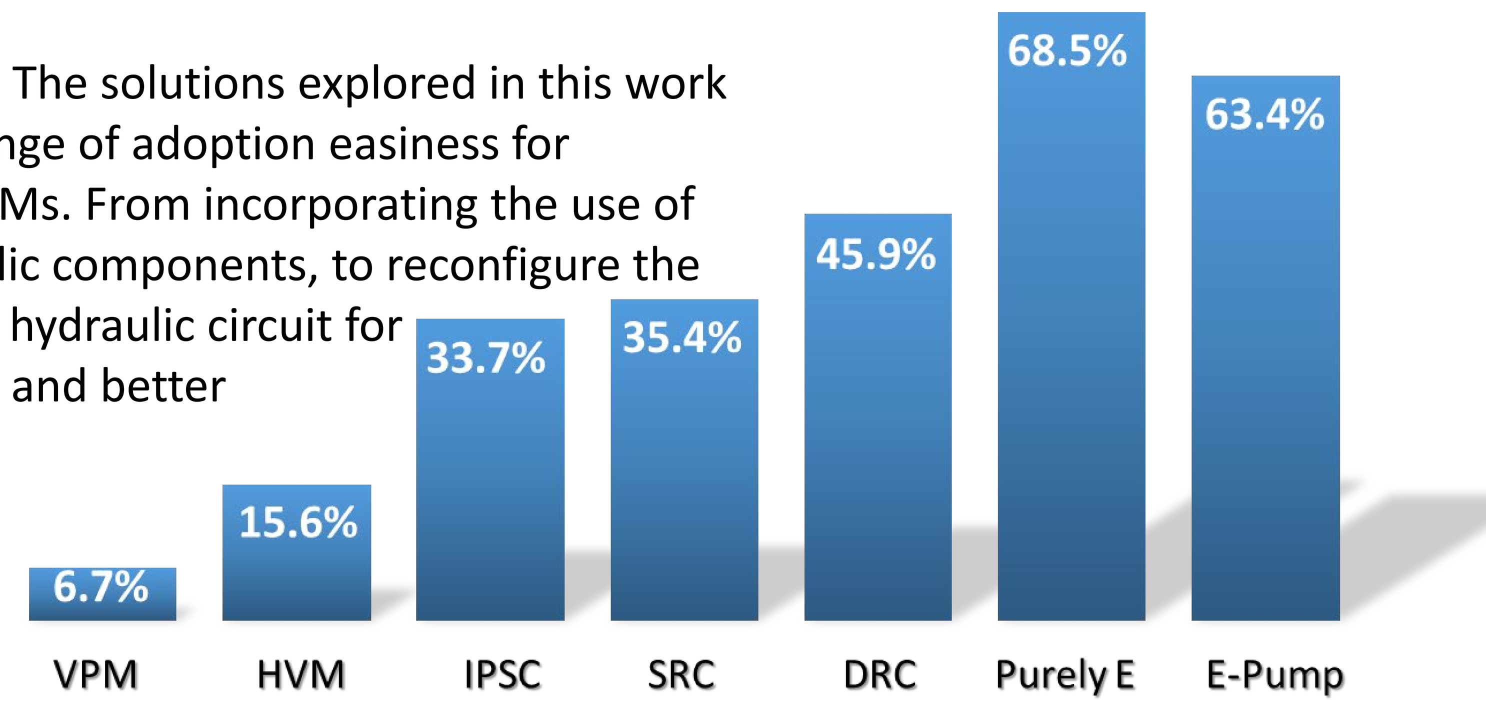


Fig. 9 Power Saving Introduced by All the Solutions Proposed

5 Awards and Publications

This PhD work has achieved

- 2 Best Paper Awards, one being Superior Paper Award recognized by American Society of Agricultural and Biological Engineers, the other GFPS Best Paper "Backe" Award recognized by Global Fluid Power Society.
- 3 journal publications, 5 conference proceedings and 4 granted US patents with one more to come.