PowerMix goes Rig
New Methodologies for Tractor Efficiency Optimization

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John Deere

1837: Blacksmith Shop - Self-Scoring Plough

- 70 Factories in 18 Countries - 57,000 Employees, Worldwide
- Agricultural equipment, Commercial & Consumer Equipment, Construction & Forestry and Credit

2016: John Deere world’s leading manufacturer of farm equipment.
Applications & Customer Requirements

- Power
- Reliability

→ PTO Work

→ Transport Work

→ Front Loader Work

→ Draw Bar Work

→ Comfort
→ Efficiency
6M & 6R Systems

- Engine
- Engine Auxiliaries
- Front Hitch
- Front PTO
- Transmission & Driveline
- Wheels
- Rear Hitch
- Rear PTO
- Hydraulics
- Drive Strategy
DLG PowerMix: Overview

DLG = Deutsche Landwirtschafts - Gesellschaft
(German Agricultural Society)

- Official “practical tractor test” to compare fuel efficiency
- Replication of Field Applications (1\textsuperscript{st} part):
  - Based on real field measurements
  - 12 load cycles, part and full load cycles
  - Tractor is loaded dynamically (Drawbar, PTO, Hydraulics)
- Transporttest (2\textsuperscript{nd} part)
  - Road measurement with trailer
DLG PowerMix: 12 Field Cycles

Ploughing (2 cycles)
Cultivating (2 cycles)
Rotary Harrow (3 cycles)
Mowing (3 cycles)
Manure Spreading (1 cycle)
Baling (1 cycle)
DLG PowerMix: Field Cycles

Unscaled dynamic load cycle (Manure Spreading)

- Total Load
- Drawbar Load
- PTO Load
- Hydraulic Load

relative Power [kW / kW(PTO)] vs Time [sec]
DLG PowerMix: LoadCar for Field Cycles

400 m oval concrete track  Wheel brakes  Hydraulic load (SCV)  PTO load unit
DLG PowerMix: Transport

- Hilly road
- 6 part runs (only uphill) + flat run
- Trailer weight depends on max PTO power
Powertrain-in-the-Loop
Motivation for DLG PowerMix Replication

The DLG PowerMix

... is a representative test method but ...
... it requires fully functional prototype at DLG
... test results are influenced by outer conditions

→ Goal: Replication of DLG PowerMix on test rig
  • Predict DLG PowerMix results early in development program
  • High level of repeatability
Test Bed Configuration

• 4 Wheel dynos + PTO dyno
• Hydraulic load unit
• Air conditioning
Test Bed Configuration

Test Rig

Fuel Exact

Consumption measurement

Puma Open

Speed Torque Request

CAN

AVL In Motion

Visualization

3D Road

Vehicle Model

IPG Truck Maker

Test Control

3D Road – Tire Contact

Maneuver Steps

Vehicle Model

Driver Model

Gas Brake Shift Request
Vehicle & Implement Models

PowerMix Field & PowerMix Transport

Vehicle Model
- Multi-Body-System
- Kinematics
- Tires
- Aerodynamics

DLG LoadCar
- Includes load cycles (desired values)
- Vehicle speed sensor for evaluation
- Kinematics (steering system)

DLG Trailer
- Multi-Body-System
- Tires
- Hitch
Road Simulation

DLG Test Track & Road Profile „Odenwald“

Road Measurement

Test Configuration

Online Visualization
Automation & Visualization
Test Results: PowerMix Field

Z3K (full load, rotary harrow)

Good correlation for PTO Power

Comparable vehicle behavior
Test Results: PowerMix Transport

Uphill, part run #5

Comparable vehicle behavior
→ shifting points
Conclusion

- Powertrain-in-the-Loop test method provides powerful tool to replicate DLG PowerMix
- The test results show good correlation between DLG and Mannheim test rig
- Applicable in early development phase
- Reproducible test results (lab conditions, high level of automation)