“Vehicle in the Loop” Test Methodology for Tractor Efficiency Optimization

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John Deere History

1837: Blacksmith Shop - Self-Scoring Plow

John Deere

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.
Agriculture Equipment

Global Operating Model

- 5 Global External Platforms
- A platform consists of a portfolio of “like” product lines

Crop Harvesting
- Combines
- Front-End Equipment
- Cane
- Cotton

Turf and Utility
- Utility Vehicles
- Riding Lawn Equipment
- Commercial Mowing
- Golf
- Walk-Behind Mowers

Hay and Forage
- Self-Propelled Forage Harvesters
- Heads
- Balers
- Mowing

Crop Care
- Seeding
- Tillage Application Equipment

Tractors
- Large
  - (8R, 9R)
- Mid
  - (6M, 6R, 7R)
- Utility
  - (5er Serie)
- Loader
6R Tractor Overview

**Transmissions:**
- Power Shift
- Infinity Variable
- Dual Clutch

**Tires:**
- RA: 650 / 85 R38
- FA: 600 / 70R28

**Hitches & PTOs:**
- Front Hitch & Front PTO
- Rear Hitch & Rear PTO

**System:**
- Power Tech Engine
- Cooling System

**Cab:**
- Comfort View Cab
Agricultural Application Areas

- PTO Work
- Transport Work
- Front Loader Work
- Draw Bar Work
DLG PowerMix Test Overview

DLG:

- Deutsche Landwirtschafts-Gesellschaft (German Agricultural Society)
- Independent organization with focus on agricultural and food testing

Basis of Test:

- 13 cycles representing work performed by a tractor
- Tractor is loaded dynamically by drawbar, PTO and hydraulics
- Allows comparison of fuel consumption between different tractors

Cycle Development:

- Field measurements carried out by DLG
- Supplemented with field data from manufacturers and different universities.
DLG PowerMix Test Overview

- Ploughing (Z1P,Z2P)
- Cultivating (Z1G, Z2G)
- Rotary Harrow (Z3K,Z4K, Z5K)
- Mowing (Z3M, Z4M,Z5M)
- Manure Spreading (Z6MS)
- Baling (Z7PR)
DLG PowerMix Test Overview

Dynamic Load Profile (unscaled) - Manure Spreading Test Cycle
DLG PowerMix Test Overview

DLG test track and load truck in Groß-Umstadt

Tractor rear end and load truck attachment

400m Oval Concrete Track

Hydraulic Load (SCV)

PTO Load Unit
Motivation for DLG PowerMix Replication

- **Today’s Tractor Development Programs:**
  - Clear focus on fuel economy (Market)
  - Significant changes in powertrain area (Emissions)

- **DLG PowerMix**
  - is a representative test method but ...
  - ...requires fully functional prototype at DLG

**Gap:** Design already frozen, changes are difficult to implement!

**Solution:** PowerMix Replication

Predict DLG PowerMix results **early in development program** (or even concept selection) with **high level of repeatability** (identify small differences)
Test Bed Configuration

Test Rig

Fuel Exact

Consumption measurement

Puma Open

Speed Torque Request

InMotion

Visualization

Test Bed Interface

3D Road

Road – Tire Contact

Vehicle Model

Axle Torque Speed

Driver Model

Gas Brake Shift Request

Truck Maker

Test Control

Maneuver Steps
Test Bed Configuration

Front and Rear Axle drive

Rear PTO drive

Hydraulic Load
Vehicle Modeling

Vehicle structure:

- Multi body system (Vehicle Body, Cab Body, wheels,...)
- Data for the vehicle parametrization
Road Simulation

DLG Test Track & Road Profile „Odenwald“

Road Measurement

Test Configuration

Online Visualization

Video Data

GPS Data

Google Earth

IPG Movie
Implement Model I: DLG Load Car

- Load Profile
- PT2 Function
- PID Control
- Drawbar Force
- Brake Torque
- PTO Torque, Hydraulics Power

Unscaled Load Profile
PowerMix Field
Test Results: PowerMix Field

Cycle Z3P – Rotary Harrow
(Heavy PTO Work)

- Accurate replication of DLG test results

<table>
<thead>
<tr>
<th>Engine Speed [pm]</th>
<th>Vehicle Speed [km/h]</th>
<th>PTO Power [kW]</th>
<th>Engine Speed [rpm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>: DLG Results (1Hz)</td>
<td>: Test Rig Results (50Hz)</td>
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</table>
Test Results: PowerMix Field (6215R DD)

- Initial results integrated over cycle show less than 1% deviation from DLG test result
Implement Model II: DLG Trailer

- 3 Axle Drawbar
- Variable Loads

Modular structure
- Multi-body-system
- Brake System
- Tires
- Hitch
- Aerodynamics
- Sensors
Power Mix Transport
Test Results: PowerMix Transport

Odenwald Road : Hill Track #5

Full load acceleration on hilly road

- DLG Results
- Test Rig Results

Vehicle Speed [km/h]

Draw Bar Force [N]

Engine Speed [rpm]
Test Results: Power Mix Transport (6215R DD)

Delta BSFC (Hill Tracks): ~3.0 %
Summary & Conclusion

- Vehicle in the Loop test methodology provides powerful tool to replicate DLG PowerMix
- The test results are showing good correlation between DLG PowerMix and Mannheim LabPowerMix Test
- Several influencing factors (ambient temp, steering, wheel/road interaction) eliminated or reduced
- High level of automation improve repeatability
- Applicable at an early prototype stage or even concept selection