DLG-PowerMix

Performance measurement and energy efficiency under practical relevant and repeatable conditions

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DLG-PowerMix

Basics – performance tests according OECD Code 2

• Static measurement of the tractor performance:
  • pto power
  • drawbar power
  • hydraulic performance

• In this stage the following criteria were not considered:
  • interactions respectively feedbacks
  • behaviour during shift sequences
  • relation to practice (e.g. inhomogeneous soil)
Power Take-Off (PTO) Power measurement in a engine speed range from high idle down to 900 rpm

Measurement of

- torque and power output
- fuel consumption hourly and specific
- Reagent consumption hourly and specific

tractors not only in use under full load conditions
Basic ideas of DLG-PowerMix

• Variable load profiles simulating field work operations
• Simulation of full load and part load conditions
• Simultaneous and variable load on all three possible power ports (power take-off, driveline, hydraulic selective control valve); therefore interaction
• better repeatability compared with tests at the field
• results in g/kWh, to get a comparison of energy efficiency over all engine power classes
DLG-PowerMix cycles field operations – origin

raw data
DLG-PowerMix cycles field operations – origin
DLG-PowerMix cycles field operations – origin

- Drawbar load
- Power take-off load
- Hydraulic load
Process of DLG-PowerMix Test – scaling (100 kW)

Drawbar power (Z1G – cultivator 100% load)
Process of DLG-PowerMix Test – scaling (200 kW)

Drawbar power (Z1G – cultivator 100% load)
# DLG-PowerMix

## DLG-PowerMix cycles field operations – full load and part load cycles

<table>
<thead>
<tr>
<th>Load type</th>
<th>Name of cycle</th>
<th>Driving speed [km/h]</th>
<th>pto speed [min-1]</th>
<th>acceptance criteria for each cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drawbar work</strong></td>
<td>ploughing 100%</td>
<td>Z1P</td>
<td>9</td>
<td>- ave. decrease of driving speed &lt; 2,5 km/h exception: tractor is not able to spend more power; e.g. Z1G</td>
</tr>
<tr>
<td></td>
<td>ploughing 60%</td>
<td>Z2P</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cultivator 100%</td>
<td>Z1G</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cultivator 60%</td>
<td>Z2G</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Drawbar work + pto work</strong></td>
<td>power harrow 100%</td>
<td>Z3K</td>
<td>6</td>
<td>ave. Decrease of pto speed &lt; 7,5% and of driving speed &lt; 2,5 km/h</td>
</tr>
<tr>
<td></td>
<td>power harrow 70%</td>
<td>Z4K</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>power harrow 40%</td>
<td>Z5K</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mowing 100%</td>
<td>Z3M</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mowing 70%</td>
<td>Z4M</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mowing 40%</td>
<td>Z5M</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td><strong>Drawbar + pto + hydraulic work</strong></td>
<td>manure spreading</td>
<td>Z6MS</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>balling</td>
<td>Z7PR</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

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*Note: DLG-PowerMix is a brand of farm machinery.*

*Image credit: DLG*
Basics of DLG-PowerMix Test – transport cycle
dynamic measurement of hill sections 1 - 6

- total length: 36 km
- altitude: 150-370 m
- rise from 2% to 12%
Process of DLG-PowerMix Test – receiving inspection

Measurement of
- Exhaust emission check
- Full load performance curve including nominal pto speed
- Part load points
- Full load- and part load curve also in boost mode (if available)

For scaling the PowerMix cycles (adapting the right implement) we need the maximum available power of the tractor.
DLG PowerMix Chassis Dynamometer - The field on a test bench

With support from

Federal Ministry of Food and Agriculture

by decision of the German Bundestag
DLG-PowerMix

DLG PowerMix Chassis Dynamometer - The field on a test bench
**DLG-PowerMix**

**DLG PowerMix Chassis Dynamometer**

### Vehicle
- **Wheelbase**: 2005 mm to 6000 mm
- **Width**: 1500 mm to 3900 mm
- **Weight**: 60 t gross weight or 15 t / wheel

### Climate control
- **Temperature range**: 15 – 45 °C
- **Standard temp.**: 25 °C
- **Flow rate**: 100000 m³/h
- **Wind speed**: 10 or 20 km/h

### Measurement equipment
- Fuel and reagent consumption
- Gaseous exhaust emission

### Power take-off Dynamometer
- **Speed range**: ± 1400 rpm
- **Power**: 700 kW
- **Torque**: 0 to 7000 Nm

### Hydraulic Dynamometer
- **Power**: 0 to 150 kW
- **Flow rate**: 0 to 500 l/min

### Chassis Dynamometer
- **Speed range**: ± 105 km/h
- **Power**: 700 kW (gross or per axle)
- **Traction force**: 90 kN / roll (max. 135 kN)
### DLG PowerMix Chassis Dynamometer

<table>
<thead>
<tr>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power unit</strong></td>
<td>Direct drive (without transmission)</td>
</tr>
<tr>
<td><strong>Speed range</strong></td>
<td>± 105 km/h</td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>700 kW (gross or per axle)</td>
</tr>
<tr>
<td><strong>Traction force</strong></td>
<td>90 kN / roll (max. 135 kN)</td>
</tr>
<tr>
<td></td>
<td>Max. force at 0 km/h possible</td>
</tr>
<tr>
<td><strong>Draw-down forces</strong></td>
<td>Up to 100 kN per axle</td>
</tr>
<tr>
<td><strong>Tandem axle possible</strong></td>
<td></td>
</tr>
</tbody>
</table>
Climate control

Temperature range: 10 – 45 °C
Standard temp.: 25 °C
Flow rate: 100000 m³/h
Wind speed: 10 or 20 km/h
Repeatability
Z7PR (Balling) load profile

- Drawbar load
- Power take-off load
- Hydraulic load
Z7PR (Balling) measured five times in a row
Z7PR (Balling) measured five times in a row
Z7PR (Balling) measured five times in a row

Hydraulic power [kW]

Time in s
Z7PR (Balling) measured five times in a row

Average spec. fuel consumption = 321.04 ± 0.3 g/kWh
### DLG-PowerMix

**Z7PR (Balling) measured five times in a row**

<table>
<thead>
<tr>
<th>Measurand</th>
<th>Measuring unit</th>
<th>Mean value</th>
<th>Standard deviation</th>
<th>Percentage deviation from the mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawbar pull</td>
<td>kN</td>
<td>7.66</td>
<td>± 0.011</td>
<td>0.146</td>
</tr>
<tr>
<td>Driving speed</td>
<td>km/h</td>
<td>8.48</td>
<td>± 0.023</td>
<td>0.267</td>
</tr>
<tr>
<td>Power at the drawbar</td>
<td>kW</td>
<td>18.57</td>
<td>± 0.072</td>
<td>0.390</td>
</tr>
<tr>
<td>Engine speed</td>
<td>1/min</td>
<td>1964.30</td>
<td>± 0.671</td>
<td>0.034</td>
</tr>
<tr>
<td>Power Take-Off power</td>
<td>kW</td>
<td>40.10</td>
<td>± 0.022</td>
<td>0.056</td>
</tr>
<tr>
<td>Hydraulic power</td>
<td>kW</td>
<td>11.51</td>
<td>± 0.004</td>
<td>0.034</td>
</tr>
<tr>
<td>Gross power</td>
<td>kW</td>
<td>70.17</td>
<td>± 0.075</td>
<td>0.107</td>
</tr>
<tr>
<td>Hourly mass fuel consumption</td>
<td>kg/h</td>
<td>22.53</td>
<td>± 0.007</td>
<td>0.029</td>
</tr>
<tr>
<td>Hourly volumetric fuel consumption</td>
<td>l/h</td>
<td>26.88</td>
<td>± 0.026</td>
<td>0.096</td>
</tr>
<tr>
<td>Specific fuel consumption</td>
<td>g/kWh</td>
<td>321.04</td>
<td>± 0.271</td>
<td>0.084</td>
</tr>
<tr>
<td>Hourly mass reagent consumption</td>
<td>kg/h</td>
<td>0.55</td>
<td>± 0.016</td>
<td>2.849</td>
</tr>
<tr>
<td>Specific reagent consumption</td>
<td>g/kWh</td>
<td>7.83</td>
<td>± 0.22</td>
<td>2.807</td>
</tr>
<tr>
<td>Relative reagent consumption</td>
<td>Mass %</td>
<td>2.37</td>
<td>± 0.082</td>
<td>3.479</td>
</tr>
</tbody>
</table>
Conclusion

- simulation of realistic field- and transport activities
- comparability across all engine power ranges
- Highly repeatable
- Interactions will be considered
- the real energy efficiency of the vehicle (fuel input and power output on the tyres, on the pto and on the hydraulic scv’s) will be determined
We measure 12 field cycles and 2 transport cycles for a DLG PowerMix test.

The total result are the average out of this 12 field cycles results plus the result of the transport test.

Not each tractor is a specialist for all kind of work, e.g. some are good for heavy drawbar work, others are specialists for transport work…

Since Stage 3B/Tier 4 interim, the DLG Test Center measures the fuel and reagent consumption during tests.

**Problem:**

It’s difficult to compare the consumable costs for a mobile machine equipped with SCR and one with DPF, due to the price per liter reagent is heavily dependent to the quantity you buy.
DLG-PowerMix

DLG PowerMix CALCULATOR - Example for settings and results

Settings:
• Focus on transport work (60 heavy, 40 % light)
• Fuel price 1 €/liter (with tax refund)
• Reagent (AdBlue) price 0.40 €/liter
• Engine power range between 300 and 400 PS
### DLG PowerMix CALCULATOR - Results due to previous settings

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Price per kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Deere 7310R e20</td>
<td>0.690 €/kWh</td>
</tr>
<tr>
<td>Fendt 939 Vario 54</td>
<td>0.716 €/kWh</td>
</tr>
<tr>
<td>Case IH OPTUM CVX 300</td>
<td>0.808 €/kWh</td>
</tr>
<tr>
<td>New Holland T7.316 AutoCommand</td>
<td>0.808 €/kWh</td>
</tr>
<tr>
<td>STEYR Terrus 6500 CVT</td>
<td>0.808 €/kWh</td>
</tr>
</tbody>
</table>

Ordered by the total price per €/kWh.
Why all this effort?
For that reason!

• Farmers want a neutral and practical relevant information about the energy efficiency of a tractor

• Regarding future regulation it isn’t useful to look only at the engine or at measurements in real life. The DLG PowerMix could be an alternative to infield emission measurements or to a further engine related emission regulation.

The DLG PowerMix is the world wide unique test procedure to measure the energy efficiency of a tractor under repeatable dynamic load conditions which are related as close as possible to real field conditions.
DLG-PowerMix

Test Center Technology and Farm Inputs

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