New Architecture Development & Market Barriers, New Technology Development, Hybridization, Market Barriers, etc.

INDUSTRY PERSEPECTIVE
INDUSTRY PERSPCETIVE

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Engineering Director, Case New Holland
CNH Industrial Strategy and Fluid Power Needs

Gary Kassen, Engineering Director – Hydraulics/Pneumatics

Golden, CO
September 12, 2017

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CNH Industrial – 2016 Sales $23.7 B

-55% Off-Highway

Trucks
Buses and Coaches
Firefighting Equipment
Civil Protection and Defense Vehicles
Skid Steer Loaders
Crawler Excavators
Engines and Transmissions
Tractors
Combines
CNH INDUSTRIAL: A FIVE-TIME LEADER IN DOW JONES SUSTAINABILITY INDICES

<table>
<thead>
<tr>
<th>Year</th>
<th>CNH Industrial Score</th>
<th>Industry Average Score</th>
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</thead>
<tbody>
<tr>
<td>2011</td>
<td>81</td>
<td>49</td>
</tr>
<tr>
<td>2012</td>
<td>85</td>
<td>51</td>
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<td>2013</td>
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<td>2014</td>
<td>87</td>
<td>50</td>
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<tr>
<td>2015</td>
<td>91</td>
<td>52</td>
</tr>
<tr>
<td>2016</td>
<td>90</td>
<td>52</td>
</tr>
</tbody>
</table>
Megatrends & Related Material Topics

Material Topics relevant to Fluid Power

Source: CNH Industrial Sustainability Report, 2016
Innovation to Zero

- Defects - less warranty/service
- Leaks – No one quality problem with hydraulics
- Waste – Hydraulic oils (longer service life)
- Environmental Impact - Economical environmentally friendly fluids
CO2 & Other Air Emissions

- CO2 (Efficiency)
  - Limit or reduce system losses
  - Variable displacement pumps for cooling & lubrication circuits - provide flow on demand to these circuits
  - Lower engine speeds during roading or lower power operation (use larger displacements to maintain productivity)
  - Independent metering to reduce throttling losses.
  - Flatter oil viscosity curves

- Other Emissions
  - CNG
  - LP
  - Hydrogen

Fluid Power Challenge: Reduce space and higher efficiency to reach equivalent operating time
Methane Power Tractor

PERFORMANCE - TIER 4A T6.175 VS T6 METHANE POWER

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>T6.175 TIER 4A</th>
<th>T6 METHANE POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAX POWER (kW)</td>
<td>129 @ 1800 RPM</td>
<td>132 @ 1800 RPM</td>
</tr>
<tr>
<td>MAX TORQUE (Nm)</td>
<td>726 @ 1500 RPM</td>
<td>740 @ 1500 RPM</td>
</tr>
</tbody>
</table>

Methane Tractor debut at 2017 Farm Progress Show

06 September 2017
Methane Advantages

- \( CO_2 \) [g/kWh]: Cursor 9 diesel vs. Cursor 9 NG, -14%
- PM [mg/kWh]: Euro VI limits vs. Cursor 9 diesel vs. Cursor 9 NG, -99%
- \( NO_x \) [g/kWh]: Euro VI limits vs. Cursor 9 diesel vs. Cursor 9 NG, -31%

Natural gas (fossil) CO\(_2\) -14%
Bio-methane CO\(_2\) -100%
ATS solution is simpler for CNG/LPG engines compared to diesel not requiring any SCR with related components (DEF tank, pipes and dosing module), resulting in ~90% smaller volume (ref. Tier4B).

Key Challenge is the extremely high exhaust gas temperatures of gas engines when compared with current diesel technology – 750/800 °C Vs. 550 °C.
Total Cost of Ownership – Commercial filling station

Methane

Fuel Price

-20 / 25%

From 1.2 to 1.4 €/kg

From 0.9 to 1.1 €/kg

+7%

Energy Value (Mj per kg)

44

48

-17%

Engine efficiency

100

83

Fuel cost (€/hrs) – Contractors operators (VAT excluded)

-15 / 20%

24

20

Fuel Consumption: Diesel: 27L/hrs - Methane: 25 kg/hrs
Engine Efficiency: Diesel: 45% - Methane: 37.5 (average field data)
Reference Yearly Usage: 1500 hrs/year
Pump Price: average price across IT/FR/UK/DE/ES/PO/NL

Not considering urea usage (2% saving) and the elimination of potential fuel theft, the Methane tractor could achieve more than €5500 per year savings compared to a diesel powered tractor.
Total Cost of Ownership – Energy Independent Farm Methane

Not considering urea usage (2% saving) and the elimination of potential fuel theft, the Methane tractor could achieve more than €13,000 per year savings compared to a diesel powered tractor.
New Holland T6 LP Powered Tractor

Similar Benefits to Methane

- Reduced operating cost 20%-40%
- Less daily maintenance
- No fuel leak soil contamination
- Significant reduction in in-cab and drive-by noise
- 80+ percent reduction in smog-producing hydrocarbon emissions compared with Tier IV diesel
- 90% space reduction for after treatment volume

Additional Benefits to LP

- Low pressure fuel tanks
- Wide availability in the US – 70% comes from domestic natural gas
Hydrogen Fuel Cell – New Holland T6

- Splits hydrogen gas (H2) molecule to produce electricity
- Zero emissions
- Lower noise
- High efficiency (150% of diesel)
- Fuel cells are currently expensive but cost could drop dramatically if widely used in automotive
- Limited distribution infrastructure (H2) but could be produced locally on farms
- Requires tanks for pressurized hydrogen fuel (790 bar currently being used in automotive)
Autonomous Vehicles

CNH interpretation of the SAE levels of autonomy

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Level 4</th>
<th>Level 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidance</td>
<td>Coordination &amp; Optimization</td>
<td>Operator Assisted Autonomy</td>
<td>Supervised Autonomy</td>
<td>Full Autonomy</td>
</tr>
<tr>
<td>*All manned vehicles</td>
<td>*All manned vehicles</td>
<td>*Manned back-up</td>
<td>*In-field supervision of unmanned vehicles</td>
<td>*No local supervision (remote supervision or artificial intelligence)</td>
</tr>
</tbody>
</table>

Available Today — In Development
E-Braking Requirements

Autonomous Vehicles

- Traction Control
- Hill holding / hill start aid
- Brake steering
- Trailer braking (hydraulic and pneumatic)
- ABS
- Auto braking (remote and autonomous - fail operational)
E-Steering Requirements

Autonomous Vehicles

- Steering wheel and joystick capable
- Remote/autonomous function: Fail Operational
### Fluid Power Challenges

**Summary**

<table>
<thead>
<tr>
<th>Driver</th>
<th>Fluid Power Need</th>
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</thead>
<tbody>
<tr>
<td>Innovation to Zero</td>
<td>Higher reliability</td>
</tr>
<tr>
<td></td>
<td>Few leaks</td>
</tr>
<tr>
<td></td>
<td>Longer oil life</td>
</tr>
<tr>
<td>CO2 &amp; Other Air Emissions</td>
<td>Higher efficiencies</td>
</tr>
<tr>
<td></td>
<td>Reduce parasitic losses</td>
</tr>
<tr>
<td></td>
<td>Alternate power sources</td>
</tr>
<tr>
<td>Autonomous Vehicles</td>
<td>Higher safety level</td>
</tr>
<tr>
<td></td>
<td>Full EH capability</td>
</tr>
</tbody>
</table>
Topic 1 – High Performance Hydraulic fluids

What are the potential system efficiency gains utilizing hydraulic fluids that far exceed specifications defined in current standards:

- ISO 11158 HV
- DIN 51524-3
- ASTM D6158 HVHP
High Performance Hydraulic fluids

In addition to performance criteria for ISO VG 46:

- Inherent Viscosity Index ≤ 130
- Dynamic viscosity @ -40°C ≥ 10,000 cP
- Shear ≥ 15% with 20hr KRL @ 60C per ISO 26422
- ASTM D943 ≤ 7000 hrs
- Anti-wear depletion ≤ 4000 hrs
Project Outcome

Deliverables at close of project:

- Further technical data (other than OEM) to demonstrate all fluids are NOT the same
- Standardized test methods for comparing efficiency gains at the component and machine level
- Promote development of higher performing fluids within fluid blend companies on a wider scale
• New Architecture Development
  o Fundamental research needs
  o Market barriers
    – Customer acceptance
    – Reliability
    – Durability

• New Technology Barriers
  o Engine efficiency
  o Multi-modal systems
  o Control strategies

• Hybridization
  o Power storage
  o Power density
  o New material
  o Engine efficiency