Performance you can rely on.

Power Transmission Fluids

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Agenda

01 | Transmission and market trends

02 | Hardware and fluid requirements

03 | Transmission fluid formulations

04 | The future - electrification
Transmission Trend Drivers

Fuel Economy & Emissions
- Development of CVT, DCT and Higher Gear Ratio spreads
- Improvement of friction clutch, pump, seal efficiencies
- Hybrid / Electrification
- Low viscosity fluids

Driving Performance
- Shift Quality: Noise Vibration Harshness (NVH)
- Comfort
- Safety: Fun-to-Drive
- Sporty / dynamic driving style

Size and Weight
- Smaller Transmissions: Less fluid
- Increased Torque Density
Types of Transmissions

**Manual Transmission (MT)**
Driver operated clutch and gear shifts. Can be automated using servos to disengage/engage the clutch and change gear automatically.

**Stepped Automatic Transmission (AT)**
Globally the most common automatic transmission. It uses planetary gear sets and a torque converter.

**Dual Clutch Transmission (DCT)**
Automatic transmissions that use manual gear box architecture with dual clutches and input shafts.

**Continuously Variable Transmission (CVT)**
Automatic transmission that uses variator pulleys with an unlimited number of gear ratios.

**Power Split (PS)**
Uses two e-motors to mimic the performance of a CVT.

**E-axle**
Transmission used by electric vehicles. Sometimes referred to as reduction transmissions as the gear set reduces the rpm from the e-motor to drive the wheels.
Global Transmission Production

Transmission Installations

- **E-Axle (Electric)**
  - Large production increase, market share remains low

- **Power Split (PS)**
  - Large hybrid production increase, market share remains low

- **Dual Clutch Transmission (DCT)**
  - Large production increase, market share increase

- **Continuously Variable Transmission (CVT)**
  - Large production increase, market share increase

- **Automated Manual Transmission (AMT)**
  - Some production increase, market share low and stable

- **Stepped Automatic Transmission (AT)**
  - Production stable, market share decline

- **Manual Transmission (MT)**
  - Market share declines, switch to automatic transmission

Source: IHS

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EMEA Transmission Production

Transmission Installations

- **E-Axle (Electric)**
  - Large production increase, market share to surpass CVT

- **Power Split (PS)**
  - Large hybrid production increase, market share remains low

- **Dual Clutch Transmission (DCT)**
  - Large production increase, large market share increase

- **Continuously Variable Transmission (CVT)**
  - Production and market share increase, but remain low

- **Automated Manual Transmission (AMT)**
  - Slight production increase, market share low and stable

- **Stepped Automatic Transmission (AT)**
  - Production stable, market share decline

- **Manual Transmission (MT)**
  - Market share declines, shift to automatic

**Source:** IHS
Transmission Fluid Requirement

Balance of friction properties with gear protection and material compatibility

- Aeration and Oxidation
  Smaller sump, fill for life

- Friction Properties
  Clutches, synchronisers, CVT belt/chain

- Transmission Durability
  Gear, bearing, pump, synchronisers

- Viscometrics
  Pump efficiency, drag and churning losses. Gear and bearing efficiency

- Materials Compatibility
  Copper, resin, plastic
AT Hardware and
ATF Performance Requirements
Stepped Automatic Transmission Hardware

Performance you can rely on.

Photo source: BMWBLOG.COM

Torque Convertor

Planetary Gear

Clutches
Stepped Automatic Transmission Hardware

Three Main Components
- Sun gear
- Planet gears (and carrier)
- Ring gear

Gear Ratios
- Any component can be used as the input, output or locked in place to allow multiple gear ratios from one planetary gear set.
Stepped Automatic Transmission Hardware

**Plate clutches** comprise alternating friction and steel plates and are used to lock sun and planetary gears.

**Band clutch** wraps around the outside of the ring gear and when engaged locks the ring gear in place.
Stepped Automatic Transmission Hardware

Torque Converter

Four Main Components
- Pump
- Turbine
- Stator
- Lock-up clutch

Stator enables torque multiplication. Lock-up clutches added in 1970s to improve fuel economy.
Stepped Automatic Transmissions
Advantages and disadvantages

Stepped Automatic

- Torque capacity
- Fuel efficiency in ≥6-speed applications
- Launch feel

- Fuel efficiency in applications ≤5-speeds
- Packaging size
Stepped Automatic Transmissions

Fluid requirements

**Wear Protection**
- Protect planetary gear sets and bearings

**Paper On Steel Friction**
- Friction control and durability for torque converter lock up clutch, plate and band clutches

**Shear Stability**
- Resist shearing from planetary gears and oil pump

**Oxidation**
- Resist high temperatures generated in the clutch packs and torque converter
- Fill for life

**All Other Conventional Transmission Fluid Properties**
- Hydraulic performance
- Antifoaming properties
- Transmission coolant
- Seal compatibility
- Non-corrosive
- Large operating range (-40 to 170°C)
Dual Clutch Transmissions (DCT)
**Dual Clutch Transmissions**

How they work

2 input shafts are connected to two different clutches

- Odd gears connected to one
- Even gears connected to other
Dual Clutch Transmission Applications
Wet and dry clutch systems

**Dry DCT Applications**
- Used in medium segment car market
- Simplicity
- Use only gear oil
- Higher efficiency
- Heat and friction losses
- Drivability
- Torque limitation

**Wet DCT Applications**
- Used in high torque demanding vehicles
- Higher torque capacity
- Improved friction, controllability and heat dissipation
- Faster shifts
- Challenging fluid environment that requires special DCT fluid
- Cost
Dual Clutch Transmissions
Advantages and disadvantages

Dual Clutch

- Torque capacity
- Fuel efficiency
- Shift feel
- Can use existing MT manufacturing sites

- Launch feel not as smooth as stepped AT
Dual Clutch Transmission Technology Trends
Wet and dry clutch systems

Performance Requirements

**Dry-DCT**
- Gear and bearing protection
- Friction and wear control for synchronisers
- Corrosion resistance
- Material compatibility
- Oxidation control

*MTF can typically meet dry-DCT needs*

Performance Requirements

**Wet-DCT**

Same as for Dry DCT, but adding / balancing:

**Paper On Steel Friction**
- Clutch friction control
- Anti-shudder durability

**Transmission coolant**
- Enhanced material compatibility
- Enhanced oxidation stability
  - Due to high temperatures generated from the dual clutches

*Wet-DCTs require a specialised fluid*
Continuously Variable Transmissions (CVT)
Continuously Variable Transmissions
Drive belts

**Push Belt**

Force transmitted by compressional forces between belt elements

- Driving Pulley
- Driven Pulley

**Chain**

Force transmitted by tension on chain links

- Driving Pulley
- Driven Pulley

Contact surface
Continuously Variable Transmissions

Advantages and disadvantages

Continuously Variable

Output pulley has opened up to give a smaller radius for the belt to travel around

Drive pulley has closed up to give a larger radius for the drive belt to travel around

- Comfort due to no shifting
- Fuel efficiency

- Torque capacity
- Cannot utilise existing stepped AT manufacturing sites
Continuously Variable Transmissions
Fluid requirements

**Steel On Steel Friction**
- Transfer torque between pulleys and drive belt
- Wear control

**Shear Stability**
- Resist shearing from belt contact and oil pump

**Oxidation Stability**
- CVTs run hot
- Fill for life

**Paper On Steel Friction**
- Starting clutch
- Torque converter lock up clutch
- Forward-reverse clutch

**All Other Conventional Transmission Fluid Properties**
- Gear and bearing protection
- Hydraulic performance
- Antifoaming properties
- Transmission coolant
- Seal compatibility
- Non-corrosive

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<table>
<thead>
<tr>
<th>OEM Requirements</th>
<th>CVTF</th>
<th>DCTF</th>
<th>ATF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel On Steel Friction</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td>Wear Protection</td>
<td>✓</td>
<td>✓</td>
<td>□/✓</td>
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<tr>
<td>Paper On Steel Friction</td>
<td>□/✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Oxidation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Air-release</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<tr>
<td>Gear Protection</td>
<td>□</td>
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<tr>
<td>Material Compatibility</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓: Major  □: Minor  ✗: Not Required
Shudder / Drive Feel
Clutch Friction Deterioration and Shudder

Self-Excited Driveline Vibration

- **Intermittent Shudder**
- **Continuous Shudder**
- **No Shudder**

Torque Measured at Wheel of Car (in lbs)

Time (sec)
Sh-h-h-udder Occurs!

Power transmission fluids must deliver specialised friction requirements.
Typical Transmission Additive Treat Levels

- **Base Oil** (Group I, II, III, IV) 76-92%
- **Red Dye**
- **Additive Package** 8-24%

**Additive Package**

- **Performance package** 5-10%
- **Seal Swell agent** 0-3%
- **Pour Point Depressant** 0-0.5%
- **Viscosity Modifier** 3-10%
Typical Transmission Additives

- **Dispersant**
  - Sludge & Varnish Control

- **Anti-oxidants**
  - Oxidation Control

- **Anti Wear**
  - Gear, bearing, Synchro, drive belt, pulley and pump wear control

- **Friction Modifiers**
  - Control clutch, synchro and drive belt friction

- **Corrosion Inhibitors**
  - Prevent corrosion of bearings and copper containing elements
Typical Transmission Additive Treat Levels

- **Base Oil (Group I,II,III,IV)** 76-92%
- **Red Dye**
- **Additive Package** 8-24%

**Additive Package**

- **Performance package** 5-10%
  - **Seal Swell agent** 0-3%
  - **Pour Point Depressant** 0-0.5%
  - **Viscosity Modifier** 3-10%

**PTF**
Typical Transmission Additives

- **Seal Swell**: Control swelling, hardness & tensile strength of elastomers
- **Pour Point Depressant**: Lowers temperature at which fluids start to gel
- **Viscosity Modifiers**: Reduce rate of change of viscosity with temperature
Electrification
# Vehicle Electrification Architectures

<table>
<thead>
<tr>
<th>Vehicle Electrification Architecture</th>
<th>ICE</th>
<th>Motor</th>
<th>FE %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stop/Start</strong></td>
<td>Propulsion</td>
<td>ICE Starting if Equipped</td>
<td>2-4</td>
</tr>
<tr>
<td>Micro Hybrid</td>
<td></td>
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<tr>
<td><strong>MHEV</strong></td>
<td>Propulsion</td>
<td>ICE Assist</td>
<td>8-11</td>
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<tr>
<td>Mild Hybrid</td>
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<tr>
<td><strong>HEV</strong></td>
<td>Propulsion</td>
<td>Propulsion</td>
<td>20-35</td>
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<tr>
<td>Full Hybrid</td>
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<tr>
<td><strong>PHEV</strong></td>
<td>Propulsion</td>
<td>Propulsion</td>
<td>50-60 Equivalent</td>
</tr>
<tr>
<td>Plug-In Hybrid</td>
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<td></td>
</tr>
<tr>
<td><strong>EREV</strong></td>
<td>Range Extension</td>
<td>Propulsion</td>
<td>60-70 Equivalent</td>
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<tr>
<td>Ext. Range Electric</td>
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<tr>
<td><strong>BEV</strong></td>
<td>None</td>
<td>Propulsion</td>
<td>70-80 Equivalent</td>
</tr>
<tr>
<td>Battery Electric</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Global Transmission – Electrification Split

Propulsion System Design

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel Cell</th>
<th>Electric</th>
<th>Hybrid-Full</th>
<th>Hybrid-Mild</th>
<th>ICE: Stop/Start</th>
<th>Internal Combustion Engine (ICE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td><strong>100%</strong></td>
<td><strong>90%</strong></td>
<td><strong>80%</strong></td>
<td><strong>70%</strong></td>
<td><strong>60%</strong></td>
<td><strong>50%</strong></td>
</tr>
<tr>
<td>2020</td>
<td><strong>90%</strong></td>
<td><strong>80%</strong></td>
<td><strong>70%</strong></td>
<td><strong>60%</strong></td>
<td><strong>50%</strong></td>
<td><strong>40%</strong></td>
</tr>
<tr>
<td>2025</td>
<td><strong>80%</strong></td>
<td><strong>70%</strong></td>
<td><strong>60%</strong></td>
<td><strong>50%</strong></td>
<td><strong>40%</strong></td>
<td><strong>30%</strong></td>
</tr>
</tbody>
</table>

- **Fuel Cell**: Market share very low
- **Electric**: Production increase, market share gain
- **Hybrid-Full**: Production increase, market share increase
- **Hybrid-Mild**: Large production increase, market share increases
- **ICE: Stop/Start**: Production stable, market share decline rolls to hybrid mild
- **Internal Combustion Engine (ICE)**: Market share declines, switch to ICE/stop-start
Most parallel hybrids in the market are P2 designs

- Allows electric only drive
- Gear ratios can be used to optimise efficiency
Power Split Design

- Combines the ICE with 2 e-motors via a power split device to power the car.

- The power split device enables the transmission to perform like a continuously variable transmission.

- The E-motors are able to boost the ICE output or charge the batteries depending on the driving mode.

- Driving modes
  - E-motor only is used for launch and low speed driving.
  - ICE output is boosted by the e-motors during acceleration.
  - ICE drives the vehicle and e-motors charge the battery during cruising.
  - ICE disconnected and e-motors charge the batteries during breaking.
Power Split Advantages and Disadvantages

- Fuel efficiency
- Comfort due to no shifting
- Electric only driving is possible

- Cost
- Requires new manufacturing setup

Performance you can rely on.
**E-Axle Design**

- High speed E-motor provides power to the wheels via a reduction gear set.

- Architectures:
  - Helical gear set with e-motor situated parallel to the axle.
  - Planetary gear set with the e-motor situated on the axle.
  - Single or multiple gear ratios:
    - Due to high torque at low RPM a single reduction gear ratio is possible
    - Multiple reduction gear steps can also be included to improve efficiency
      - Has to be balanced with Drag losses

- Uses:
  - Battery and extended range electric vehicles
  - Used in combination with a conventional drive train to provide hybridisation and 4-wheel drive
E-Axle Advantages and Disadvantages

**Off-Axis E-Axle**
- E-Motor
- Helical gear pair
- Axle

**On-Axis E-Axle**
- Axle
- Planetary gear set
- E-Motor

**Advantages**:
- Fuel efficiency
- Acceleration
- Fully electric vehicle
- Packing size

**Disadvantages**:
- Cost
- Requires new manufacturing setup

Performance you can rely on.
Transmission Fluid Requirement

- **Friction Properties**
  Clutches, synchronisers, CVT belt/chain

- **Transmission Durability**
  Gear, bearing, pump, synchronisers

- **Aeration and Oxidation**
  Smaller sump, fill for life

- **Viscometrics**
  Pump efficiency, drag and churning losses, Gear and bearing efficiency

- **Materials Compatibility**
  Copper, resin, plastic, insulating coating

- **Thermal Capacity**
  Cool the windings

- **Electrical Properties**
  Electrical, Insulator

**Balance of electrical properties with gear protection and material compatibility**
## Fluid Requirements Comparison

<table>
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<tr>
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<td>✖</td>
<td>✖</td>
</tr>
<tr>
<td>Wear Protection</td>
<td>✓</td>
<td>✓</td>
<td>✖</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Paper On Steel Friction</td>
<td>✖   / ✓</td>
<td>✓</td>
<td>✓</td>
<td>✖   / ✖</td>
<td>✖ / ✖</td>
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<td>✓</td>
<td>✖   / ✓</td>
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<tr>
<td>Electrical Properties</td>
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<td>✖   / ✓</td>
<td>✖   / ✓</td>
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</tr>
</tbody>
</table>

- ✓: Major
- ✖: Not Required
- ☐: Minor

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