Infineum

Power transmission fluids

Outline

1

Transmission and Market Trends

- Hardware overview
- Market overview and market drivers
- Driveline types by region

2

Automatic Transmissions – Stepped Planetary (AT)

- Hardware components and their impact on ATF
- Testing for ATF
- Service Fill specifications
- ATF formulations

3

Automatic Transmissions – Dual Clutch (DCT)

- Hardware components and their impact on DCTF
- DCTF formulations

4

Automatic Transmissions – Continuously Variable (CVT)

- Hardware components and their impact on CVTF
- CVTF formulations

5

Summary

What does a transmission do?

A transmission adapts the output of the internal combustion engine to the drive wheels.

Important element in the "feel" of driving for consumers

Power Transmission Fluids (PTF)

Describe fluids necessary for proper operation of automatic transmissions including: stepped automatic transmissions, dual clutch transmission, continuously variable transmission, etc.

Automatic Transmission Fluids (ATF)

Generally refer specifically to fluids for stepped automatic transmissions

Types of transmissions

Stepped Automatic Transmission (AT)
Most common automatic transmission that uses a planetary gear set and a torque converter

Continuously Variable Transmission (CVT)
Automatic transmissions that use variator pulleys with an unlimited number gear ratios

Dual Clutch Transmission (DCT)
Automatic transmissions that use manual gearbox architecture with dual clutches

Automated Manual Transmission (AMT)
Manual transmissions that use servos to engage clutch and change gears automatically

Dedicated Hybrid Transmission (DHT)
Combines stepped automatic transmission with electric motor (e.g. Toyota's Hybrid Synergy Drive)

Reduction Transmission (Electric)
Transmissions used by purely electric vehicles to increase torque output from electric motors (Nissan Leaf)

Manual Transmission (MT)

Automatic transmissions

Stepped Automatic

STEPPED AT PROs

+ Torque Capacity

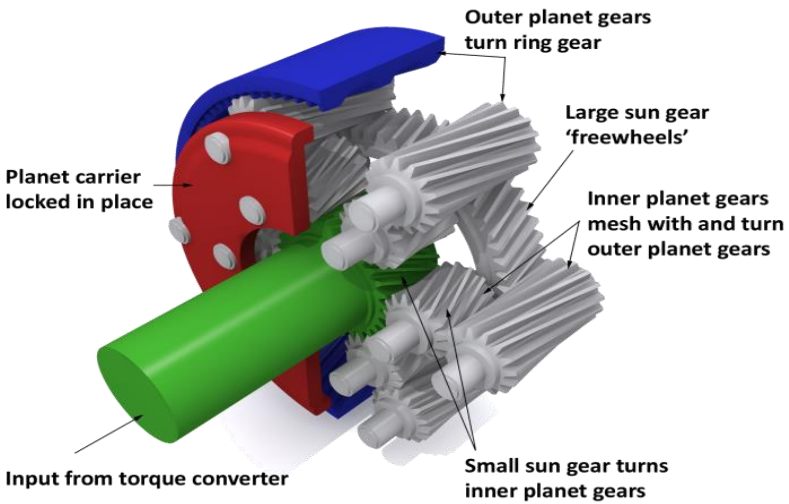
+ Fuel Efficiency in 6-speed + applications

+ Launch Feel

- Fuel Efficiency in applications with fewer than 5-speeds

- Packaging Size

STEPPED AT CONs



Dual Clutch

DCT Pros

+ Torque Capacity

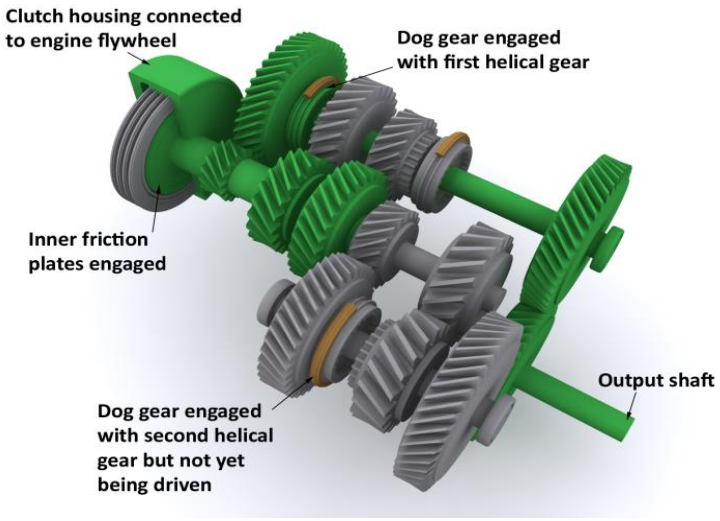
+ Fuel Efficiency

+ Shift Feel

+ Can use existing MT manufacturing sites

- Launch feel not as smooth as stepped AT

DCT Cons



Continuously Variable

CVT Pros

+ Comfort due to no shifting

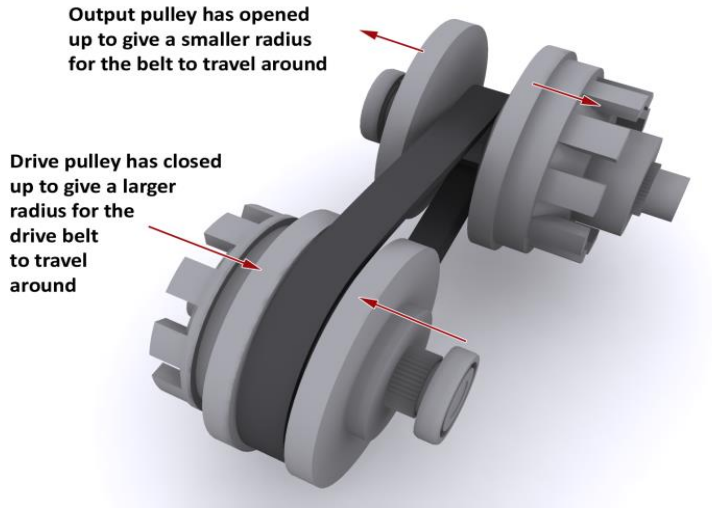
+ Acceleration

+ Fuel Efficiency

- Torque Capacity

- Cannot utilize existing stepped AT manufacturing sites

CVT Cons



Transmission trend drivers

Fuel Economy And Emissions

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

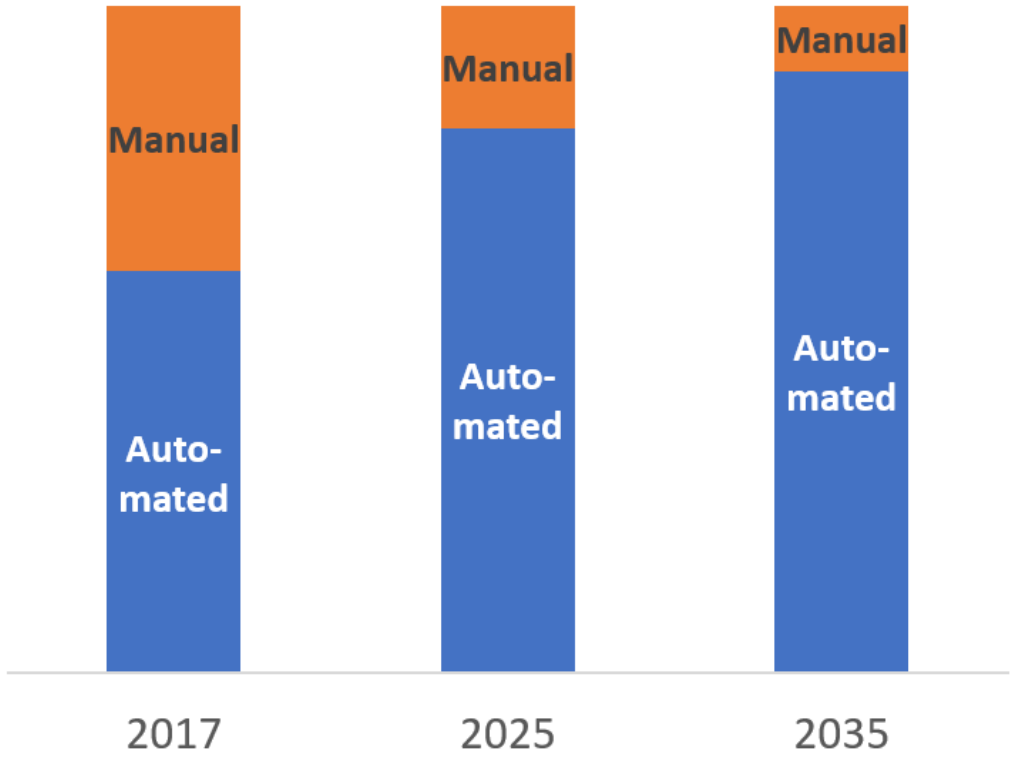
Driving Performance

- Shift Quality / Noise-Vibration-Harshness (NVH) /Comfort
- Safety/Fun-to-Drive – sporty – dynamic driving style – adapts to suit your individual driving style

Compact Size and Reduced Weight

- Smaller Transmissions – Less fluid
- Increased Torque Density

Global transmission installations

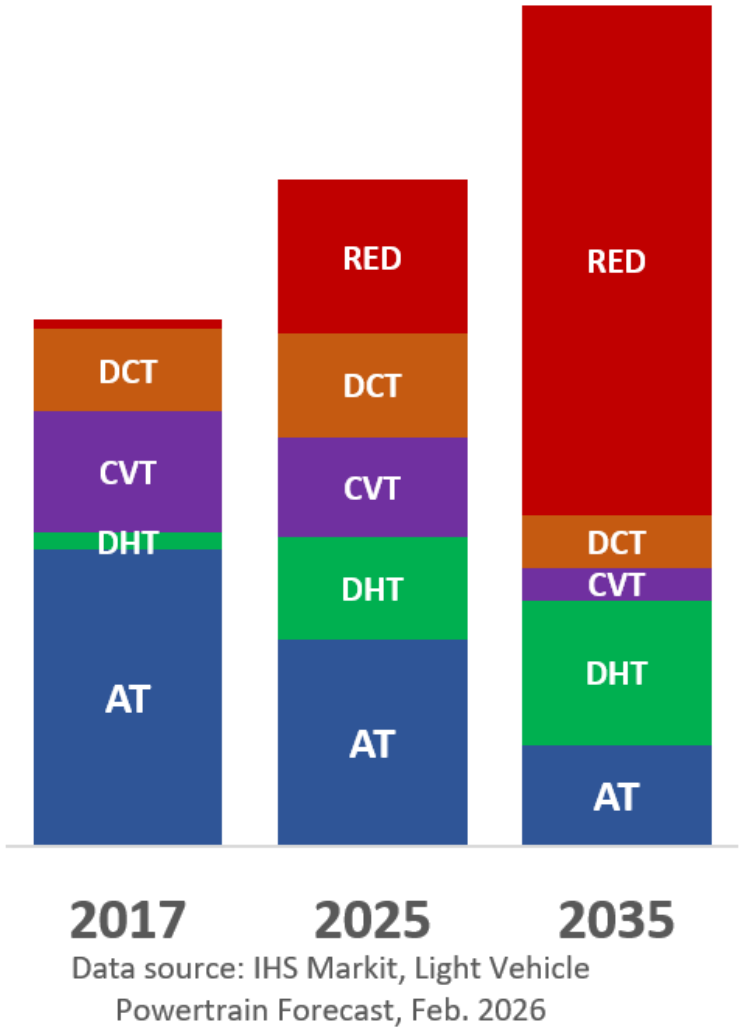


Passenger Car And Light Duty Truck Transmission Installations

Manual
Market share declining with inherent lower cost now being offset by fuel economy *debit*.

Automated
Market share increasing with fuel economy now better than manual. Increasing diversity in design.

Global automated transmission installations



Data source: IHS Markit, Light Vehicle Powertrain Forecast, Feb. 2026

Reduction Transmission (RED)
Large electric vehicle increase, market gaining momentum

Dual Clutch Transmission (DCT)
Production peaking with market share gains in China and Europe

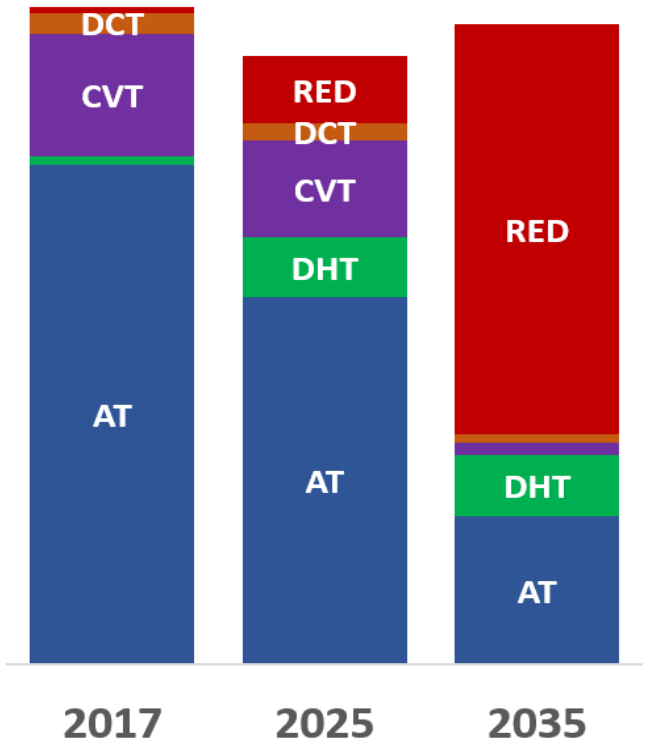
Dedicated Hybrid Transmissions (DHT)
Large hybrid vehicle increase, continuing market share growth

Continuously Variable Transmission (CVT)
Production now cresting with future electrification taking market share

Stepped Automatic Transmission (AT)
Production slowly declining, with growing diversity of designs

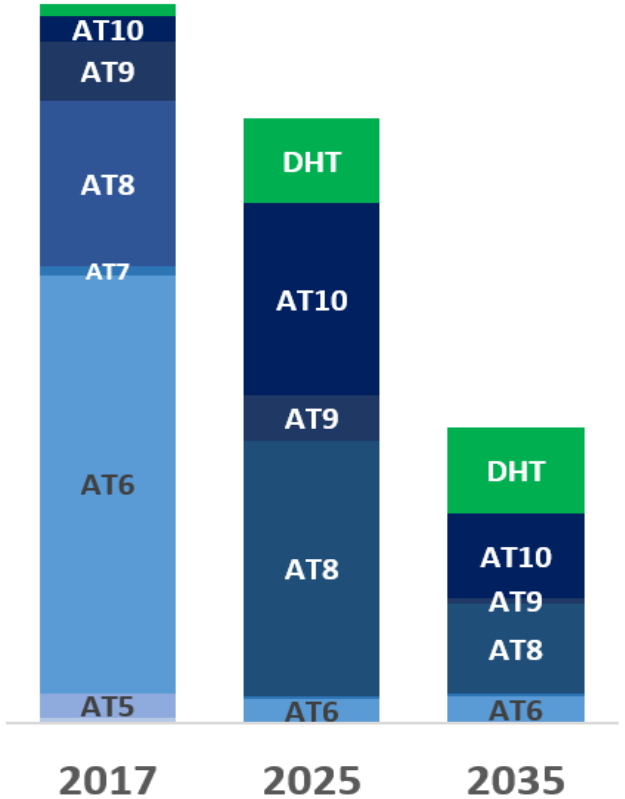
Transmission hardware trends: North America installations – CAFE impacts

NA Growth in Non-Conventional Designs



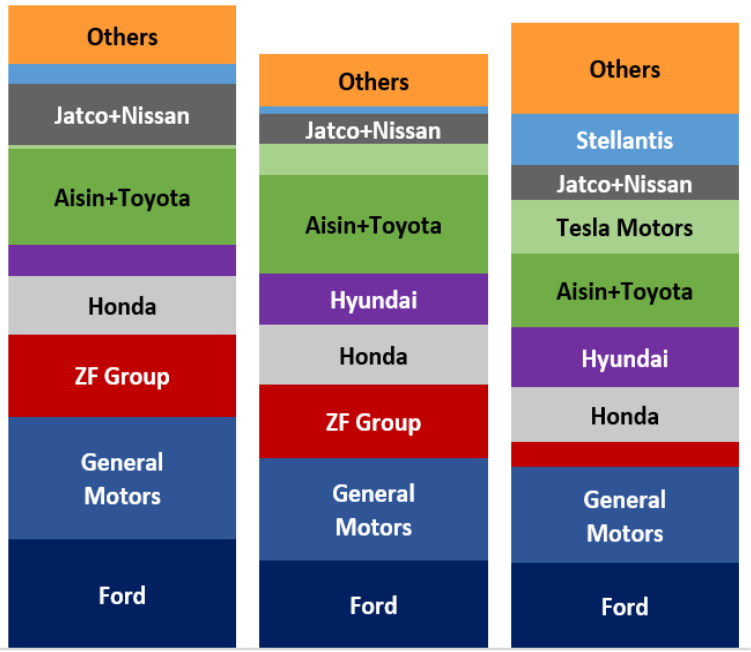
Data source: IHS Markit, Light Vehicle Powertrain Forecast, Feb. 2026

Increasing Speeds and Hybridization of Automatics



Data Source: IHS Markit, Light Vehicle Powertrain Forecast, Feb. 2026

More Segmentation as Vehicle OEMs Develop Reduction Gearboxes



Data Source: IHS Markit, Light Vehicle Powertrain Forecast, Feb. 2026

Data Source: *IHS Automotive, Feb 2026*

US PTF service fill growth in low viscosity ATF & CVTF

Ford Type F: Used ‘67-’80, almost no demand
- Low cost, hard shift, other applications

DIII/M: Used ‘87-’07, declining as parc evolves
- Low cost and use as PSF keeping market afloat

MERCON® V: Used ~‘96-’12, declining market
- All out of warranty period

ATF+4®: ‘98-’20, demand slowly declining
- Still used by Stellantis in transfer cases and some manuals too

Import Multi-Vehicle: Growth to ~1/3 of market
- Greater, if also for GM and Ford licensed applications

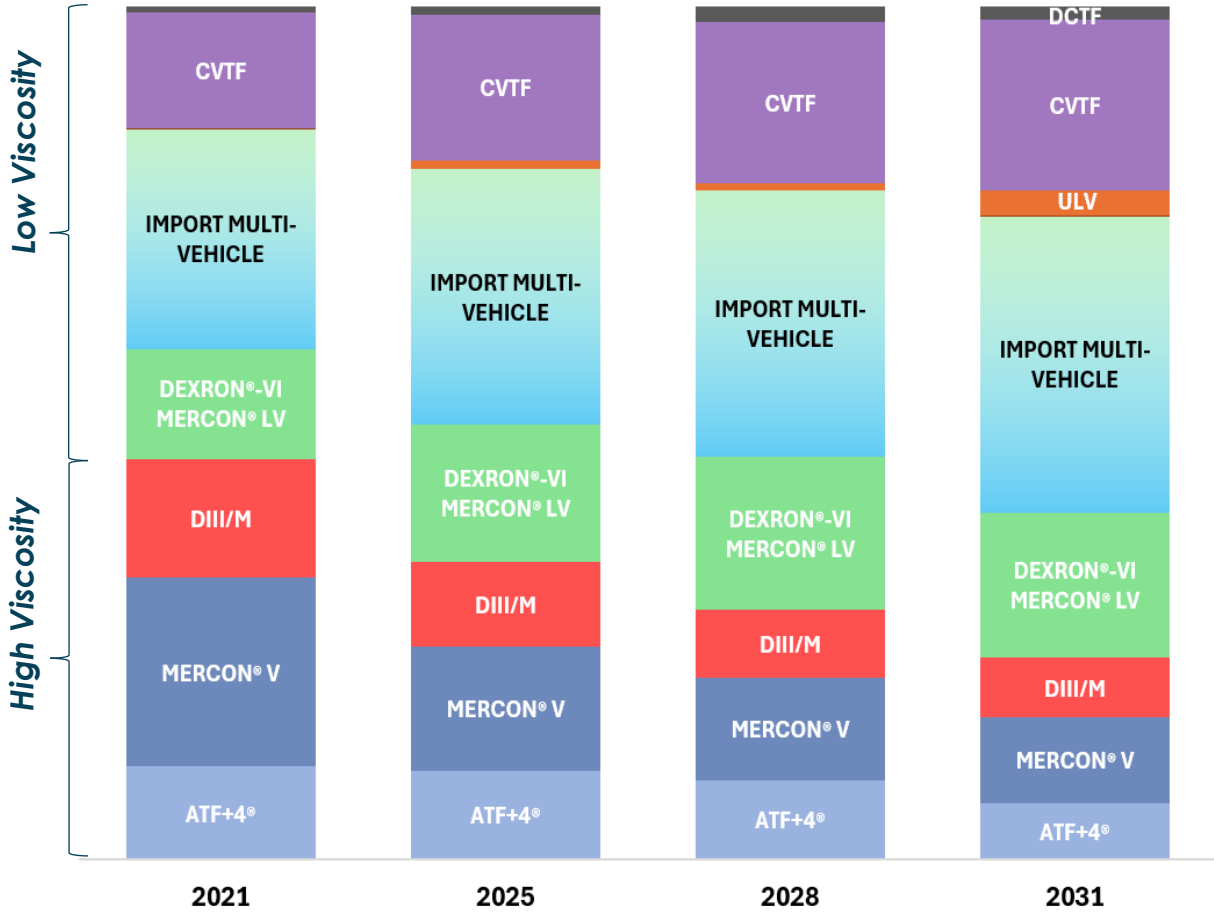
DEXRON®-VI/MERCON® LV: ’06-Today, growing
- Ford & GM 6-Speeds maintain demand for years to come

Ultra Low Viscosity [ULV]: ‘16-Today: negligible demand
- Recently introduced, long ODI, lack of SF licenses will delay SF growth

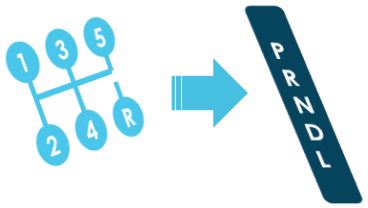
CVTF: ‘02-Today, growing demand
- CVT parc levelling off but relatively short ODIs supports SF growth

DCTF: ‘03-Today little demand, small growth
- Few DCT installations in US

US PTF SERVICE FILL MARKET ~100M Gals

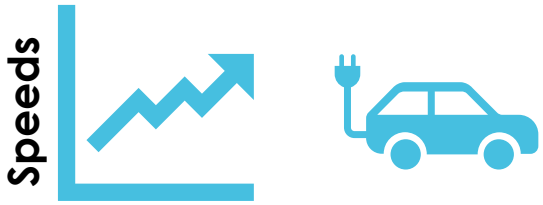


Market summary



Growing use of automated transmissions.

- Now providing better fuel economy than manuals.
- Manual production is now lower than automatics.



Stepped Automatics are still the majority

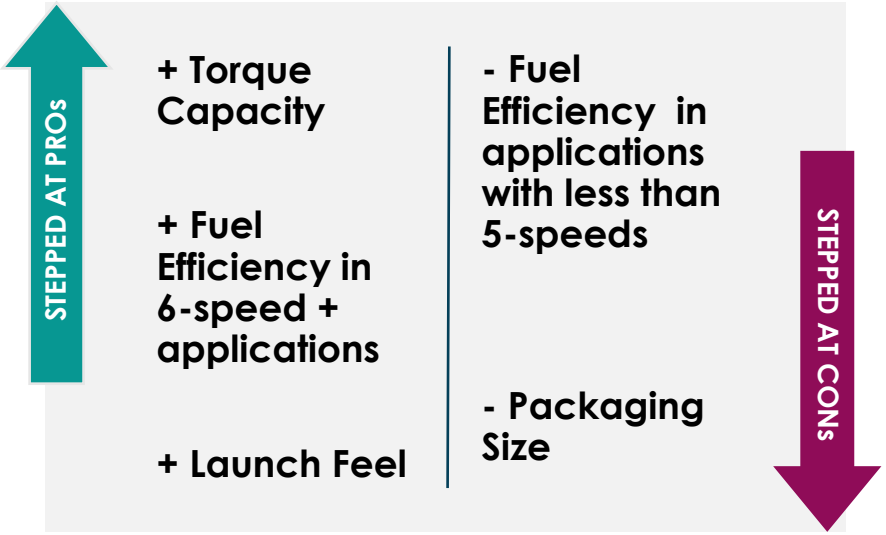
- Gaining more gears – most now >8-speeds.
- Major manufacturers are Ford, GM, ZF and Toyota.
- CVTs and DCTs are gaining market share.
- Increasing use of hybrid and reduction gear boxes for electric motors.

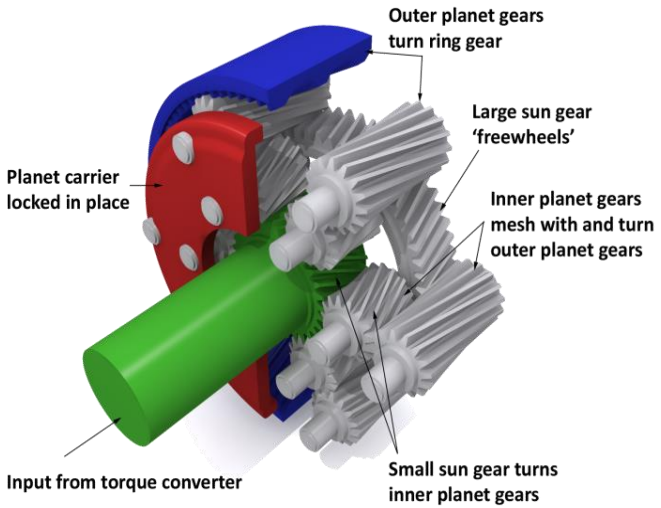
Most automatic transmission fluids are now lower viscosity.

- Less churning loss leads to better fuel economy.
- Import multi-vehicle ATFs gaining market share, often with GM and Ford approvals.
- CVT fluid demand increasing, with short drain intervals

ATF hardware and ATF performance requirements

Stepped planetary automatic transmission





Hardware

- **Planetary Gearset –** gear ratio control
- **Torque Converter –** fluid-coupling to transfer power from engine to transmission
- **Clutch Packs**
- **Valve-Body**

Market

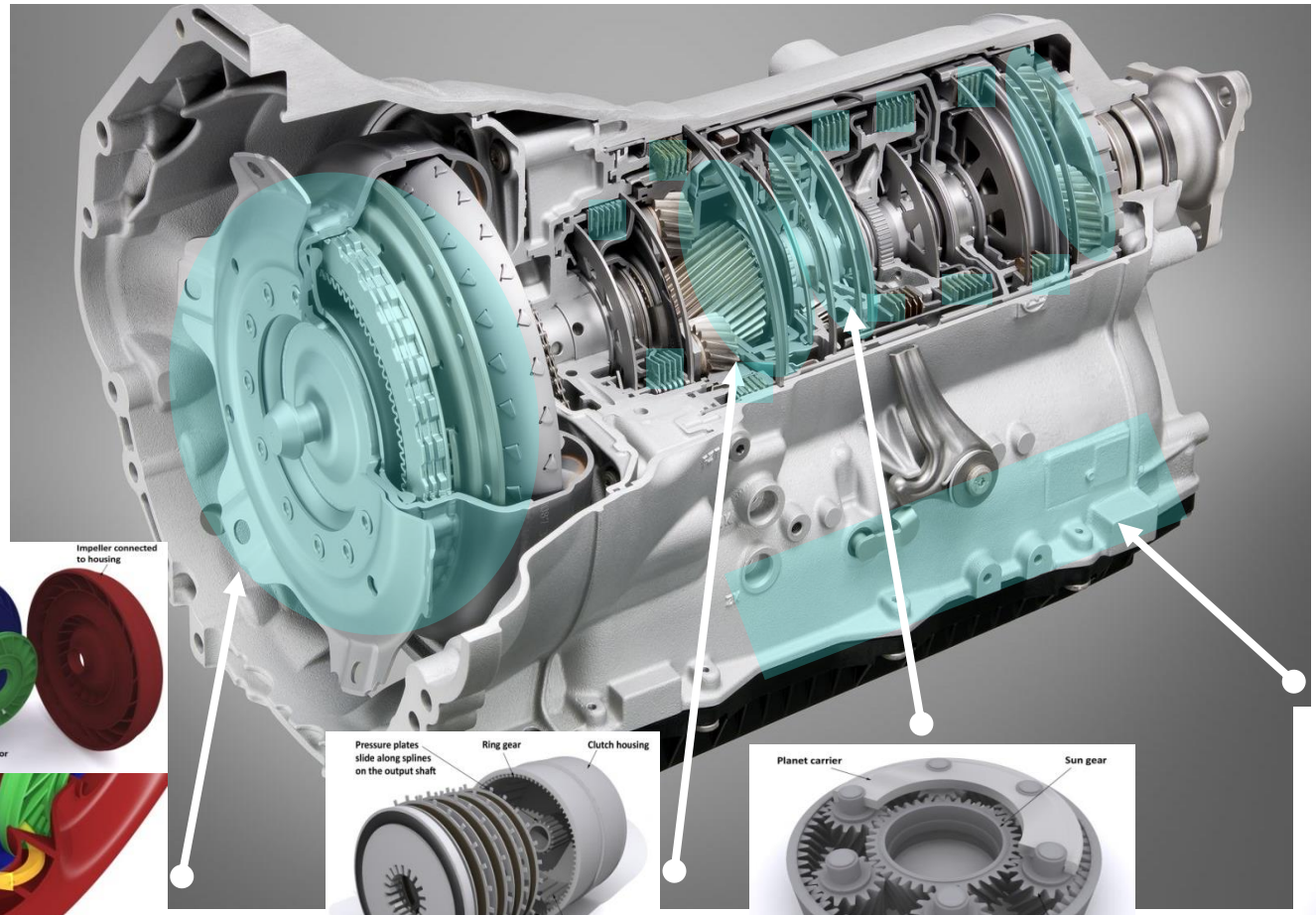
- Most common global transmission type

Manufacture

- GM Hydra-Matic was the first mass-produced fully automatic planetary AT

Automatic transmission hardware

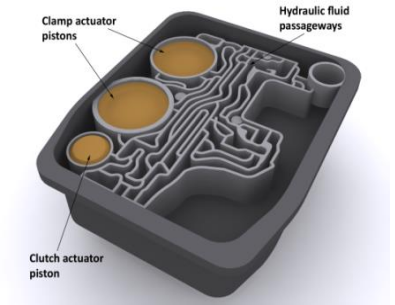
Photo source: BMWBLOG.COM



Torque Convertor

Clutches

Planetary Gear



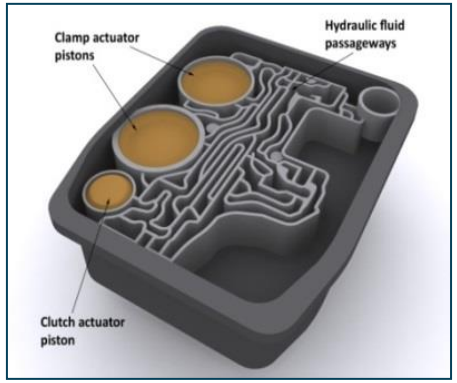
Valve Body

Automatic transmissions hydraulics

Hydraulic System

Components

- Valve body
- Pump
- Filter
- Cooler



- Used to pressurize piston plate for clutches
- Used to move band-activation pistons up and down

ATF requirements

- Act as a Hydraulic Fluid
- Antifoam properties
- Large operating range (-40C to 175C)
- Resist oxidation
- Remove Heat Efficiently
- Ensure seal performance

Automatic transmission gear reduction

Planetary Gearsets

Three Main Components

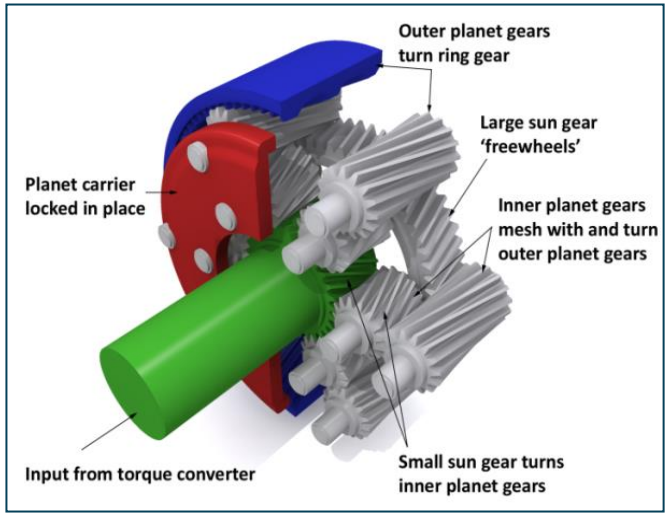
- Sun Gear
- Planet gears (and carrier)
- Ring Gear

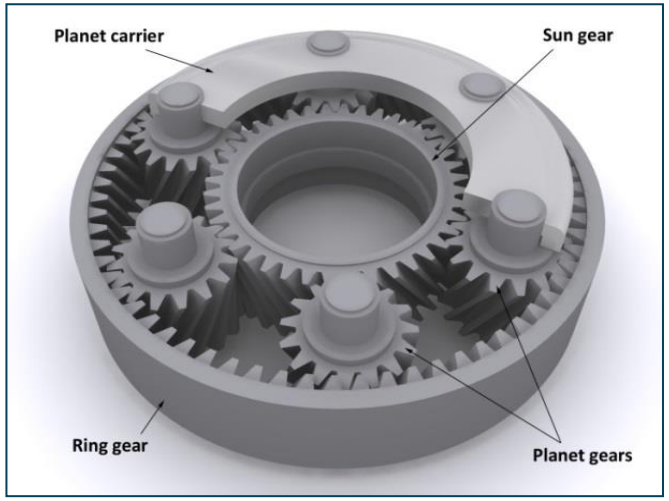
Any one of these components can be locked in place; more importantly, any one can be an input or output drive

- Different gear ratios possible from one planetary gear set

ATF requirements

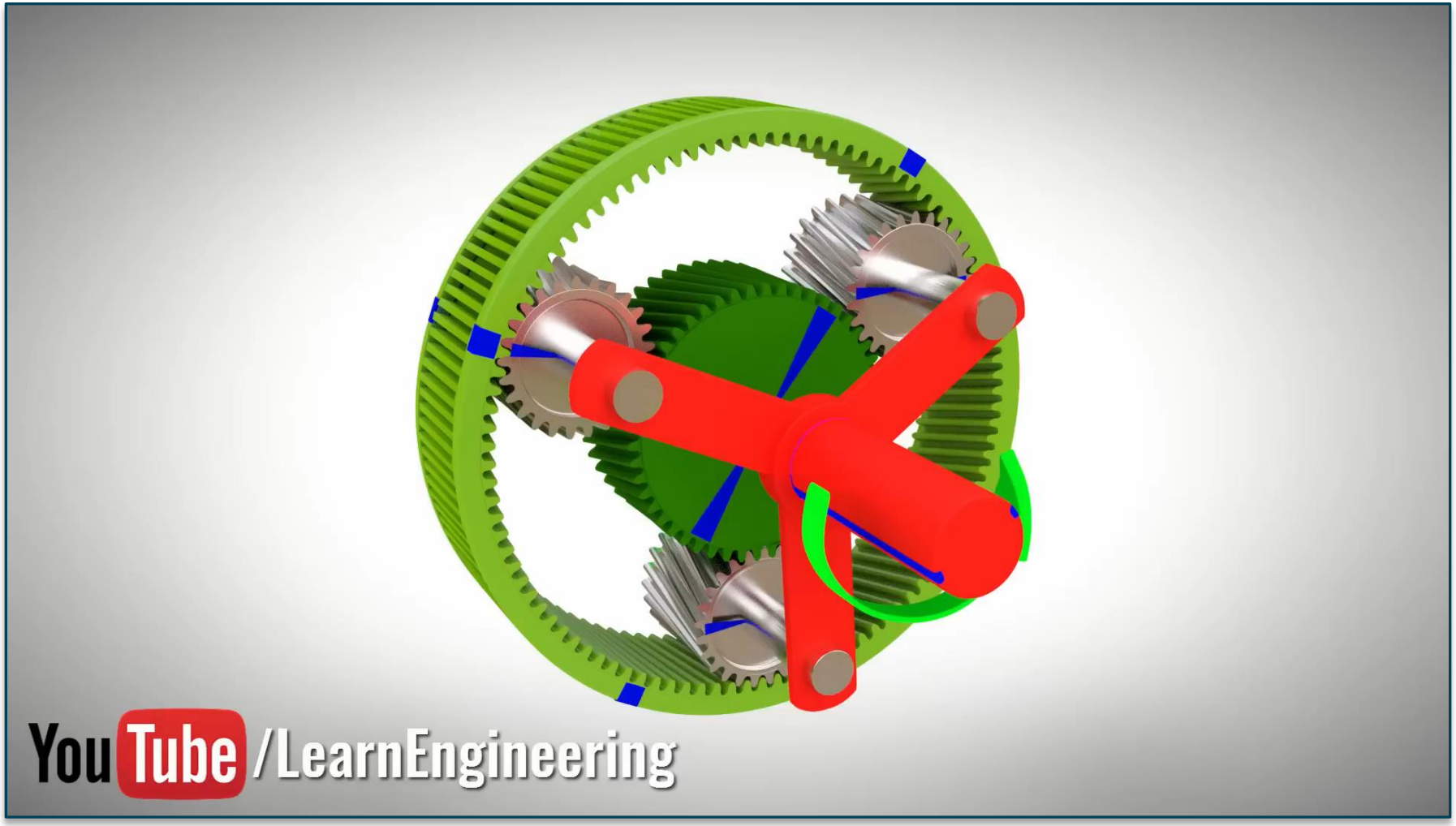
- Provide anti-wear performance
- Shear Stability
- Corrosion protection





Planetary Gear

Automatic transmission planetary gearset



Sabin Civil Engineering: https://www.youtube.com/watch?v=ARd-Om2VyiE

Automatic transmissions clutches

Shifting

- Plate Clutches
- Band Clutches

Fuel Economy

- Torque Converter Clutches

Automatic transmission clutches – plate and band clutches

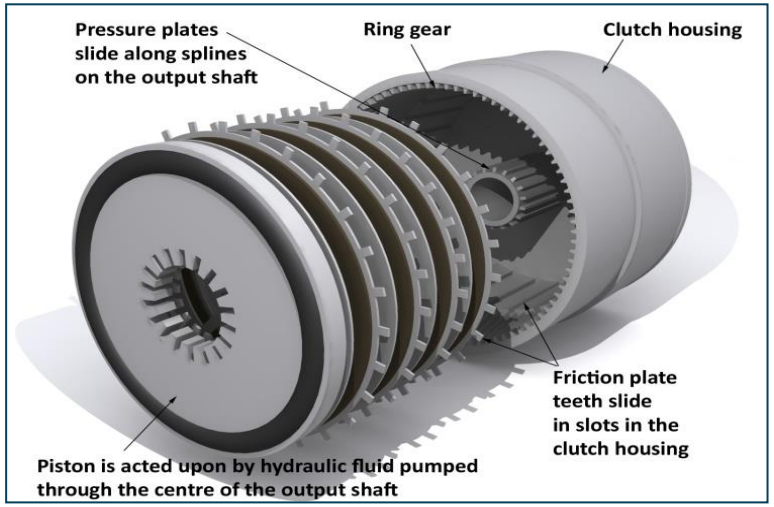
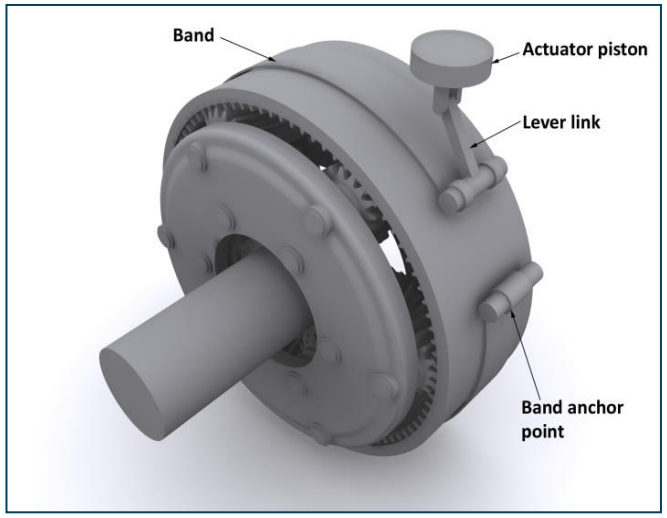


Plate Clutch

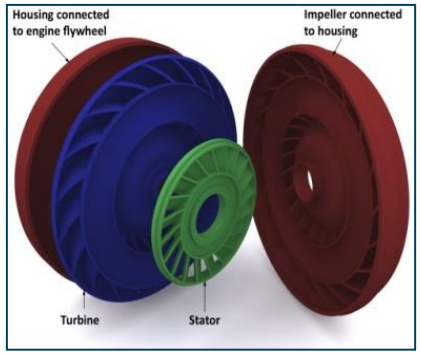


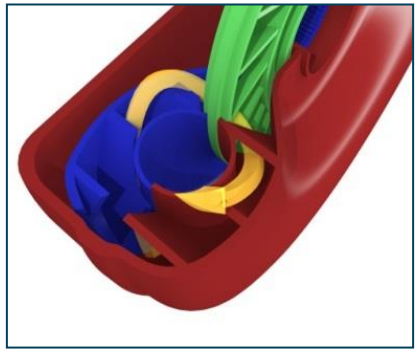
Band Clutch

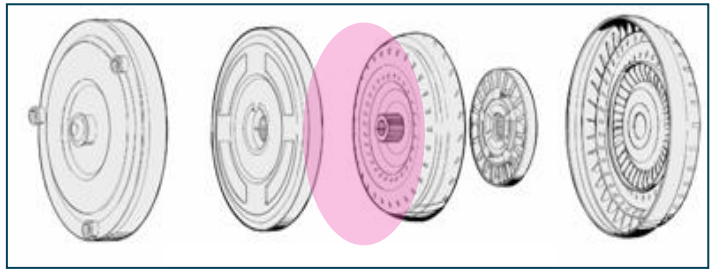
ATF requirements

- Remove heat efficiently
- Resist oxidation
- Deliver specialized friction requirements

Automatic transmission torque converter







Torque Converter Lock-Up Clutch

Torque Converter Clutch

Large energy loss without clutch

Clutches added in 1970s to improve fuel economy

- Full lock-up at highway speeds

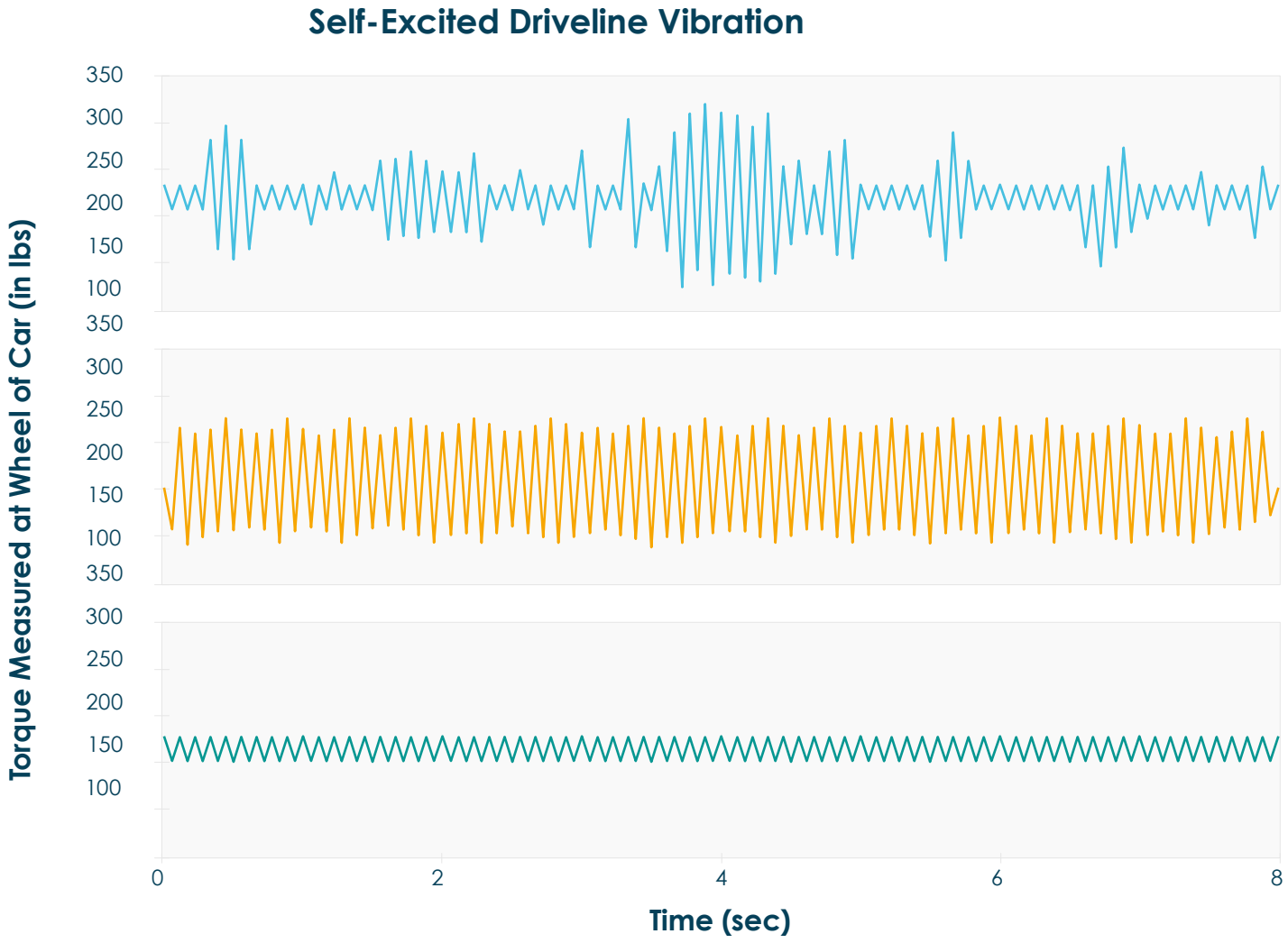
Lock-up clutch evolved for improved comfort and additional fuel economy benefits

- Slipping clutch at low speeds

ATF requirements

- Act as a Hydraulic Fluid
- Large operating range (-40C to 175C)
- Deliver specialized friction requirements

Torque converter clutch friction deterioration shudder



Intermittent Shudder

Continuous Shudder

No Shudder

ATF performance requirements

Act as a Hydraulic Fluid

Provide Anti-wear performance

Remove heat efficiently

Ensure transmission seal performance

Shear Stability

Corrosion protection

Antifoam properties

Large operating range
(-40°C to 175°C)

Resist oxidation

Deliver specialized friction requirements

Stepped automatic transmission summary

The automatic transmission has 4 major components:

- Torque Converter – transfer power from engine to transmission
- Planetary Gear Set – changes output speed
- Valve Body – the "brain" of the transmission
- Clutches (plate or band) – changes gear ratios

The fluid needs to do the following:

- Act as a hydraulic fluid
- Protect the Gear Set (Anti-Wear)
- Remove heat efficiently
- Ensure seal performance
- Resist oxidation
- Protect against corrosion
- Deliver specialized Friction Characteristics

Fluid trends and testing automatic transmission fluids

Key performance tests for ATF

Viscometrics

- Kinematic viscosity @ 100^{0}C (KV100)
- Brookfield viscosity @ -40^{0}C (BF-40)
- Shear stability 20hrs KRL (KV100 and apparent viscosity), Sonic Shear

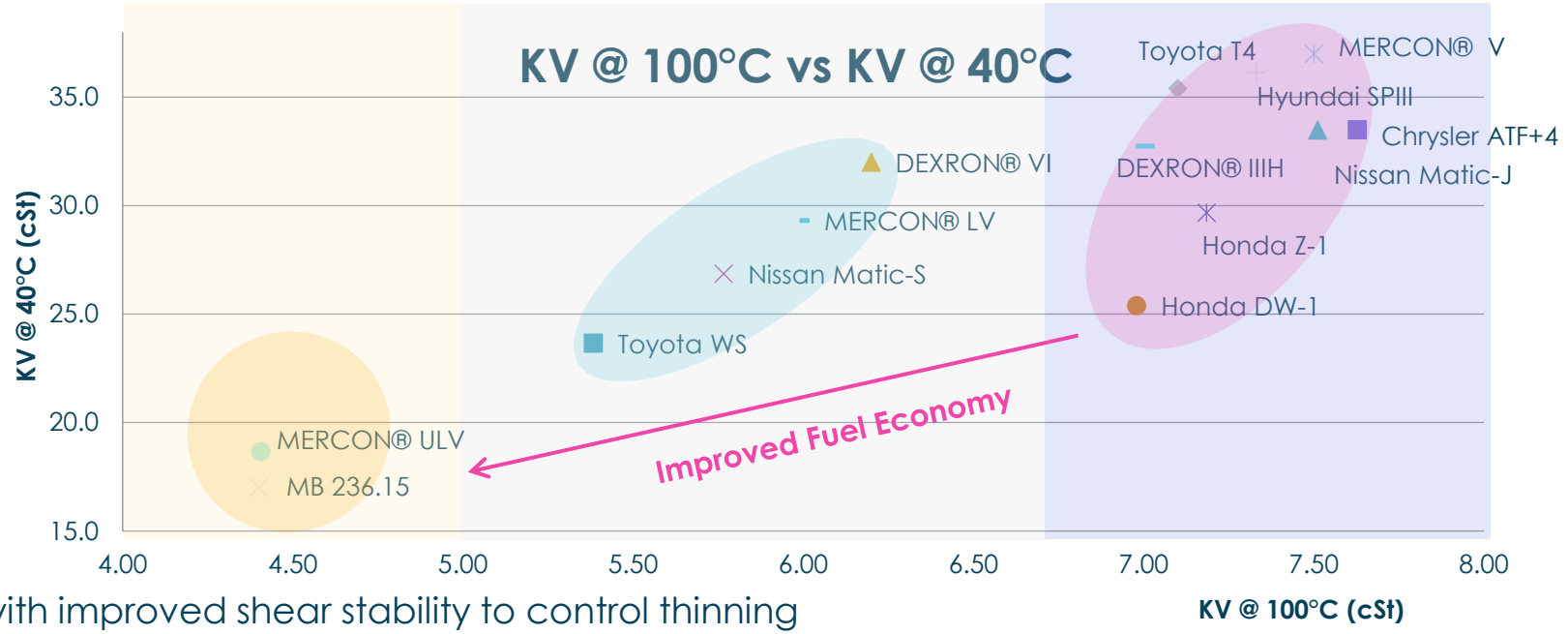
Performance

- Lubrication of transmission parts at high temperature
- Transmission operability at cold temperatures - *cold morning start*
- Ensures aged ATF adequately lubricates transmission parts

New generation ATFs – lower viscosity for fuel economy

Latest 6+speed transmissions use lower viscosity ATF

Reduces fluid resistance and friction losses



- Coupled with improved shear stability to control thinning

Some OEMs replacing high-vis ATF with low-vis ATF

Others maintain two specs – notably Ford, Hyundai and Toyota

Key performance tests for ATF

Oxidation

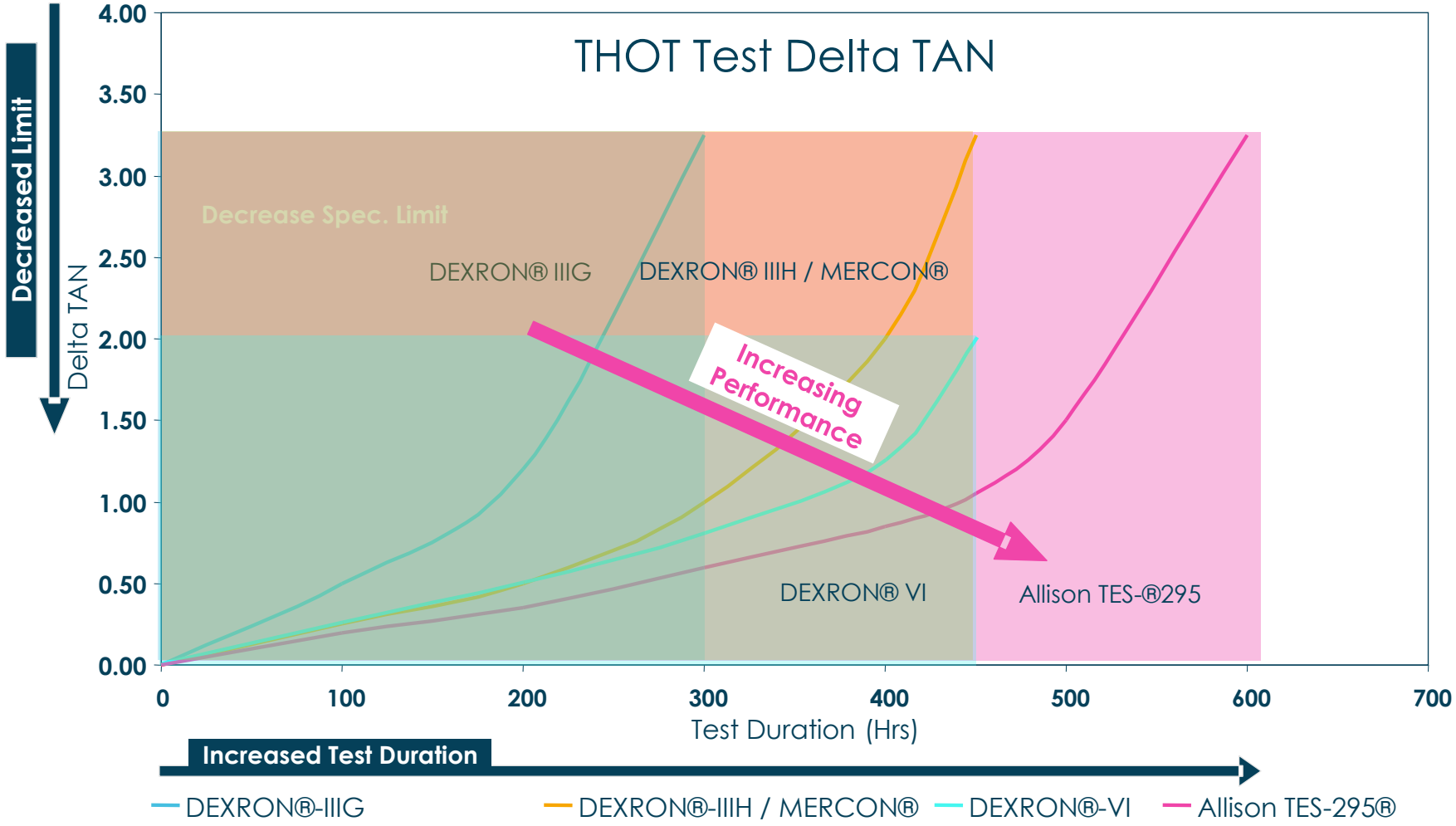
- Aluminum Beaker Oxidation Test (ABOT) - Ford
- Turbo Hydra-Matic Oxidation Test* (THOT) - GM
- Indiana Stirring Oxidation Test (ISOT) - Asia Pacific OEMs
- CEC L-48-A-00 (A), DKA Oxidation Test – European OEMs

Performance

- Chain scission → Loss of lubrication
- Viscosity increase → Sluggish operation
- Sludge formation → Clogged valve body
- Acid formation → Corrosion
- Friction Modifier attack → Poor shifting

***GM THOT** has been made obsolete

Trends in oxidation performance



Key performance tests for ATF

Clutch Friction

Shifting Clutch

- SAE#2 Friction and Anti-Shudder Durability (ASD) rig – US and Asia Pacific OEMs
- Band Friction test – GM
- Plate Friction test – GM and Ford
- Cycling test – GM

Torque Converter Clutch

Low Velocity Friction Apparatus (LVFA) for ASD – Asia Pacific OEMs

Performance

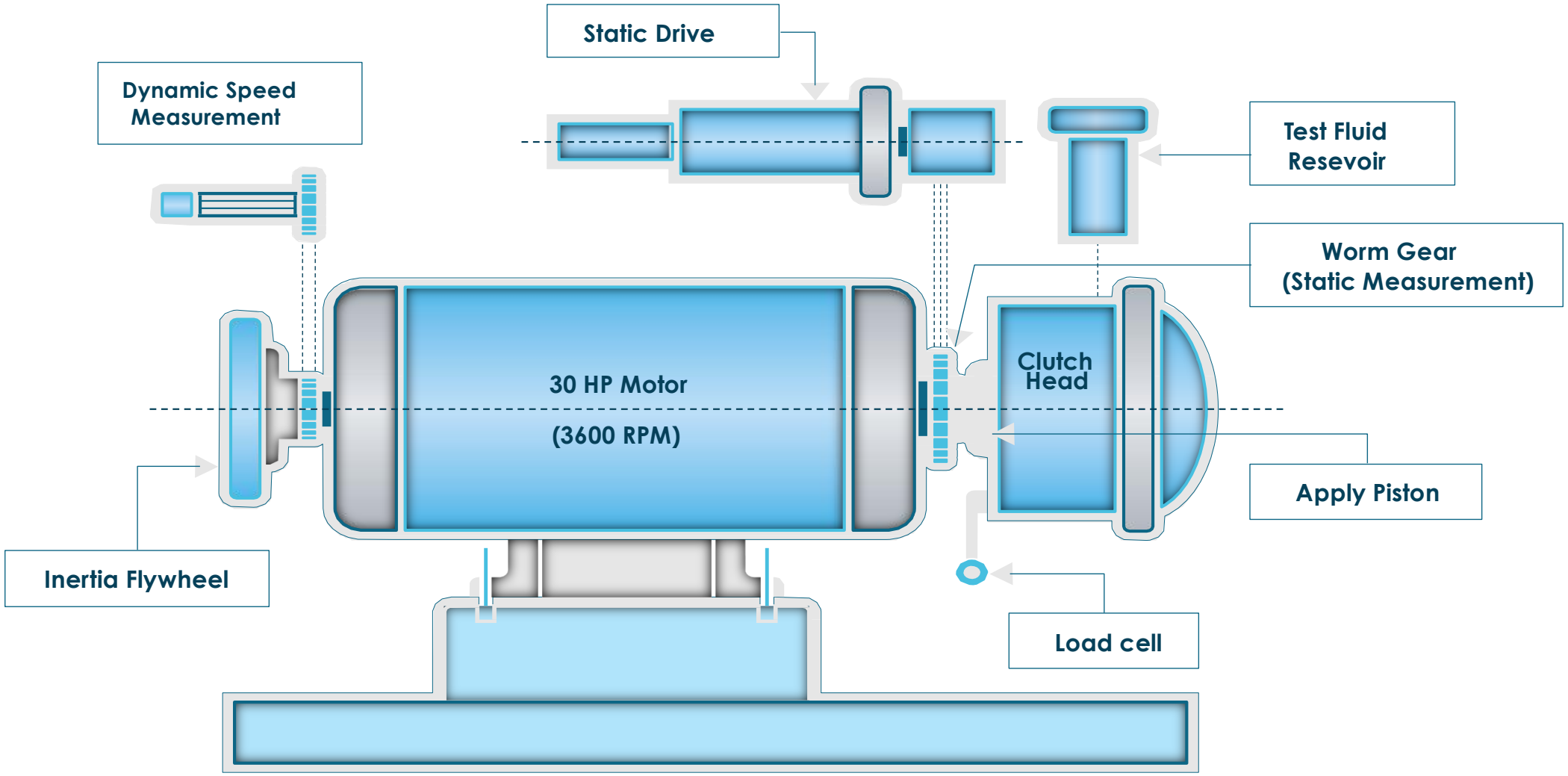
Shifting Clutch

- Abrupt, harsh shift
- Elongated shift and potential slippage
- Gives clutches good holding power, high transmission capacity

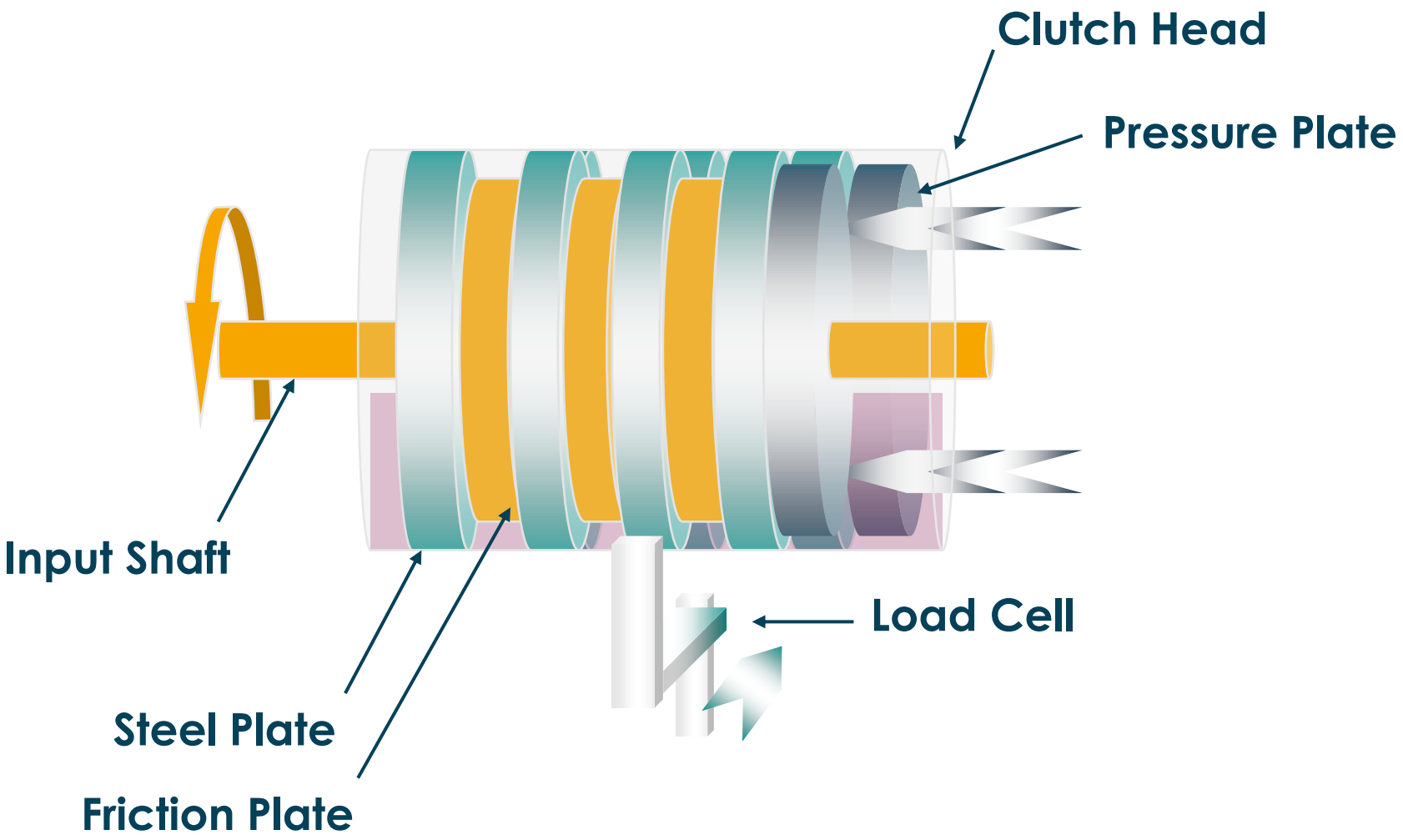
Torque Converter Clutch

Anti-Shudder durability

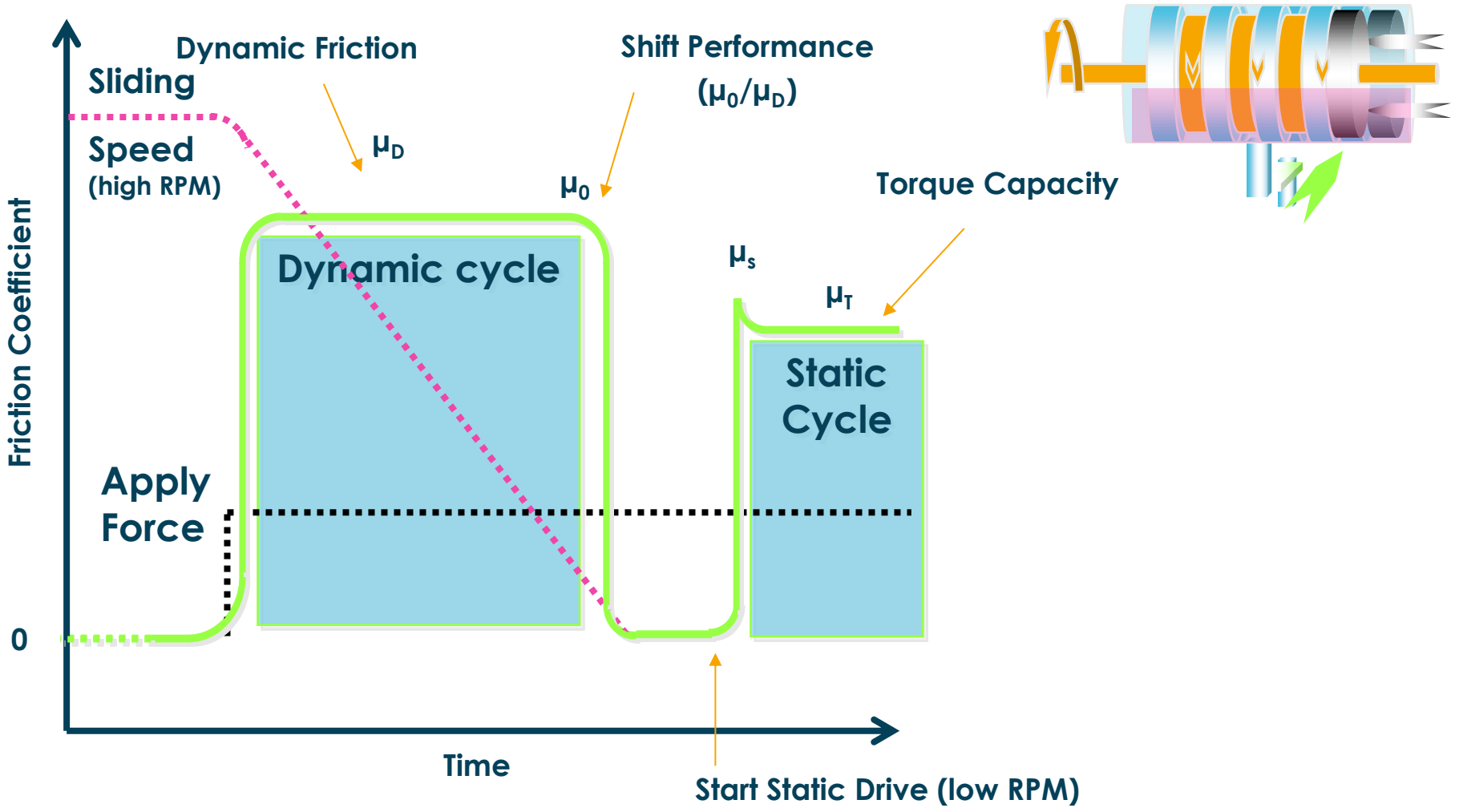
SAE no. 2 friction test machine



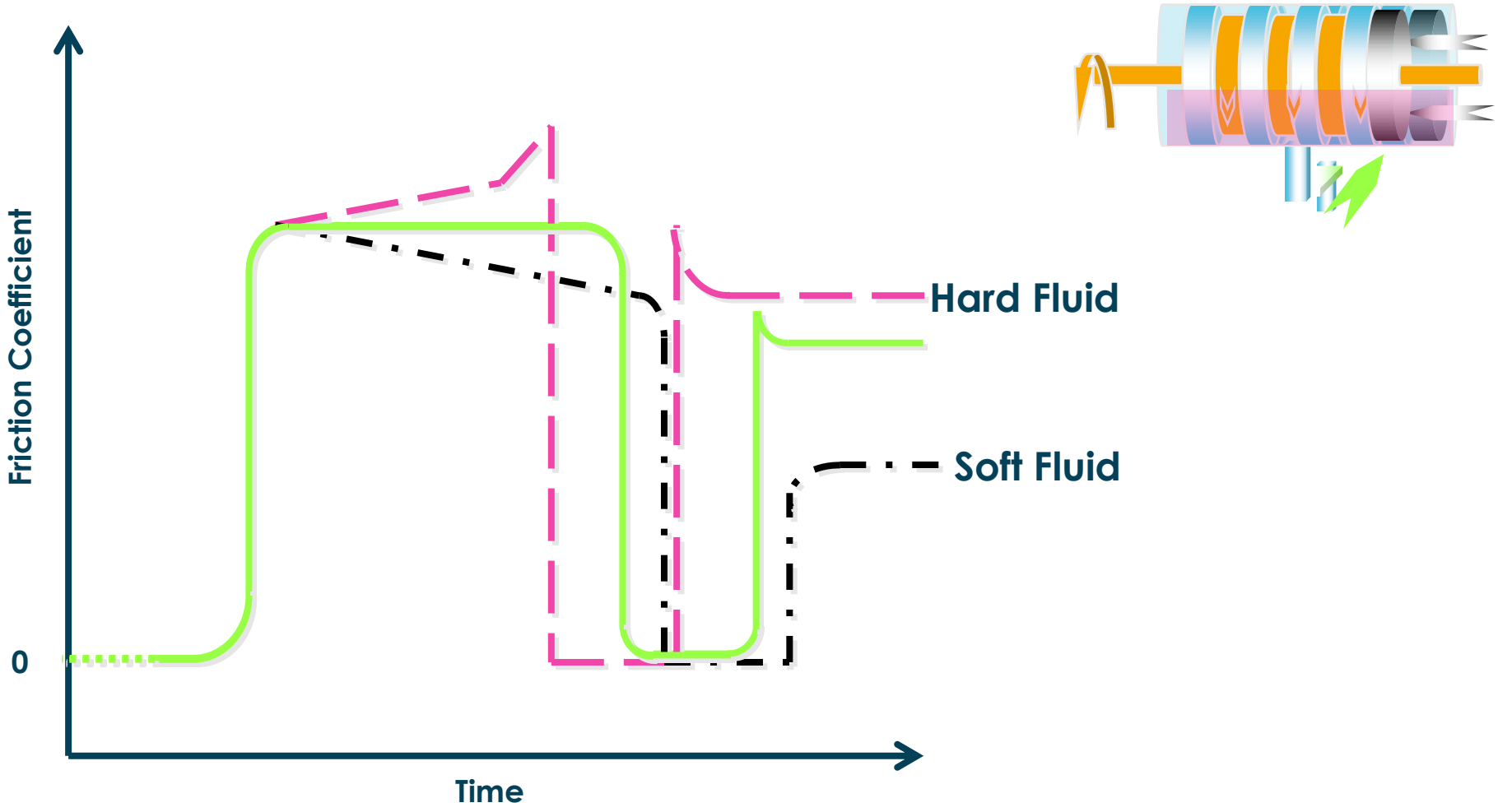
SAE no. 2 friction test machine clutch head



Output from SAE no. 2 friction test machine



Output from SAE no. 2 friction test machine



Desirable clutch friction fluid performance

Dynamic friction (μ_D) → high, flat

- Short shift minimizes energy transfer to fluid

Low speed friction (μ_0) → slight decrease

- High value - abrupt, harsh shift
- Low value - elongated shift and potential slippage

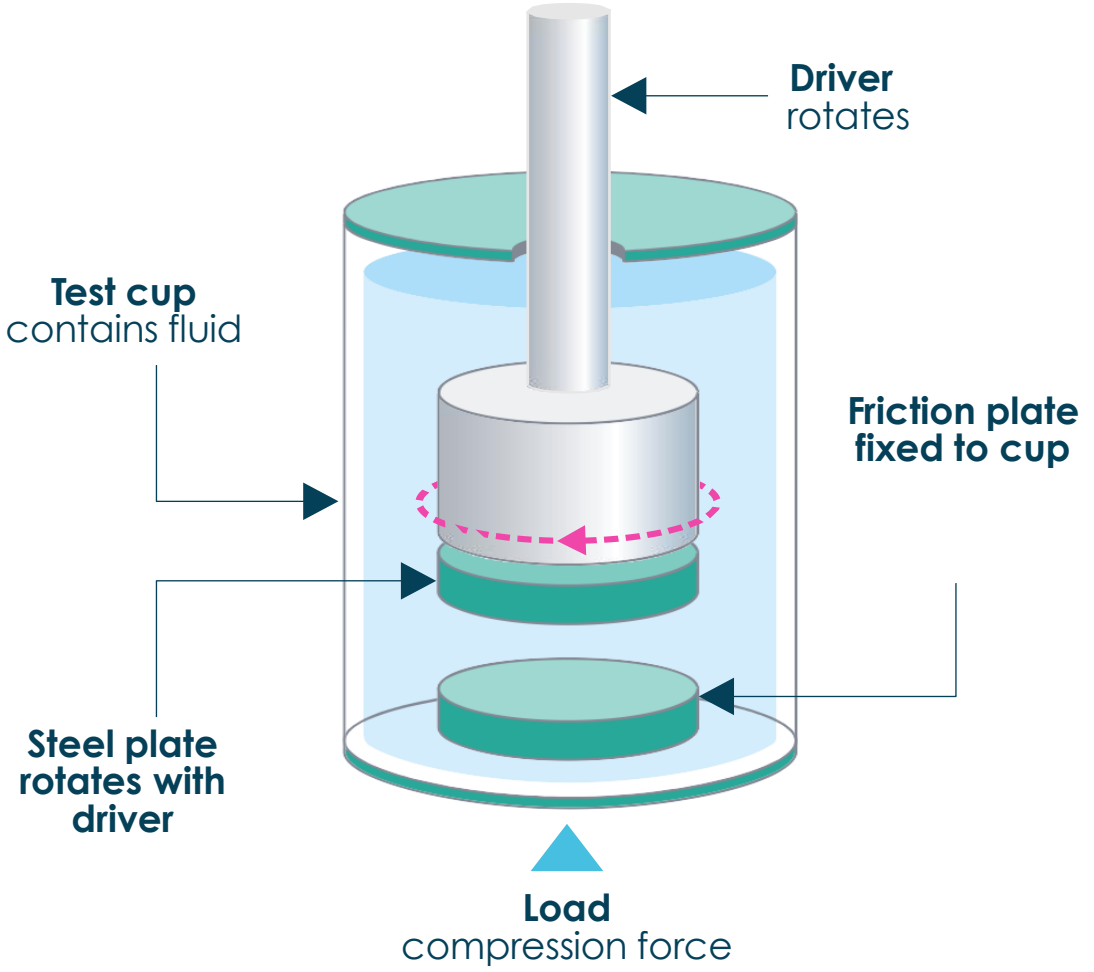
Static friction (μ_T) → high

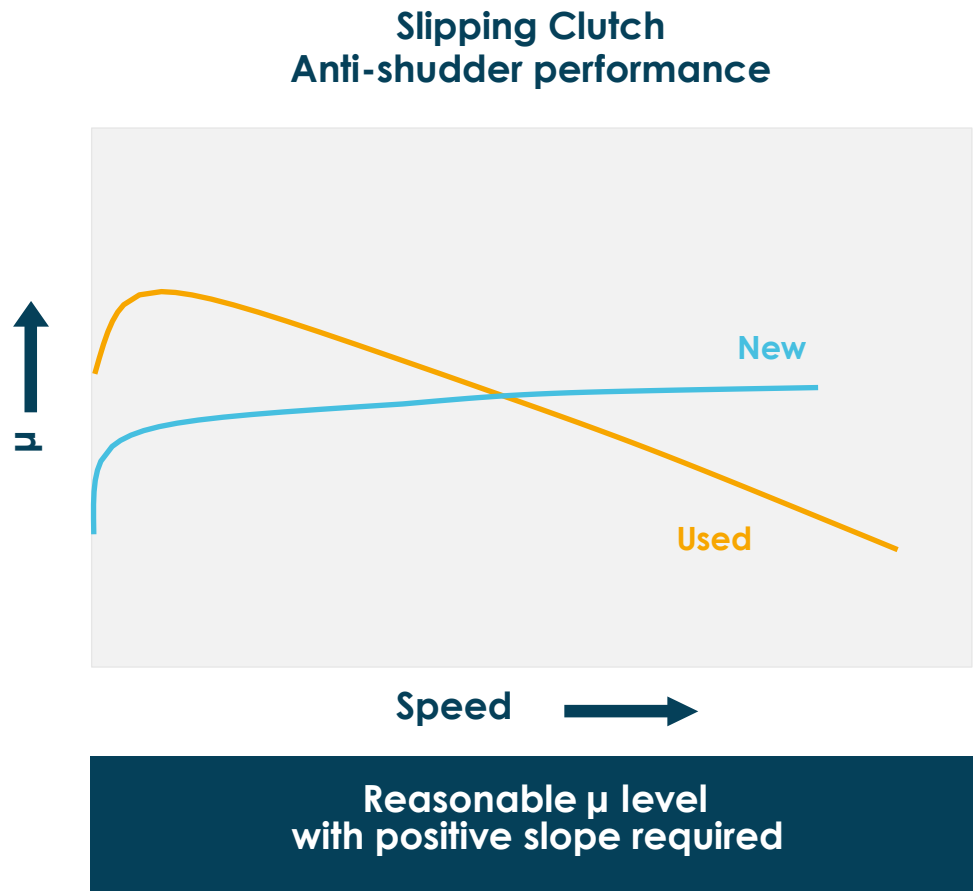
- Gives clutches good holding power, high torque capacity

Trend

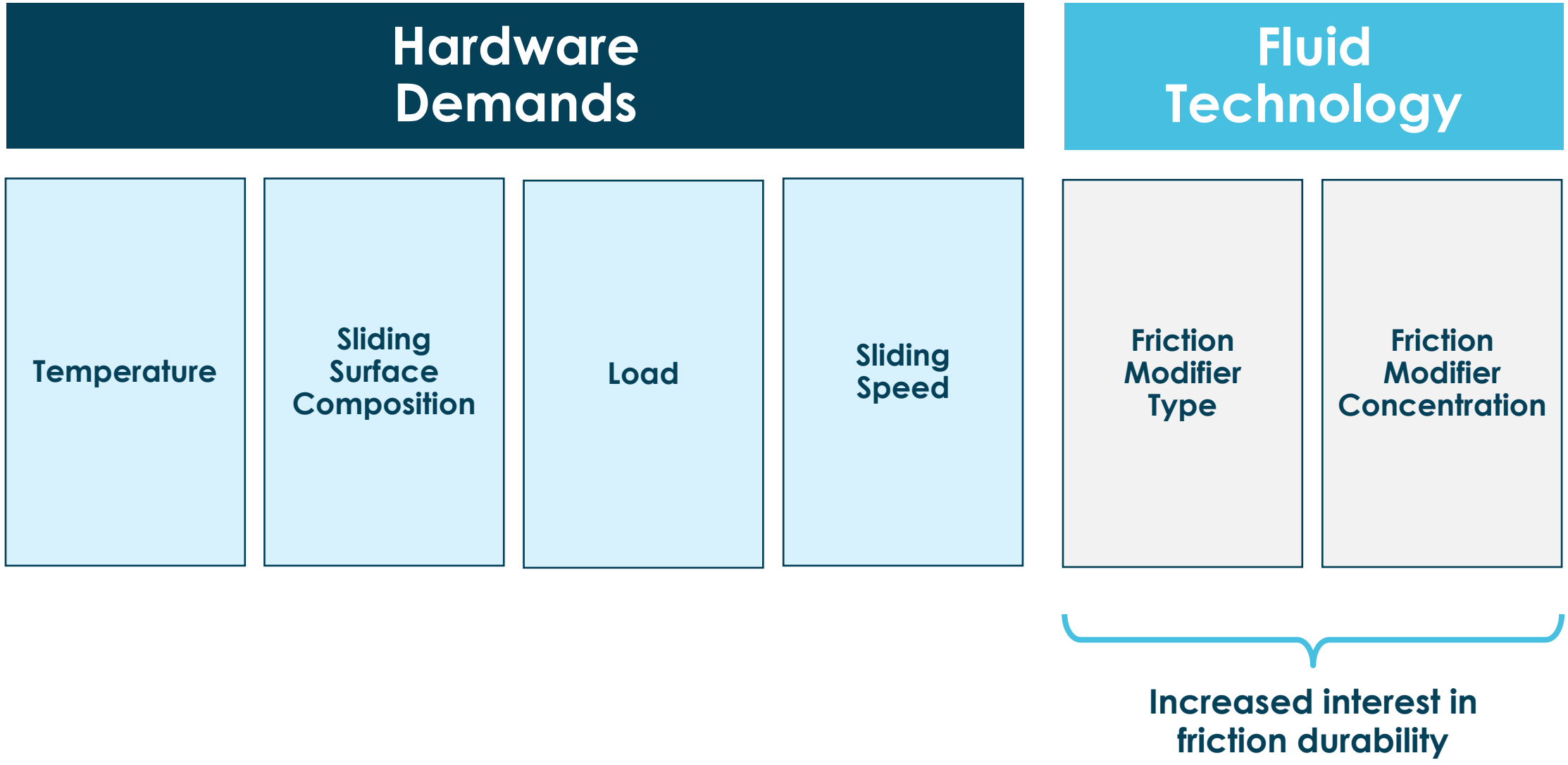
- Increase friction durability

Low velocity friction apparatus (LVFA)





What affects friction?



ATF performance summary

ATF must meet exacting
requirements for a variety of parameters

Key Performance Attributes

- Viscometrics
- Oxidation resistance
- Friction stability and durability

ATF service-fill specifications

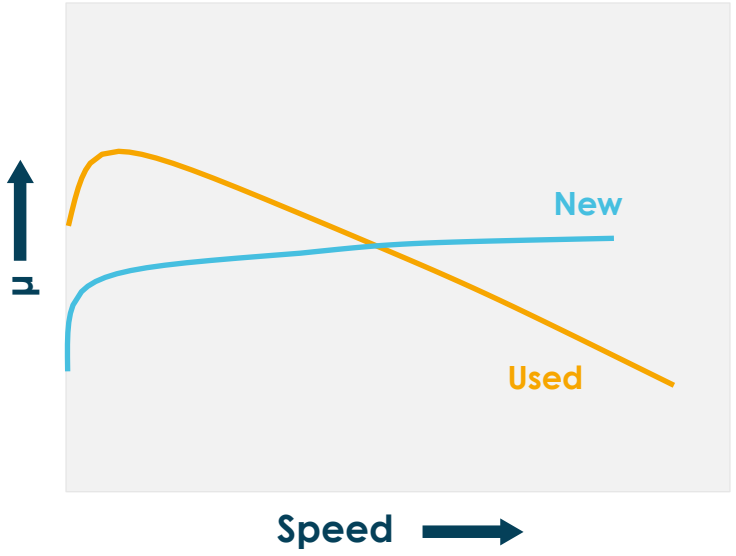
Passenger car ATF specifications

OEM		High Viscosity	Low Viscosity	Ultra Low Viscosity
North American OEMs	Ford	MERCON® **MERCON® V**	**MERCON® LV**	MERCON® ULV
	CHRYSLER	ATF +3® ATF +4®	MOPAR® 8 & 9	-
	GM	DEXRON® II DEXRON® III	**DEXRON® VI** DEXRON® HP	DEXRON® ULV
European OEMs	Mercedes-Benz	MB 236.10	MB 236.12	MB 236.17
	BMW	Lifeguard 5	Lifeguard 8	-
Asia Pacific OEMs	Toyota	Toyota T-IV	Toyota WS	-
	Nissan	Matic J/K	Matic S	-
	Honda	Honda Z-1	Honda DW-1	-
	Hyundai	Hyundai SP-III	Hyundai SP-IV	-

***Bolded specifications are open to licensing**

Key JAMA requirements

Slipping Clutch
Anti-shudder performance



Reasonable μ level with positive slope required

As many ATF specifications are not available for public licensing, **many OEMs recognize JASO testing requirements for ATFs.**

JASO Specifications
- JASO 1-A $_{13}$– Standard JASO ATF specification
- JASO 1-A $_{13}$-LV – Low Viscosity (6.5 cSt max)
- JASO 2-A $_{13}$– JASO 1-A $_{13}$ without ASD Performance

Shear Stability
- Method: JASO M347
- Requirements: KV100 after shear 5.2 min

Friction Characteristics (Shifting Clutch)
- Method: JASO M348 SAE#2 (NW-461E)
- Requirements: Torque capacity, Dynamic friction stability, and shift performance

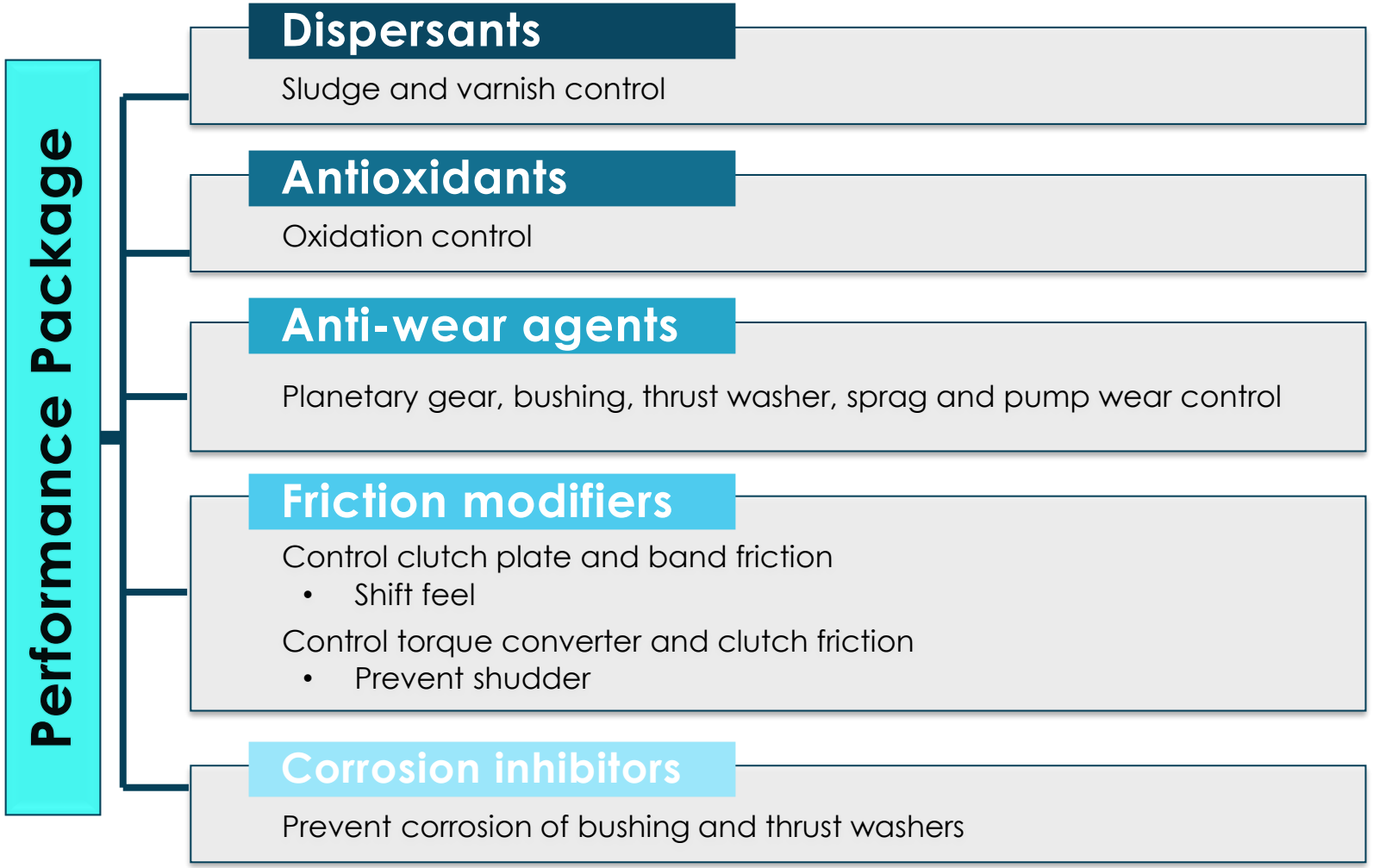
Anti-Shudder Performance (Torque Converter Clutch)
- Method: JASO M349 LVFA (D-0600-02)
- Requirements: Durability of positive m-V slope

Heavy-duty ATF specifications

OEM	Region / Type	Standard Drain Interval	Intermediate Drain Interval	Long / Extended Drain Interval
Allison Transmission	1000/2000, 3000, and 4000 Series	Allison TES-389™	-	Allison TES-295® Allison TES-468™ Allison TES-668®
	H 40 EP™ H 50 EP™	-	-	Allison TES-468™ Allison TES-668®
	5000, 6000, 8000, and 9000 Series	Allison TES-439™	-	Allison TES-353™
VOITH	North America	Service Bulletin 13 & 118 Standard Drain (36K mi)	-	Service Bulletin 13 & 118 Long Drain (72K mi)
	Europe	G607 – H55.6335xx Standard - 60,000 km	-	G1363 – H55.6336xx Long - 120,000 km
ZF	EcoMat	ZF TE-ML 14A 30,000 km	ZF TE-ML 14B 60,000 km	ZF TE-ML 14C 120,000 km
	EcoLife	ZF TE-ML 20B 60,000 km	-	ZF TE-ML 20C 120,000 km
MAN	All	339 Type V1/Z1	339 Type Z2/Z11	339 Type V2/Z3/Z12
VOLVO	All	STD 1273,40 – Trucks STD 1273,41 – VCE	-	STD 1273,42 – VCE
Mercedes-Benz	All	MB 236.7 MB 236.9	-	-

ATF formulations

Typical ATF additives



Typical ATF additives

Seal swell additives

Control swelling, hardness, and tensile strength of elastomers

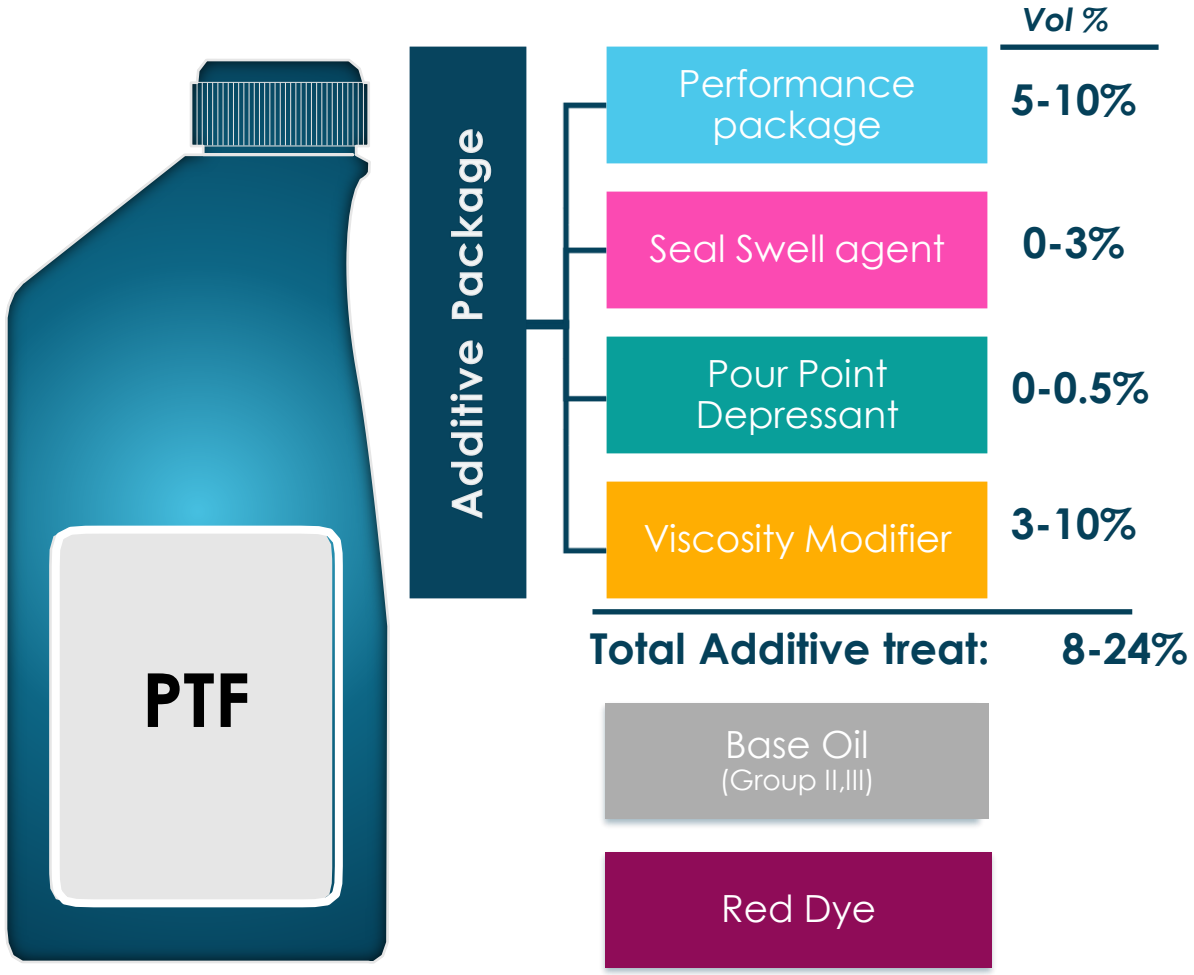
Pour point depressant

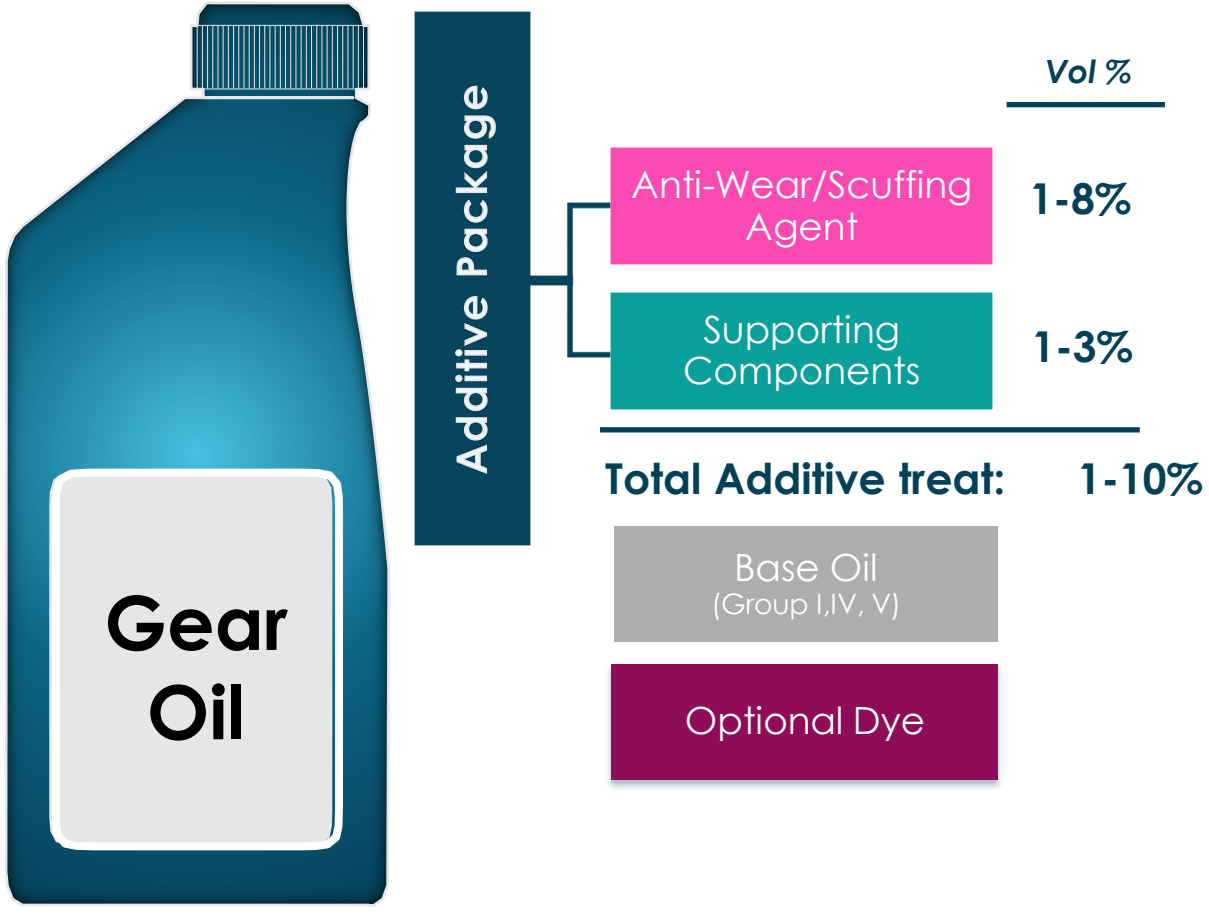
Reduces temperature at which fluid starts to gel

Viscosity modifiers

Reduce rate of change of viscosity with temperature; dispersant type also provides sludge and varnish control

Typical ATF additive treat levels

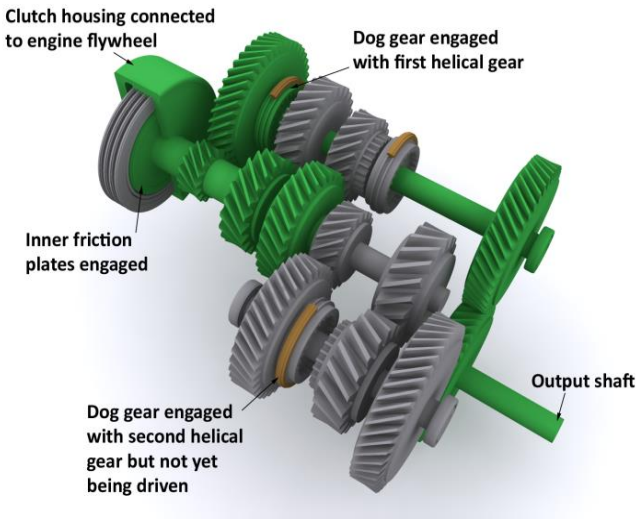




Other automatic transmissions

Dual clutch transmissions (DCT)

Dual clutch transmissions technology update



DCT Pros

+ Fuel Efficiency

+ Shift Feel

+ MT manufacturing (EU)

- Launch feel may be not as smooth as stepped AT

DCT Cons

Hardware

Combines elements of both manual and automatic transmissions

Market

DCT currently attracting great interest

Especially in Europe and China where DCT installations in new vehicles approach 20%

Manufacture

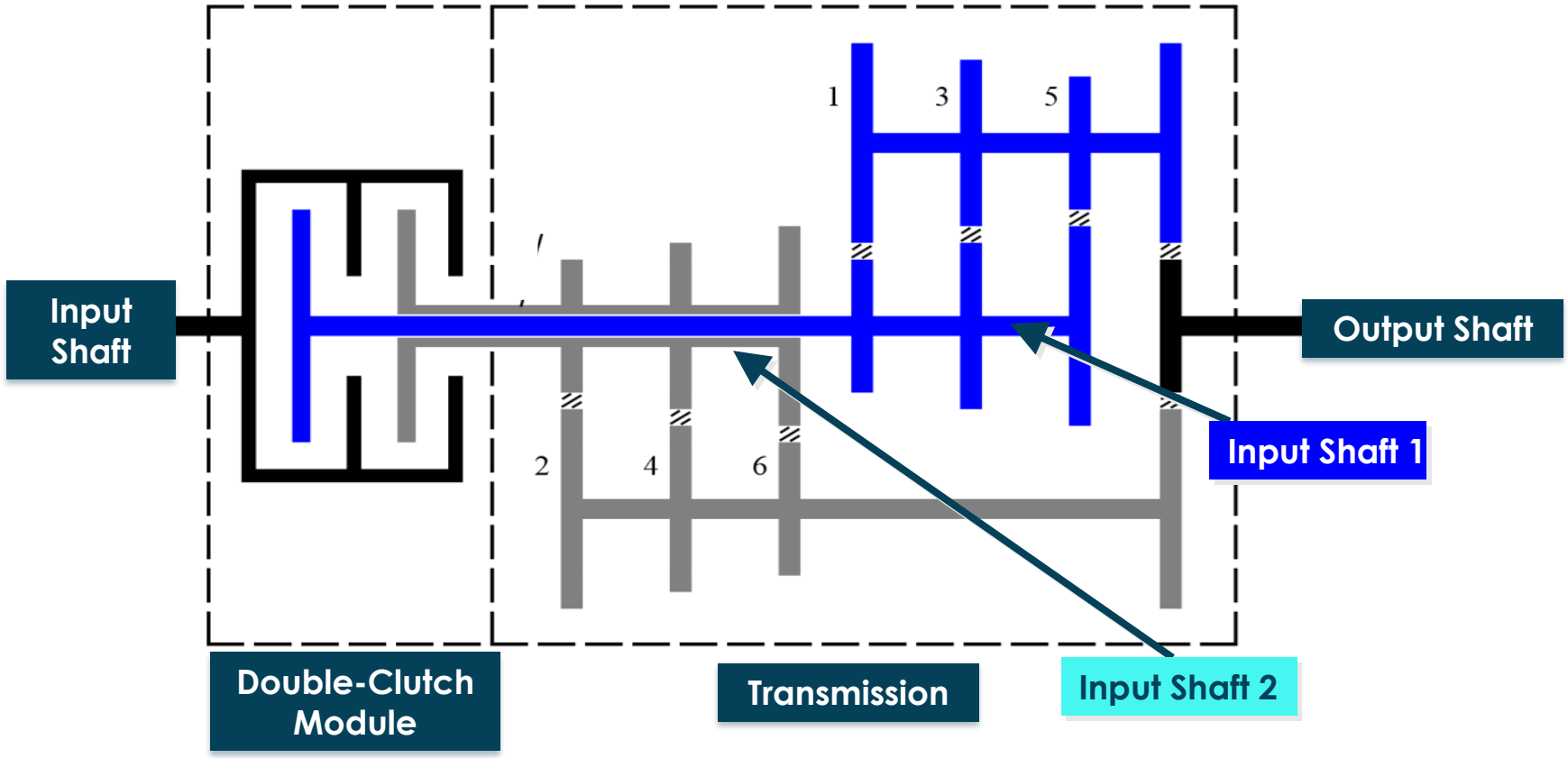
First commercial transmission introduced by VW

Driven by fuel efficiency and driver comfort

Dual clutch transmissions how they work

Two input shafts are connected to two different clutches

- 1,3,5 gears are connected to one
- 2,4,6 gears are connected to the other



Youtube DCT Video - https://www.youtube.com/watch?v=cd10wif87Qk

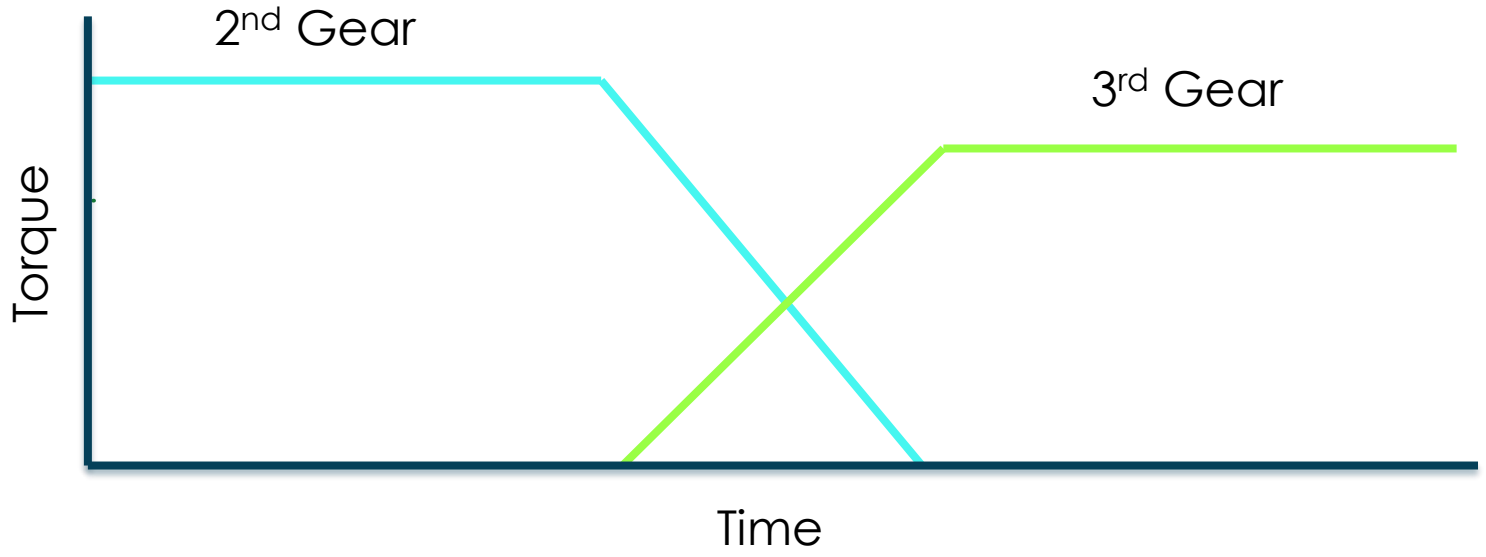
Dual clutch transmissions how they work

Consecutive gears can be "synchronized," but only one gear is connected to engine via active clutch

e.g; While 2nd gear is synchronized and engaged, 3rd is "synchronized" and disengaged.

To change from 2nd gear to 3rd gear, the secondary clutch opens (disengages) while the primary clutch closes (engages)

Shortest shift time of any production transmission type



How DCTs shift

TREMEC https://youtu.be/t8aGgSbtoJE?si=B4ZDucY6x88Dpm3b

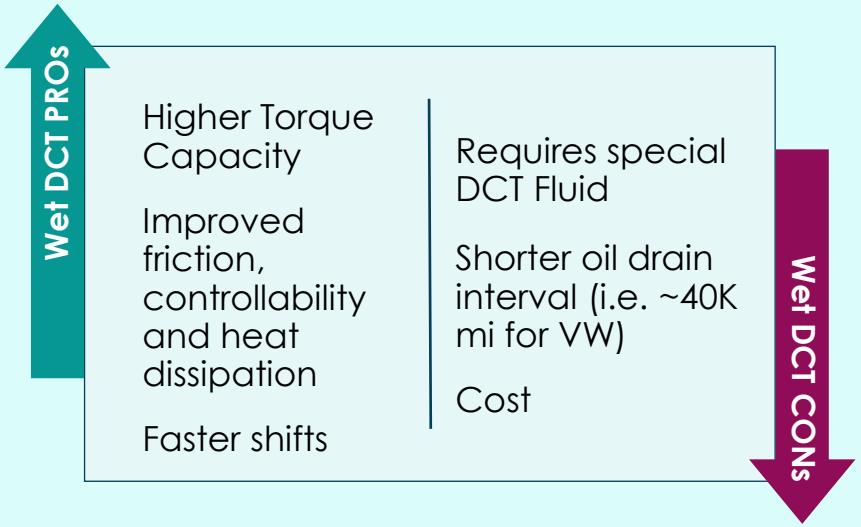
Dual clutch transmission technology trends wet and dry clutch systems

Dry-DCT applications

- Used in medium segment car market
- Torque limitation of 250Nm

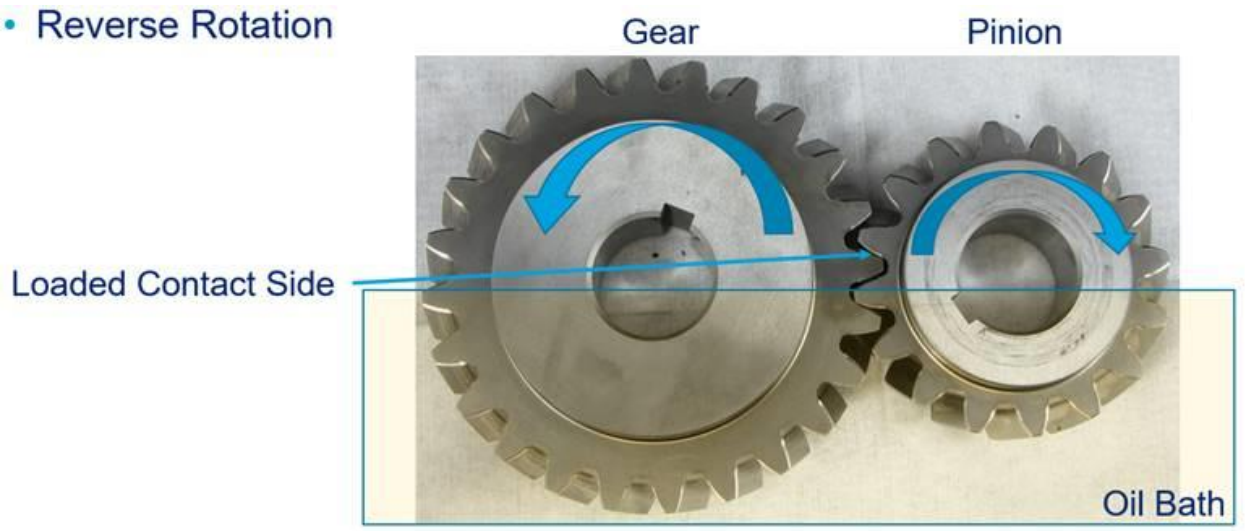
Wet-DCT applications

- Used in high torque demanding vehicles to improve heat dissipation and friction performance.
- Also finds application with very small engines, where heat dissipation is critical



FZG scuffing testing

- Gears are partially submerged in oil and rotated with force applied to them
- During testing, the force applied to the gears is increased in load stages until the gears fail
- **Typical test variables:**
  - Temperature
  - Gear Size: A10 or A20
  - Rotation speed: 8.3 or 16.6
  - Rotation direction: Forward or Reverse



DCT fluid summary

Dry-DCT fluid requirements

- Gear Pitting protection
- Friction and wear control for synchronizers
- Corrosion resistance
- Material compatibility
- Oxidation control

Manual Transmission Fluids typically can meet dry clutch DCT needs

Wet-DCT fluid requirements

- Maintain all requirements of Dry DCT
- Balance Clutch Friction control and Anti-Shudder Durability

Manual Transmission Fluids typically can NOT meet wet clutch DCT needs

Continuously variable transmissions (CVT)

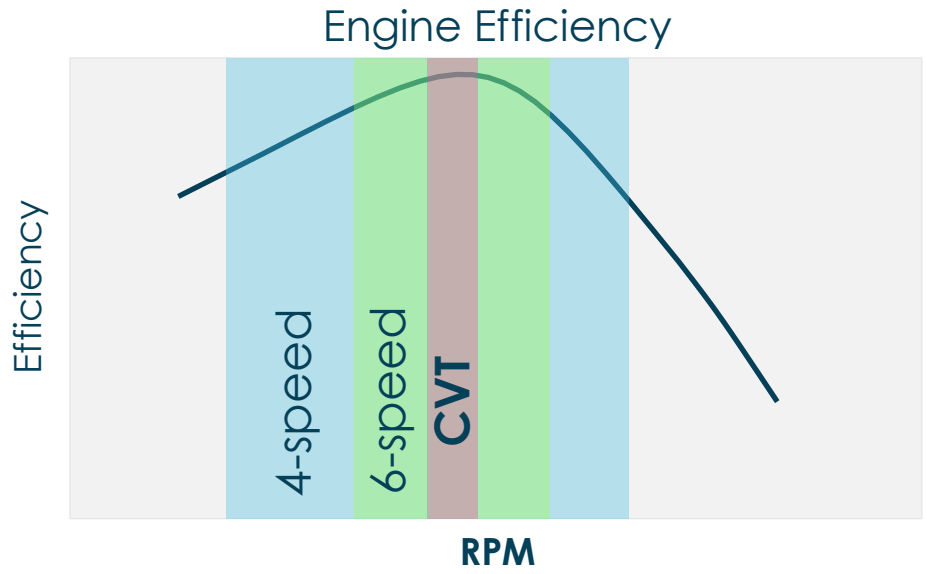
Continuously variable transmissions hardware

Variator

- Key component allowing continuous step-less change in gear ratio
  - Engine run at optimum efficiency
  - Fuel economy and performance
- Smooth power delivery, no ‘shift shock’
- Driving performance – minimum power loss during ratio changes

Types

- Steel belt – push or pull belt types
- Toroidal – traction drive
- Hydromechanical – combination of hydraulic and mechanical



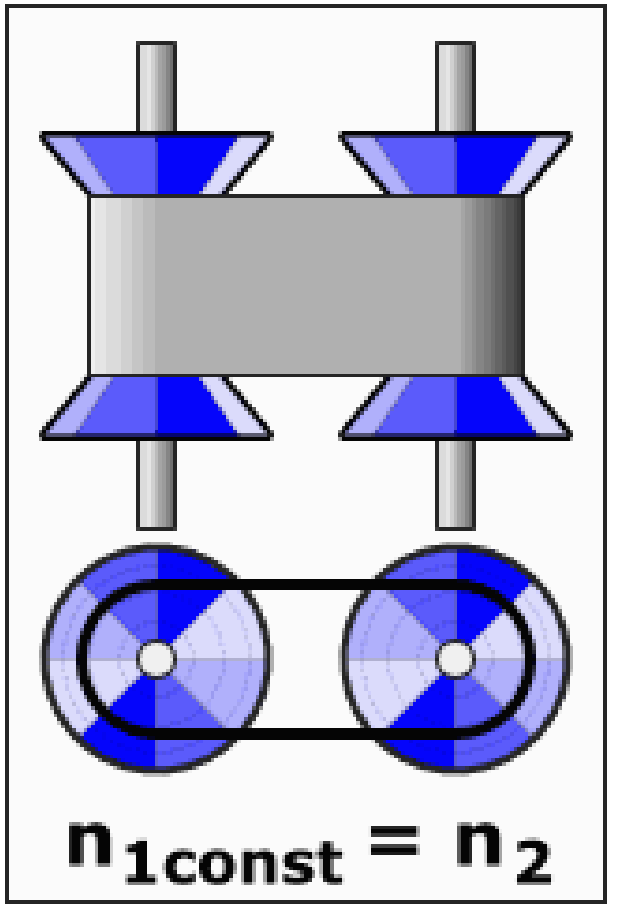
OEMS Using CVTs Today

- Nissan
- Subaru
- Honda
- Toyota
- Audi
- Ford
- GM

Continuously variable transmissions variator system

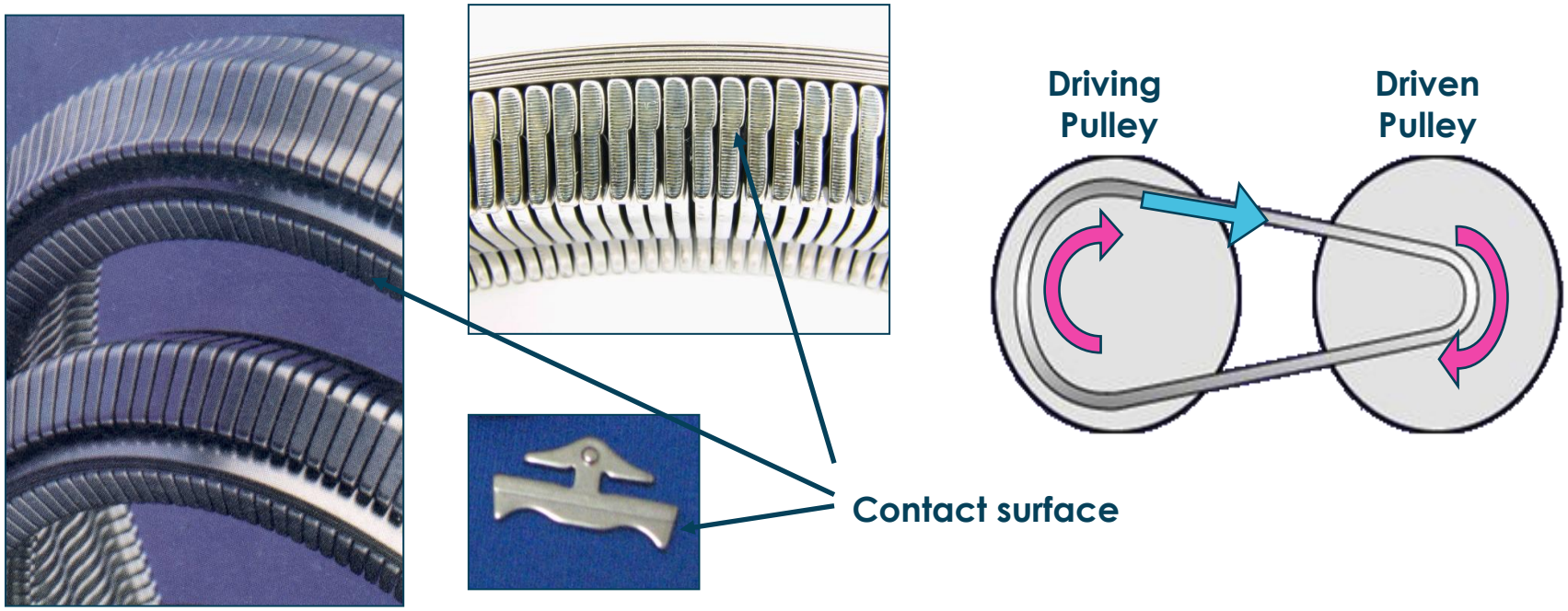
Metal ‘V-belt’ and conical pulley system

- Gear reduction ratio = Ro / Ri
  - Defined by radius of belt travel on pulley
- High clamping forces prevent belt from slipping
- Radius of belt travel controlled by width of pulley

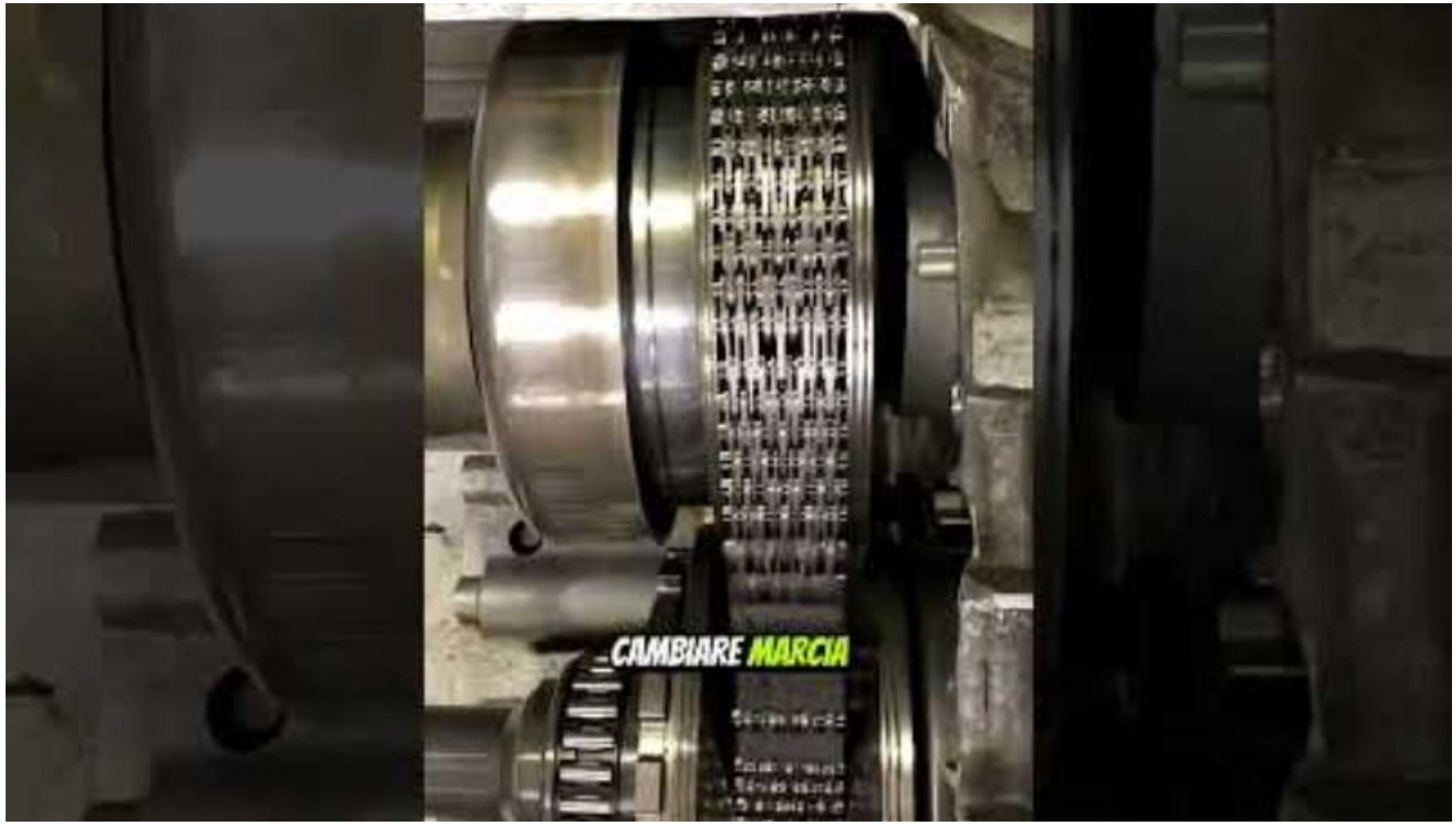


Continuously variable transmissions VDT - push belt

- Developed by Van Doorne Transmissie (VDT)
- Push belt consists of ~300 steel blocks connected by flexible steel rings
- Force transmitted from pulley to pulley via compressional forces between belt elements

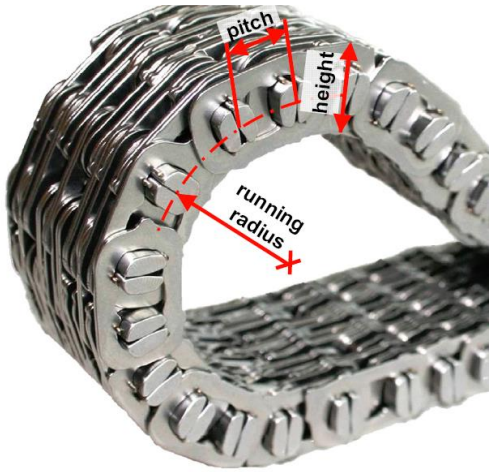


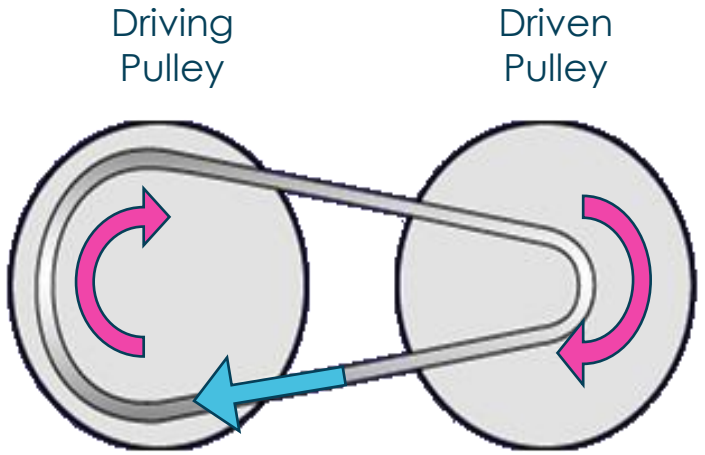
How CVTs work



Continuously variable transmissions LUK chain - pull belt

- Chain links joined by rocker pins
- Pulley clamping force acts on rocker pin ends
- Force transmitted by tension on chain links





Continuously variable transmissions fluid requirements

Steel-on-steel friction

Wear control
Fatigue and sliding wear control

Shear stability

High pressure pumps shear fluids aggressively

Oxidation stability

CVTs run hot
Fill for life application

Paper-on-steel friction

Starting clutch, torque converter clutch, forward-reverse clutch

All other conventional ATF properties

Hydraulic performance, antifoaming, transmission coolant, seal compatibility, non-corrosive

CVT fluid technology typical properties – commercially available fluids

- No public specifications exist for CVT Fluids
- Typical properties of commercially available CVT Fluids for VDT are shown opposite.

Properties	Typical Values
Kinematic Viscosity at 100°C Viscosity Index	~ 7.00 cSt ~200
Brookfield at -40°C	<9,000 cP
Shear Stability	<10% shear Loss KV100
Typical Elements	B, P, Ca (high level), some have Zn or Mg
Cu Corrosion	1b
Oxidation Stability	Exceed JASO 1A
4 Ball Extreme Pressure	Welding Load ~160 kg; Load Wear Index ~30
JASO Anti-Shudder Durability	Durability less than 100 hours
JASO Clutch Friction M348	MuD Change: ~10% Max. Mu0/MuD: 0.91 – 1.12 Min MuT: ~0.11
Steel on Steel (SOS) Friction	0.11 – 0.13 for NS-2, TC, HCF-2, Audi CVTF, ZF CVTF 0.09 – 0.11 for HMMF

VDT: *Van Doorne Transmissions*

CVT summary

A CVT has few parts compared to other automatic transmission types

- Uses two variator pulleys and a belt or chain instead of a planetary gear set
- Has a continuum of gear ratios rather than discrete steps of ratio

CVTs allow for a smoother power delivery

- Power can be optimized for acceleration or fuel economy

CVTs cannot handle higher torque applications

CVT Fluid needs to do everything a normal ATF does, but with steel-on-steel friction performance as well

Fluid requirements comparison CVTf vs DCTF vs ATF

OEM Requirements	CVTF	DCTF	ATF
Steel on Steel Friction	✓	✗	✗
Wear Protection	✓	✓	□/✓
Paper on Steel Friction	□/✓	✓	✓
Shear Stability	✓	□	□
Oxidation	✓	✓	✓
Air-release	✓	✓	✓
Gear Protection	□	✓	✓

✓: Major □: Minor ✗: Not Required

Automatic transmission fluids summary

Transmission trends

Stepped planetary transmissions remain predominant

- Increase in gear ratios to improve fuel economy
- Reduced size and weight
- Aggressive slipping clutch

Nonconventional transmissions gain market share

- CVT growth in Asia and North America
- DCT growth in Europe and China
- RED and DHT growth from electrification

Automatic transmission fluids summary

Fluid Trends

OEMs specify ATF with:

Exact friction requirements

- Anti-Shudder Durability
- Friction Durability

Specific viscosity and shear stability requirements

Better oxidation performance for longer drain intervals

Low Viscosity ATF becoming more predominant

- Improved fuel economy
- Longer oil drain intervals

Service-Fill market preference towards Multi-Vehicle ATF

CVTs and DCTs require genuine OEM fluids

Thank you

Formulating tomorrow together

Permissions