

ATF : 2020 status and where we go from here

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Automatic Transmission Fluid (ATF) is used as a lubricant for a car's transmission to optimise performance, by acting as a coolant to prevent overheating and to provide pressure and torque for power [1]. However, transmission fluid deteriorates over time and can become contaminated which calls for fluid changes and maintenance. There are various transmission fluids that are specific to vehicles with different transmissions such as regular automatic transmission fluid, motor oil, and heavy weight hypoid gear oil [2]. For higher quality purposes, synthetic transmission fluid is made through a chemical process which achieves longer durability and is less apt to oxidise and breakdown compared to regular transmission fluid derived from crude oil. Regardless of conventional or synthetic transmission fluid, Internal Combustion Engines (ICE) contribute to 23% of greenhouse gases (GHG) emissions which elevates the issue to a prominent area of concern [3]. Therefore, with the increased pressure by the Environmental Protection Agency (EPA) to reduce CO₂ emissions, Original Equipment Manufacturers (OEMs) are investing to incorporate alternative propulsion technologies of the future. Table 1 displays the goals of each automotive vehicle company and Figure 1. depicts the projections for global Light-Duty Vehicle (LDV) sales.

Volkswagen Group	By 2030 there will be at least one electrified version of each of the more than 300 VW Group models.
Volvo	Every car Volvo launches from 2019 will have an electric motor, placing electrification at the core of Volvo's future business.
General Motors	At least 20 new all-electric models will be brought to market by 2023 – the next step towards a zero-emissions world.
Ford	Increase investments in electrification to \$11 billion by 2022 and expand electrified vehicle line-up with a total of 40 vehicles globally.
Honda	Striving to electrify two-thirds of global automobile unit sales in 2030.
Geely	Intelligent Power Strategy introduced, with a promise to launch 30 new energy models by 2020.
Toyota	Aiming to achieve annual electrified vehicle sales of 5.5 million units by 2030 as part of its 'Environmental Challenge 2050'.

Table 1: Automotive vehicle company goals for the future [3]

Technology share of global light-duty vehicle sales

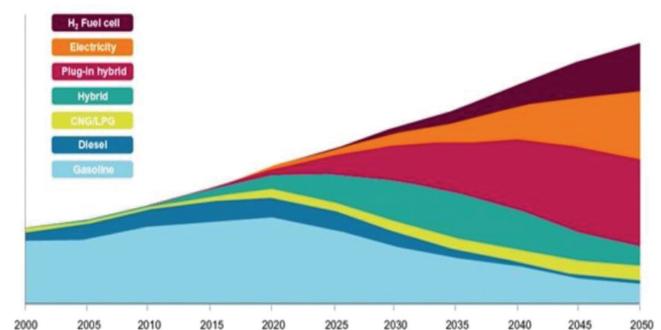


Figure 1: LDV future sales [3]

It is evident that OEMs are pushing for electric vehicles (EVs) to match new environmental standards.

Automotive companies strive to increase production and sales of electric vehicles and to shy away from ICE vehicles. Currently, hybrid vehicles are ostensibly rising in popularity due to having both ATF and electric. Through 2040, the global LDV market is projected to have the strongest growth in e-mobility coming from the sales of hybrid vehicles [1]. Hybrid vehicles incorporate both a conventional engine and an electric motor which still requires regular oil changes. In the coming years, hybrid transmission use is predicted to soar, and the usage and production of automatic and dual clutch transmissions will increase significantly [1]. Unlike manual transmission vehicles, automatic transmission vehicles change gears independently using a torque converter which is convenient and practical. However, it is salient to note that the development of EVs are rudimentary and face various barriers barring them from smooth growth [4]. Transportation, especially commercial transportation, is dominantly driven by ICE vehicles using petroleum-based liquid fuels such as gasoline and diesel [4]. Petroleum-based liquid fuels account for approximately 95% of transport energy and are projected to remain high despite the rise of EV and fuel cells [4]. Therefore, ICE vehicles are the most prudent and ensuring option for years to come, which raises the need for fuel economy improvements to reduce GHG emissions.

Gasoline Compression Ignition (GCI) engines and Octane on Demand (OOD) systems are alternatives that may serve as non-electrical approaches for improving efficiency and controlling noxious emissions [4]. Most cars utilise Spark Ignition (SI) engines which work by having an electric spark propagate fire to ignite fuel in a combustion chamber where a fuel and air mixture are compressed [4]. GCI differ by utilising glow plugs which heat up the compression chamber [4]. This process relies more on compression rather than spark plug and fuel contact which achieves higher efficiencies and EPA ratings [4]. OOD engine contains both high and low octane fuel; it operates

mainly with low octane fuel but uses high octane fuel when needed which aids GHG reduction [4]. With the continual improvement of these systems, it appears that automatic transmissions will continue to dominate for years to come.

While ICE vehicles continue to grow, electric vehicles are brought up to prominence through partial electrification in the form of hybridisation [4]. Hybrid cars can be categorised into the following types of systems: mild hybrid, full hybrid, and plug-in hybrid [5]. Mild hybrid incorporates electrical power boosts but excludes the capability of electric-only drive [5]. Full hybrid has a wide range of capabilities and can provide all-hybrid operations but has limited electric motor power and battery storage [5]. Plug-in hybrid is a full hybrid with the capability of recharging the battery which elevates the power and speed when using electric-only mode [5].

Within these types, there are five different architectures: parallel, series, power split, through the road, and complex [5]. Each of these architectures have unique transmissions for operation. For example, power split hybrids solely use an electric variable transmission (EVT) due to their ability to operate in both series and parallel. Parallel hybrids are more versatile in that they can use a vast array of modified conventional transmissions such as Continuous Variable Transmission (CVT), Stepped Automatic (AT), dual clutch (DCT) and manual [5]. Currently, automotive companies are using conventional ATF for EVT transmissions and CVT fluids for parallel hybrid transmissions because the fluid performance requirements of hybrid vehicles vaguely resemble those of ICE vehicles which render the need for dedicated hybrid fluids unnecessary [5]. A salient note of concern is that hybrids, with an integrated electric motor and transmission, will have fluids that come in contact with the electric motor. The electrical properties of the fluid will need to be examined in these cases to gain a better understanding of the

fluid's electrical conductivity. Most fluids are noted to have a conductivity level between 0.9 S/cm and 8×10^{-9} S/cm at 100°C which qualifies it as an insulator [6].

Dual Clutch Transmissions (DCT) are rising in the market and generating more interest. DCT are different than AT in that it uses clutch plates, like a manual transmission, rather than relying on a torque converter [7]. While the gears can swap automatically, there is also an option to use paddle shifters to manually shift the gears giving it more versatility [7]. AT is explicitly the simpler and more convenient option, but there are an ever-growing band of enthusiasts who prefer DCT because they want more control of their gear changes. Compared to AT, DCT are efficient because they use fewer mechanical components and slipping elements and has a high degree of freedom regarding gear ratios [8]. The salient benefit of DCT is that it improves fuel economy which entices OEMs to drive production [8]. There are two types of DCTs: wet and dry clutch [8]. Dry clutch systems have a lower torque application with smaller engines and requires Manual Transmission Fluids (MTF) [8]. Wet clutch systems have a higher torque application and require enhanced DCT Fluid (DCTF) which combines both gear protection quality of MTF and clutch friction control of ATF [8]. Wet clutch is divided into two designs: single sump for lubricating both gear and clutch or a separate sump for each [8]. Single sump designs are increasing in popularity, but the fluid needs to be explicitly designed for it to complement both the gear and clutch. Separate sumps involve using DCTF for clutch and MTF for gear box for optimal performance. A challenge to note is the need to limit shuddering when shifting gears while providing a high torque capacity. A well-balanced fluid will need to be formulated in order to achieve these goals in the future. Overall, DCTs are growing and are forecasted to grow higher than AT by 2024 which strongly emphasises fluid development for this type of transmission.

While DCT are expected to dominate the market for performance vehicles, continuous variable transmissions (CVT) are foreseen to remain popular for small automotive markets [9]. CVT is an automatic transmission that utilises a pair of variable width pulleys rather than gears for smooth acceleration [10]. Unlike AT, CVT allows for an infinite number of gear ratios and can allow operation at the optimum power band [10]. With that said, CVT is seen to only be viable for small cars with four-cylinder engines due to the difficulty of retaining optimal power at higher loads. Other than limited power capabilities, the relevant disadvantage of CVT is the absence of the gear shifting sensation which changes the experience of driving and is unnerving for some drivers. CVT drivers described the feeling to be "rubber band" like and perceives constant slipping of the transmission [9]. However, overlooking the unorthodox sensation aspect, CVT is economically more affordable than DCT and is viewed to advocate simplicity when driving, which suits comfortably for non-intuitive drivers. Also, CVTs are expected to improve in their fuel economy while operating at optimal speeds.

CVTs may also aid the engine reliability and longevity since the engine is operating at an optimal and essentially constant engine speed (RPMs).

Currently, CVT uses CVT fluids which are more complex than ordinary ATFs and are more specific in their applications. CVT fluid is formulated with full-synthetic, premium-based oils, friction modifiers, anti-wear additives, and shear stability modifiers to improve oil lifetime [11]. While ATFs focus primarily on friction control to alleviate resistance in the gears, CVT fluids are formulated to advocate friction to prevent the belts from slipping on the pulley system. Since CVT fluids are applicable for a smaller niche of transmissions, its future lies on the level of dominance of DCT and whether consumers can adjust and accept the eccentric sensation of the transmission.

Global production of DCT

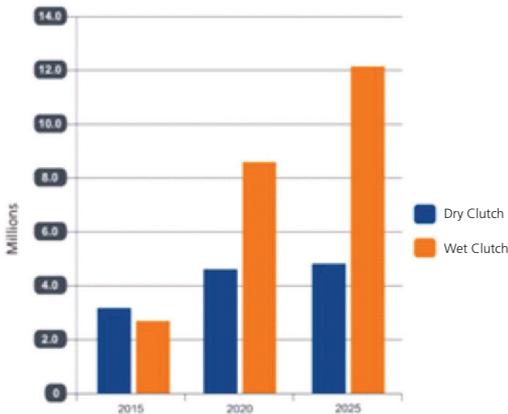


Figure 2: Global production of DCT [8]

Estimated global DCT production 2025



Figure 3: Global production of DCT vs China [8]

Aside from hybrid cars, electric vehicles (EV) are also predicted to gain traction in the future. In 2018, over 2 million EV were sold globally with China leading at 1.2 million followed by the U.S. [12]. China also leads in recycling lithium-ion EV batteries post auto use to keep costs down. However, while the battery recycling industry has potential, there is a lack of technology currently to recycle certain materials such as cobalt and nickel. Overall, EV vehicles eliminate pollution from ICE usage but the technology is nascent and still developing. It is continuing in its ascendancy in the industry due to demanding EPA regulations and is predicted to exceed 10 million EVs sales by 2025 and 50 million sold by 2040 [12]. EV is separated into two main facets: plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV). PHEV are

like conventional hybrids with both an electric motor and ICE but can be charged by plugging into an outlet and can operate on electricity and/or gasoline [13]. BEV are solely electric based and are less mature technologically compared to PHEV.

Currently, EV sales dropped significantly in the last few months which prompts concern for the future [14]. However, the long-term forecast for the market is smooth and ever-growing due to growing incentives and environmental regulations [14]. The current technical issue to address is the compatibility of the fluids due to electric motors being comprised of different materials in comparison to combustion engines. This means the electrical properties of the fluid must be modified to meet specifications. Electrical systems tend to operate above 48 V as opposed to 12 V which standard engines use [15].

The fluid must be modified to reach a balanced medium between conducting and insulating electrical currents; if the conduction is too high, there is a risk of current leakage. This would be immensely dangerous for anyone who comes in contact with the charged parts [15]. If the fluid is too effective in insulating, it could potentially cause static build-up and discharge which can damage the equipment [15], essentially by operating as a capacitor. Other plausible factors to consider include oxidation, sludge build up, and viscosity [15].

Oxidation deteriorates the oil and can increase conductivity as a result. Fluids that are prone to oxidation increase the chances of sludge build up which hinders the ability of the oil to reduce heat from the motor. Viscosity also plays a formidable role in thermal conductivity because oils with constant low viscosities allow proper heat transfer without decomposition [15]. To address these problems, additives to retain low viscosities may be included in the fuel to aid thermal conductivity. Another technical problem to address is battery energy density

and operation safety. In general, smaller and lighter batteries are more efficient and improve the overall performance of the vehicle.

2018-2019 EV Sales Comparison

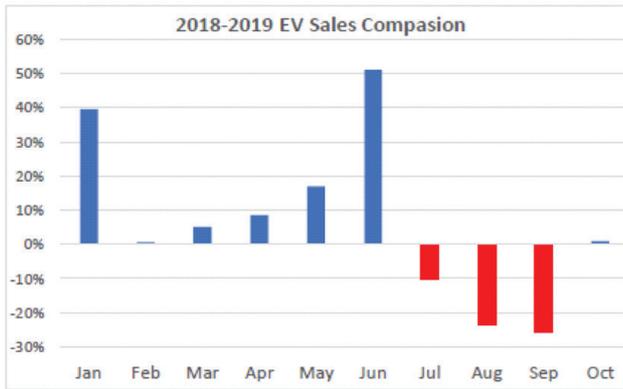


Figure 4: US EV sales in 2018-2019 [14]

Plug-In-Sales Year-Over-Year

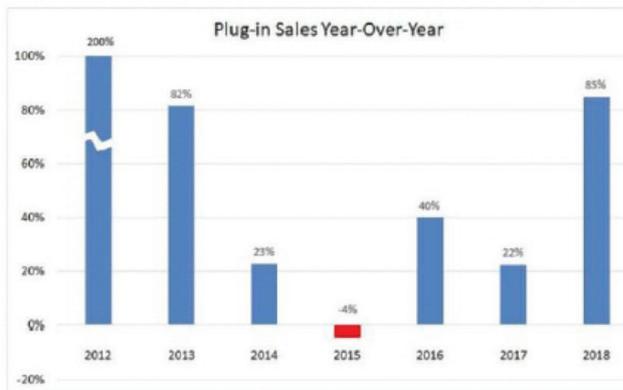


Figure 5: US Plug-in sales in last few years [14]

Also, many EVs presently use lithium ion batteries which raises the risk of fire hazards. In the next decade, OEMs are striving to resolve these issues by updating their technology for power batteries to utilise lithium air, alternative metal ion chemicals, solid state batteries, and high energy capacitors [16]. Potential goals of these technologies will be to improve the average mileage of 300-500 km and develop 240-400 KW ultra-high-speed charging to shorten charging times [16]. With the growth of e-mobility, there will be a strong push for

OEMs to increase production and create dedicated hybrid transmission fluids. Some major areas for improvement include higher volume resistivity to act as an insulator, thermal capacity to cool windings, and material compatibility as shown in Figure 6 [3].

The performance will also need to be modified to include friction, oxidation, and wear control [3]. It is found that using higher quality and less polar stocks such as Group III, III+ and IV can advance these fluids electrical and thermal conductivity properties. These higher quality stocks are tested for transmission fluid performance, and many seek to enhance durability while ensuring hardware protection via reduced viscosity. Viscosity is lowered from the typical 5.5 centistokes fluid to 4.5 centistokes fluids at 100°C with the plausibility of even lower numbers in the future [17]. Fuel economy was demonstrated to improve dramatically from 0.6% (Fluid A) to 2.3% (Fluid C) over the Factory Fill (FF Fluid) reference for fluids shown in Figure 7 [17]. The field trials had positive results indicating a green light for fluids to continue developing. Overall, a well-balanced formula for managing each property of the fluid is critical in achieving optimal performance.

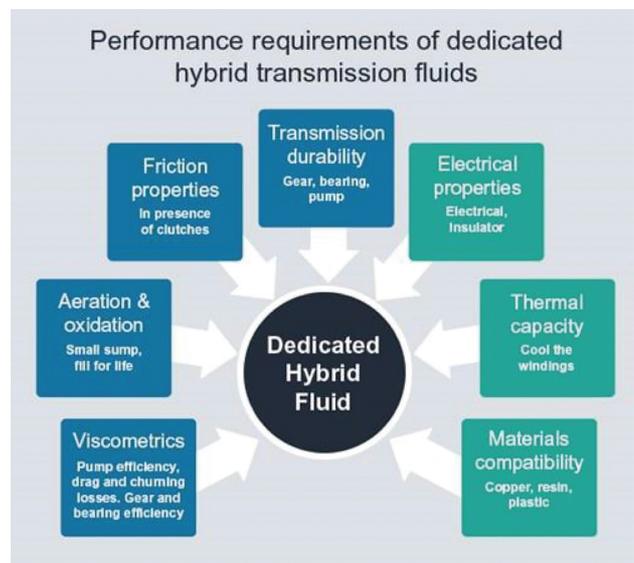


Figure 6: Performance requirements of dedicated hybrid transmission fluids [3]

Proper design of ATF matched with specific transmission can yield significant FE improvement

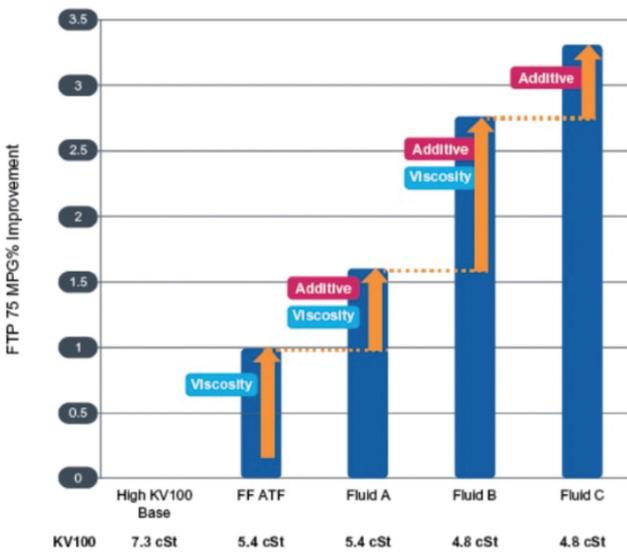


Figure 7: Fuel economy vs viscosity [17]

The transmission fluid industry is soaring in the U.S. and is projected to have a compound growth rate of 3.7%, reaching over 1.9 billion by 2025 [18]. The primary international competitor, China, is surpassing expectations and is on track to grow 5.3% over the next couple years [18]. China was prudent in forming alliances with strategic partners throughout history and was a leader in developing new machinery such as the 8-speed automatic transmission in 2007 [19]. Currently, China is focusing on fuel economy and is advocating AT as the preferred technological route [19]. They claim that the AT is the most developed technology compared to other transmissions and currently takes up more than 80% of the market share. Its driving torque range has the widest applications and is most suitable for heavy traffic environments in China [19]. Also, recent decades show that oil reserves have been increasing faster than consumption, which eliminates the concern for oil shortages [4].

However, China also looked in other directions and heavily pushed for the development of EVs in 2018

by providing considerable subsidies and incentives which drove up production and sales [12]. With a sluggish economy in 2019, China took their foot off the gas and decreased subsidies dramatically to encourage manufacturers to rely more on innovation rather than governmental assistance [20]. The EV market plummeted significantly, specifically the plug-in hybrids (PHEV), which dropped down 39% in the plug-in car market [21]. Amid these challenging times, all-electric BEV surprisingly rose 8% [21]. In 2020, China plans to phase out subsidies entirely which will give the market another setback. Nevertheless, it is plausible that in a few years, the automotive market in China will settle down and resume its dominance in this field. Overall, while AT vehicles are still dominant, electric cars are on the rise and both will be prominent for years to come which should alleviate concern in ATF markets for now.

Shengrui transmission production

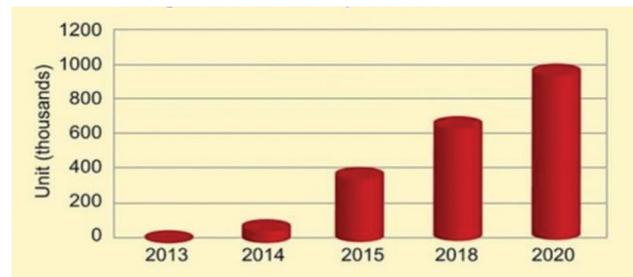


Figure 8: China's AT market forecast [19]

BYD Auto Co., Ltd.'s electric car sales are showing



Figure 9: EV sales in 2019 [22]

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Mr. Anson Law is part of a thriving internship program at Koehler Instrument company and a student of chemical engineering at State University of New York, Stony Brook, where Dr. Shah currently heads the advisory board of directors.

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