Challenges and Solutions in Hybrid Transmission Lubrication

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ICONIC Lubrificantes

ABSTRACT

The electrification process has significantly advanced in the global automotive market, with hybrid vehicles representing the majority of the electrified fleet in some countries, such as Brazil. One of the less evaluated but highly important factors in the performance of hybrid vehicles is the different demands for their transmissions. Different manufacturers have followed different designs for their hybrid vehicle transmissions, some tending towards transmissions that are the same or similar to traditional automatic transmissions, others with differentiated structures, more dedicated to the functionalities of this application, as in the case of DHTs, dedicated hybrid transmissions, which can be subjected to electrostatic sparks and magnetic currents.

Due to this scenario, lubricants dedicated to these applications have faced the challenge of adapting to different structures, one of the most significant challenges being compatibility with the materials used due to the electrical structure. Therefore, the present study aims to evaluate the corrosion and oxidation protection capacity of a standard ATF lubricant compared to a lubricant dedicated to hybrid vehicle transmissions. This evaluation will be carried out through copper corrosion tests at high temperatures and for long periods, as well as rust prevention analyses.

RESUMO

O processo de eletrificação tem avançado no mercado automobilístico, com veículos híbridos representando a maior parte desse mercado em alguns países, como o Brasil. Um dos fatores menos avaliados, mas de grande importância na performance dos veículos híbridos são as diferentes demandas para as transmissões. Diferentes montadoras têm seguido diferentes designs para suas transmissões de veículos híbridos, algumas tendendo para transmissões iguais ou muito similares a transmissões automáticas tradicionais, outras já com estruturas diferenciadas, mais dedicadas às funcionalidades dessa aplicação, como no caso de DHTs, transmissões híbridas dedicadas, que podem ser submetidas a faíscas eletrostáticas e correntes magnéticas.

Devido a esse cenário, os lubrificantes dedicados a essas aplicações tendo tido um desafio de se adequarem às diferentes estruturas, um desses desafios mais relevantes está na compatibilidade com materiais utilizados devido à estrutura elétrica. Por isso, este estudo avaliará a capacidade de proteção contra corrosão e oxidação de um lubrificante padrão ATF frente um lubrificante dedicado para atender transmissões de veículos híbridos. Esta avaliação será feita através dos ensaios de corrosão ao cobre à altas temperaturas e por longos períodos e análises de prevenção à ferrugem.

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INTRODUCTION

Environmental concerns worldwide have brought changes to various sectors in order to reduce pollutant gas emissions and mitigate the effects of global warming. In the automotive sector these changes have been brought mainly in the form of electrification of vehicles, especially light-duty vehicles. The electrification of vehicles grants a very significant reduction in the CO_2 emissions of this sector and it is more prominent in the light-duty sector considering it is less complex than the electrification of heavy-duty or off-road vehicles, considering their notably higher loads.

The light-duty vehicles electrification process has taken a couple of different routes over the last few years, with different alternatives from different OEMs, but can be mainly concentrated in mild hybrids, plug-in hybrids and battery electric vehicles. Mild hybrid electric vehicles, also known as MHEVs, are very similar to regular internal combustion cars but they have a small battery that is only charged by the internal combustion engine (ICE) and assists in the vehicle's performance. Plug-in hybrid electric vehicles, also known as PHEVs, also have internal combustion engines, but they have a larger battery, with a higher autonomy, allowing the car to function through certain extensions (depending on manufacturer) exclusively using it. Besides a larger battery, plug-in hybrids batteries are also directly chargeable. Finally, battery electric vehicles, also known as BEVs, are the ones without an internal combustion engine, running exclusively on electric motor [1].

While battery electric vehicles represent the most significant impact from the 3 models on the emissions reduction goal, it also presents a couple of challenges of implementation in a couple of places. Although the cost has been lowering over the last years, BEVs are still more expensive than internal combustion engine and hybrid cars in most places, considering the larger batteries' current cost. The absence of an ICEs also presents a need of infrastructure to charge the vehicles, that it is still being built in some countries. Considering those challenges, hybrid vehicles pose an interesting alternative for reducing emissions while avoiding some of the current issues for BEVs, especially in countries like Brazil where the infrastructure for charging is still in process of being built and the BEVs are still expensive [2].

Mild hybrid vehicles represent an interesting optimization in energy efficiency for cars, but given the small batteries the impact is limited. Plug-in hybrid vehicles represent a higher impact, allowing the benefits of an ICE vehicle, with the added efficiency and autonomy of a bigger battery. Global sales of plug-in hybrids have been constantly growing since 2014 and reached a peak of 17,3 million units in 2024, as seen in Figure 1. Consequently to its benefits of having an ICE and a larger battery, it also presents higher challenges to the lubrication.

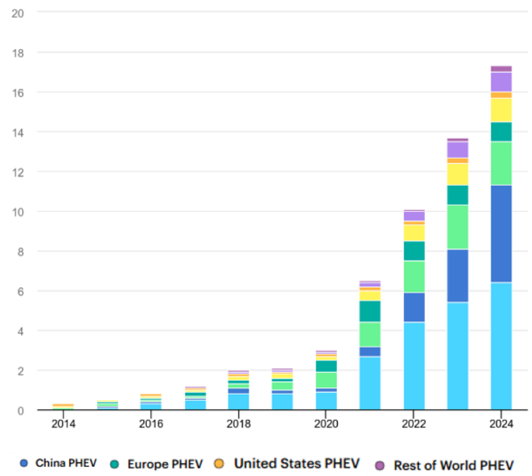

Figure 1. Global plug-in hybrid car sales, 2014-2024, in millions [3].

HYBRID TRANSMISSIONS LUBRICATION

Hybrid vehicles present a need for traditional engine oil lubricants, given the presence of the internal combustion engine, but they can also present some specific scenarios when it comes to the demands for transmission lubricants. Mild hybrids and plug-in hybrids introduce a new condition regarding the transmission, having to deal with more than one energy source, with different functioning characteristics. Mild hybrid vehicles present a smaller change in the powertrain system, given the lower impact the small battery has, but plug-in hybrids have a more significant change of scenario.

Transmissions for hybrid vehicles have varied largely throughout different OEMs (Original Equipment Manufacturers), with some keeping the same or very similar designs to traditional ICE vehicles automatic transmissions. However, especially on plug-in hybrids there have been some dedicated hybrid transmissions, or DHTs. Dedicated hybrid transmissions are transmissions designed specifically for those types of vehicles and encompass, in varying forms depending on manufacturers, the different configurations the power transfer can be executed in the system. Considering a plug-in hybrid, a type of DHT can possibly allow that the combustion engine directly powers the vehicle, while also allowing situations in which the electric motor directly powers the vehicle. It can also enable the engine to power the motor so it can directly power the vehicle and vice versa [4].

This setting creates different challenges for the fluids to be used in the lubrication of those transmissions. The power split unit, derived from the DHT can enable a range of operating conditions and with that it can demand of the lubricant contact with an additional load of electrostatic sparks and magnetic currents, demand higher thermal cooling, present a higher sensitivity to electric conductivity and to hardware material compatibility. Considering the possible presence of electrical structures, given the electric motor, the fluids are also more in contact with copper, a material highly used in these applications, so the compatibility and the corrosion protection of it are highly relevant to a lubricant in these transmissions [5].

Even though there are differences in the hybrid transmissions demands, traditional automatic transmission fluids (ATFs) have been used in several of those applications. Currently there are no institutional ATF specifications, but some OEMs have very well-known specifications that have become references for this market. One of those specifications is the General Motors ATF specification DEXRON. The DEXRON specification was first launched in the late 1960s to specify General Motors' requirements for automatic transmission fluids. The current version is known as DEXRON VI and was launched in 2006, while previous versions like DEXRON IIIH, from 2003, are still used in some countries, like Brazil [6,7].

As of today, there are still no standardized specifications for hybrid vehicles transmissions, neither from institutions nor from OEMs. The usage of traditional automatic transmission fluids is still common in these applications, but it is possible to see that the demands for lubricants in hybrid transmissions require a differentiated performance. This works intends to demonstrate the difference in performance between an older ATF product, categorized as a DEXRON IIIH, a current ATF product, categorized as a DEXRON VI, and a specific product for the hybrid transmissions demands, that also meets DEXRON VI specification requirements. This evaluation will be made focusing on these products' capacity to prevent copper corrosion, considering the relevance of compatibility with this metal in the hybrid vehicles. It will also be evaluated their rust-preventing capacity. The copper corrosion test will be conducted using the ASTM D130 standard in different temperatures and with adaptations. The rust-prevention test will be conducted following the ASTM D665 standard with different time durations [8,9].

METHODOLOGY

The copper corrosion test was conducted at 150°C for 24 and 48 hours and at 175°C for 6, 24 and 48 hours. The 150°C test was conducted according to the procedure of ASTM D130 but extending from the regular 3 hours test. The test is performed by placing a copper strip inside a test tube that is filled with the oil to be analyzed, the test tube is placed inside a vessel and this vessel is placed inside a silicone bath. After the stipulated amount of hours of the test is finished, the copper strip is removed from the test tube, classified according to the corrosion categorization chart from the standard, as seen in Figure 2.

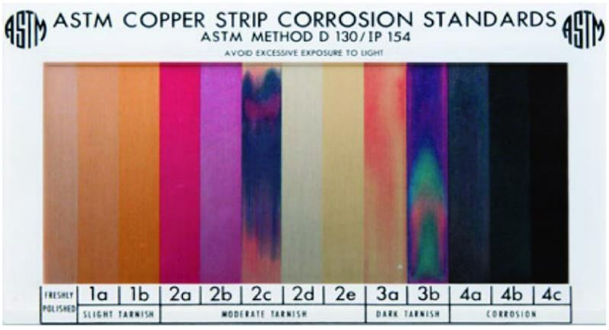

Figure 2. ASTM copper strip corrosion standard color chart [8].

The copper corrosion test at 175°C was adapted because the silicone bath did not reach the 175°C temperature. The copper strip was placed in a beaker, filled with the oil to be analyzed and said beaker was placed in a heating chamber with air circulation. The rest of the process remained the same as in the 150°C test.

The rust-prevention test was conducted in 60°C, as it is stipulated in ASTM D665, but conducted for 48 hours, while the standard stipulates a 24 hours test. The preparation procedure consists of mixing the oil sample with water in a beaker, introducing a steel test rod inside the beaker and a stirrer to keep the mixture homogeneous. The set is then put inside a liquid bath at 60°C. After the stablished time the steel test rod is evaluated for signs of rust.

RESULTS

The rust-prevention test did not show any sign of rust after the 48 h for any of the 3 products evaluated, as seen in Figure 3, showing a baseline high rust-preventing capacity of the fluids, not being a good fit to differentiate the products.

Figure 3. The 3 steel test rods after the 48 h test. Left to right: DEXRON IIIH, DEXRON VI and DEXRON VI hybrid product.

The copper corrosion test at 150°C for 24 hours did not show relevant changes in the copper strips, with all 3 of them having only a slight brightening of the copper tone, as can be seen in Figure 4. All 3 of them are categorized as 1B in the color chart from ASTM D130.

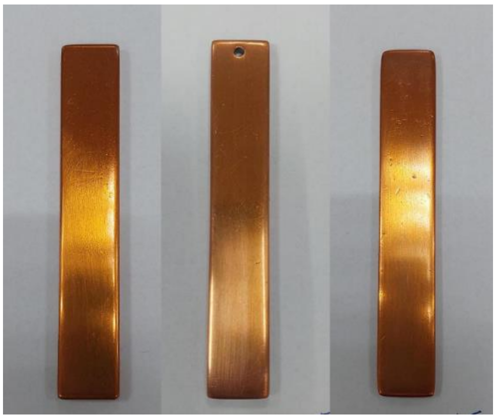

Figure 4. Copper strips after 150°C, 24 h, copper corrosion test. Left to right: DEXRON IIIH, DEXRON VI and DEXRON VI hybrid product.

In the 48 hours 150°C test both the DEXRON VI and DEXRON VI hybrid product tests presented a result classified as 1B, with the cooper strips remaining very close to the 24 hours test result, but the DEXRON IIIH product presented a harsher modification, with the copper strip showing a redish colored due to corrosion, being classified as 2A.

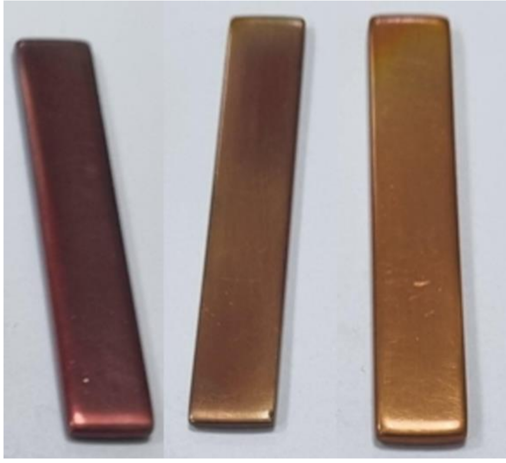

Figure 5. Copper strips after 150°C, 48h, copper corrosion test. Left to right: DEXRON IIIH, DEXRON VI and DEXRON VI hybrid product.

The copper corrosion test at 175°C for 6 hours already showed some differentiation between the products, as seen in Figure 6. The DEXRON IIH and DEXRON VI products' copper strips had a similar result, with bronze and dark tones unevenly distributed through the strips, being classified as 2C in the color chart. Meanwhile the DEXRON VI hybrid product strip presented only a darker shade of copper orange, being still classified as 1B.

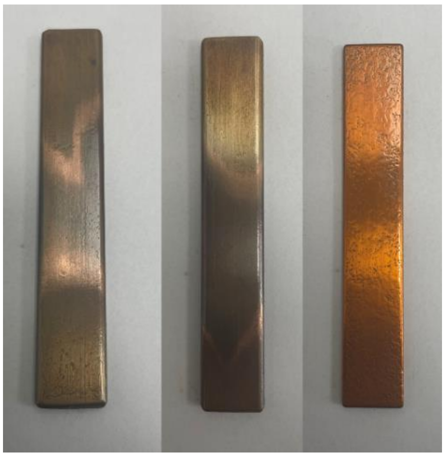

Figure 6. Copper strips after 175°C, 6 h, copper corrosion test. Left to right: DEXRON IIIH, DEXRON VI and DEXRON VI hybrid product.

In the 24 hours test at 175°C the difference between the fluids results was even more noticeable, as seen in Figure 7. The DEXRON IIIH test showed a full dark copper strip, being classified as 4B. The DEXRON VI test showed a dark bronze and black tones strip, with green shades, being classified as 4A, demonstrating a high level of corrosion but less than the dark black of the DEXRON IIIH product test. The DEXRON VI hybrid product test showed a significant less dark copper strip, with shades of red and green, being classified as 3B.

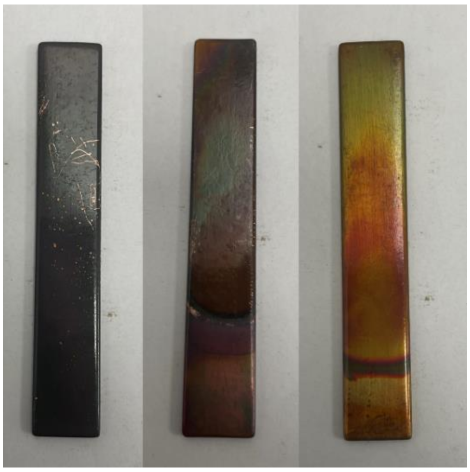

Figure 7. Copper strips after 175°C, 24 h, copper corrosion test. Left to right: DEXRON IIIH, DEXRON VI and DEXRON VI hybrid product.

Finally, the 48 hours at 175°C test showed extreme corrosion results for the DEXRON IIIH product, being classified as 4C. The DEXRON VI product test showed a better result, keeping a very similar result as the 24 hours test, being still classified as 4A. The DEXRON VI hybrid product test showed a less colored result than the 24 hours test, but with some darker tones, but kept in the same classification of 3B, as it can be seen in Figure 8.

Figure 8. Copper strips after 175°C, 48 h, copper corrosion test. Left to right: DEXRON IIIH, DEXRON VI and DEXRON VI hybrid product.

CONCLUSION

The rise of electrified vehicles poses a series of new challenges for their transmission lubricants. With new demands such as materials compatibility and the lack of stablished standards, it is relevant to study the importance of dedicated fluids for these applications and their advantages.

The rust-prevention test conducted in this study showed that the traditional ATFs have enough robustness in this category as the dedicated fluids, not being a fitted analysis to differentiate these oils.

The copper corrosion test was able to demonstrate the difference in performance in this category between the older fluid (DEXRON IIIH), the mainline ATF fluid (DEXRON VI) and the dedicated for hybrid transmissions fluid (DEXRON VI hybrid product). The copper corrosion test at 150°C is part of the requirements of the DEXRON VI specification, but restricted to 3 hours and the extension to larger periods and higher temperature (175°C) was able to show the differentiation between the products. Although the color chart form the ASTM D130 is a visual categorization and has limitation to categorize products, it was possible to see (in the classifications and on the general visual inspections) that the DEXRON IIIH product had an overall worst performance, keeping a relatively good result until 6 hours at 150°C but increasingly getting more distant from the others through the rest of the conditions. The DEXRON VI regular product shows a good performance in most of the parameters, especially in the 150°C test, but in the 175°C tests it was possible to visualize the performance gap in corrosion protection between it and the DEXRON VI hybrid transmission product.

It is possible to conclude that a dedicated transmission fluid product does perform better in the corrosion protection category than regular ATFs, showing the relevance of using the correct fluid, especially considering the high relevance that copper compatibility and copper corrosion protection have for hybrid vehicles transmissions.

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