Study of Tribological Characteristics of Continuous Variable Transmission Oils

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Abstract

Reduction of friction and wear of moving parts in transmission is very important in order to get the best fuel efficiency and reduce loss of power. At all times, there must be fluid film to separate moving surfaces. Efficiency of fluid film depends on the tribological characteristic of its viscosity and temperature. The objectives of this study are to investigate the anti-friction and anti-wear characteristics of PROTON Continuous Variable Transmission Fluid (CVTF) and HONDA CVTF in different operating conditions. Several rotational speed, temperature and load have been evaluated for data analysis using a Four-ball Tester Machine. A charge-coupled device (CCD) microscope has been used to measure the wear scar diameter on the ball bearing. Results show that the frictional torque values of HONDA CVTF are lower than PROTON CVTF at speed of 1000rpm until 2000rpm. The magnitude of frictional torque does not affect the value of wear scar diameter. The PROTON CVTF gives better CVTF performance based on the lower value of wear scar diameter as compared to HONDA CVTF.

Keywords

Frictional torque; coefficient of friction; average wear scar diameter; continuous variable transmission fluids

Introduction

Transmission oils have been generally utilized for quite a while since the automotive transmission began. It is vital because transmission operation needs a lubricant to reduce the friction of sliding surfaces between the metal contacts of mechanical components inside the engine and transmission. It is also used to prevent corrosion, transfer of heat and provide cooling. Continuous variable transmission fluid (CVTF) is used in vehicles with continuous variable transmission. It started to occupy most market share of all transmission installed in passenger cars by many automotive car manufacturers company, especially in Japan [1].

In particular, there is an increasing number of cars that are equipped with continuous variable transmissions (CVTs), which vary the ratios continuously without the use of stepped gears. The reason is that CVTs achieve better fuel efficiency than stepped automatic transmission fluid (ATF) [2]. Most CVT fluids contain combination of additives that improve lubricating qualities such as anti-wear additives, corrosion inhibitors, extreme pressure additives, detergents and dispersants, anti-foam additives, seal swell inhibitors, gasket conditioners and pour point depressant [3]. CVT is different compared to the step-type automatic transmission (AT), as step ATs employ friction plates with paper (cellulose) friction material, whereas CVTs have a steel interface between steel reinforced v-belts and pulley [4]. Each element of the chain must have conical sides that fit the pulley, because the belt runs on the outermost radius, requiring different friction properties, strong wear protection and high film strength.

EXPERIMENT

This research was conducted to evaluate the anti-friction and anti-wear characteristics of transmission oils by using Four-ball tester machine. For this experiment, three main components were involved which were the Four-ball tester machine, ball bearing and the lubricant. The test was conducted by using ASTM 4172 four-ball wear test standard to evaluate the wear protection properties of the lubricant. The average duration for each test was 60 minutes. The variable parameters for the experiment were speed and load. All the apparatus and equipment had been calibrated before starting the experiment. Wear scar diameter was measured after the experiment. The main purpose of measuring the wear scar diameter was to compare the effectiveness of the lubricants to protect the surfaces. Wear scar diameter was viewed on computer by using specific wear scar measurement software. Table 1 shows the Proton CVTF and Honda CVTF oils properties, wear additives, corrosion inhibitors, extreme pressure additives, detergents and dispersants, anti-foam additives, seal well inhibitors, gasket conditioners and pour point dispersant. Every transmission oil has their own viscosity index value. Lubricating oil that has high value of viscosity index is classified as good lubricating oil compared to those with lower value of viscosity index.

RESULTS AND DISCUSSION

Frictional Torque

The value of friction torque could be extracted straight away from the software. There were six sets of frictional torque data of CVTF, with three sets of speed and temperature.

Table 1: CVTF Oil's Properties

Properties	PROTON CVTF	HONDA CVTF
Viscosity @ 40°C, cSt	32	37.7
Viscosity @ 100°C, cSt	7.4	8.3
Viscosity Index	205	205
Flash Point, ˚C	192	340
Pour Point, ˚C	-40	-40

Figure 1 shows the value of frictional torque against variable speed for Automatic Transmission Fluids and Continuous Variable Transmission Fluid.

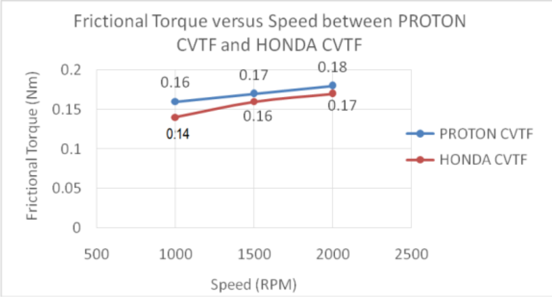

Figure 1: Graph of Friction Torque against Speed

The graph in Figure 1 shows that the values of frictional torque of PROTON CVTF were higher than HONDA CVTF when varying the speeds at 1000rpm, 1500rpm, and 2000rpm. At 1000 rpm, the difference of the frictional torque value between both lubricants was 0.02 Nm, while at 1500rpm and 2000rpm the value was only 0.01 Nm. The frictional torque of HONDA CVTF was assumed to be low due to its additives not being very effective at low speed and low temperature to generate frictional torque. The frictional torques generated for both fluids were increased at higher speed to ensure the fluid surface maintains and transfer the torque. It was assumed that, the surface films generated would be effective at low temperature and load. Based on Table 1, the viscosity of HONDA CVTF was higher than PROTON CVTF's viscosity at 40˚C and 100˚C. It was assumed that HONDA CVTF's anti-wear additive was higher than PROTON CVTF's anti-wear additive. However, since the speed did not change the viscosity very much, the HONDA CVTF frictional torque was not much different compared to PROTON CVTF at different running speed.

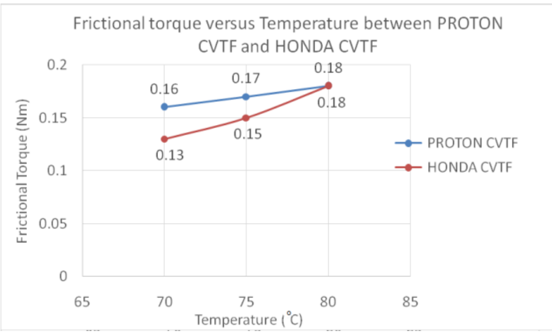

Figure 2: Graph of Friction Torque against Temperature

The graph in Figure 2 shows that the frictional torque of PROTON CVTF was higher than HONDA CVTF when varying the temperature from 70˚C and 75˚C, but at 80˚C, the frictional torque value between both lubricants was the same with 0.18 Nm. At 80˚C, HONDA CVTF, which had higher viscosity than PROTON CVTF at running temperature, started to effectively transfer frictional torque and maintain fluid film so that the friction torque would increase and become equal to that of PROTON CVTF. Normally, lubricant which has low viscosity would create very thin fluid film due to high temperature before the fluid film starts to break down due to high temperature that exceeds the limitation of temperature or flash point. As seen in Table 1, the PROTON CVTF's flash temperature was lower than HONDA CVTF's flash temperature.

Meanwhile, the frictional torque of PROTON CVTF was slightly higher than HONDA CVTF frictional torque at 70˚C and 75˚C. It was assumed that anti-friction and anti-wear additive concentration of Proton CVTF would be more active than HONDA CVTF anti-wear additive at these two temperatures. Meanwhile, the frictional torque of Proton CVTF and HONDA CVTF still increased at temperature of 80°C, but later the HONDA CVTF additives started to be very active. This is in accordance to the normal range of CVT operating temperature between 50°C-80°C. However, when the lubricant reaches its maximum temperature, it may dry out because of the high evaporation. Liquid lubricants lose their load carrying capacity at high temperature. So, at maximum temperature, the CVTF's fluid film will slightly break down faster than when increasing friction torque.

In addition, the frictional torque may be influenced by the oxidation rate. The rate of oxidation might increase with increase of temperature. When a lubricant experiences high temperature, its fluid film will become thinner. It was observed that, the rate of oxidation for PROTON CVTF became higher than HONDA CVTF. Thus, the HONDA CVTF's anti-wear additive was higher than PROTON CVTF's anti-wear additive due to increase of temperature.

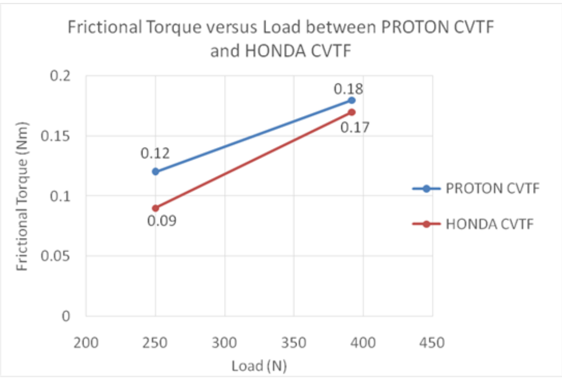

Figure 3: Graph of Frictional Torque against Load

Based on Figure 3, it can be seen that the friction torque of HONDA CVTF was lower than PROTON CVTF at loads of 250N and 392N. It was observed that at low load, both lubricants suffered less friction torque. As the load increased, the frictional torque became higher. When the speed of 2000rpm was used at applied load of 250N and 392N, the fluid film of HONDA CVTF became thicker than PROTON CVTF due its high viscosity, so there was less friction torque exerted on ball bearing for HONDA CVTF. When the applied load was increased, the temperature was also rapidly increased. Thus, at higher load, the PROTON CVTF's fluid film was assumed to break down slightly faster compared to HONDA CVTF.

Wear Scar Diameter

After one hour of test, the ball bearings were taken out from the ball pot and the four-ball tester machine. The wear scar diameter was measured by putting the ball bearings on CCD microscope as shown in Appendix B. The image of wear worn surfaces for several balls was taken by using high resolution microscope, as shown in Appendix D. The images and values of wear scar were taken by using the same device for all three ball bearings. Then, the average values of wear scar diameter were plotted in the line graph.

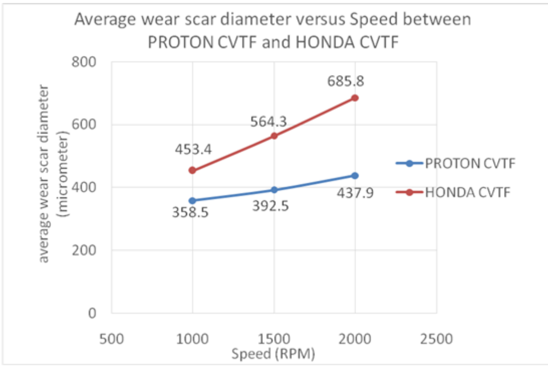

Figure 4: Graph of Average wear scar diameter against speed

Based on Figure 4, the wear scar diameters of PROTON CVTF were lower than HONDA CVTF at 1000rpm, 1500rpm and 2000rpm. This was due to its low viscosity which had provided good friction film to protect the ball bearing surfaces, and given low wear rate at low temperature. It was assumed that concentration of HONDA CVTF's anti wear additive was more than PROTON CVTF's anti wear additive. In addition, high viscosity will give appropriate amount of fluid film at running temperature [1].

The average wear scar diameter of PROTON CVTF and HONDA CVTF at 1000rpm was the lowest. It was assumed that PROTON CVTF's friction modifier and anti-wear additives were more active than HONDA CVTF. The molecules were attached to the surface to form a layer of molecules film which reduced friction and wear [5]. Friction modifier is effective especially at low speed. The anti-wear additives protect the contacting surfaces at higher temperature above the range of effectiveness by friction modifier. Its protective surface layer is usually more durable than that generated by friction modifier [1].

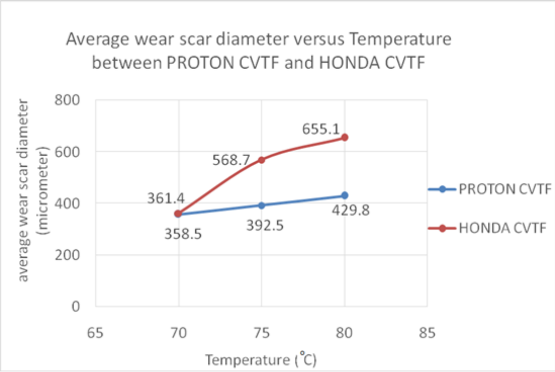

Figure 5: Graph of WSD against Temperature

Based on Figure 5, the wear scar diameter of PROTON CVTF was lower than HONDA CVTF at 70 ˚C, 75˚C and 80˚C. Low viscosity CVTF gave low wear rate at low temperature. It was assumed that concentration of PROTON CVTF's extreme pressure additive might be higher than HONDA CVTF's extreme pressure additive. That was the reason why at high temperature condition, the wear scar diameter of HONDA CVTF was much higher than PROTON CVTF. In addition, the HONDA CVTF's flash point was higher than PROTON CVTF flash point. Low value of flash point will give higher volatility of oil [5]. At elevated temperature, oils may be dry out because of evaporation, and the fluid film will become less and thinner.

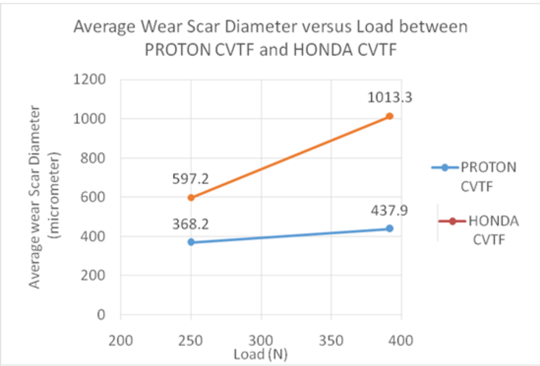

Figure 6: Graph of WSD against Load

Based on Figure 6, the wear scar diameter of PROTON CVTF was lower than HONDA CVTF at 250N and 392N. Low viscosity grade will give low wear rate at low temperature. It was assumed that concentration of PROTON CVTF's extreme pressure additive was higher than HONDA CVTF's extreme pressure additive. That was the reason why at high load condition, the wear scar diameter of HONDA CVTF was much higher than PROTON CVTF, as its fluid film became thin due to evaporation [6].

Conclusion

The frictional torque values of HONDA CVTF became lower than PROTON CVTF at speed of 1000rpm until 2000rpm. The magnitude of frictional torque did not affect the value of wear scar diameter. The wear scar diameter of the ball specimens increased with the increase in speeds from 1000rpm to 200rpm, temperature from 70˚C to 80˚C and load from 250N until 392N. As conclusion, PROTON CVTF gives better continuous variable transmission fluid performance and higher frictional torque as compared to HONDA CVTF.

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