Technology to Restore the Performance of used CVT fluids by Adding Additives

Akira SUGIMURA* Gou KATOU* Makoto MAEDA**

Abstract

Fluids for continuously variable transmissions (CVTs) are designed by our company to be non-replaceable. However, under certain operating conditions, the additives can deplete significantly, causing shocks during the engagement and release of wet clutches. This study explored the mechanism of additive depletion and its impact on the performance of fluids. The insights gained were then used to develop more effective the additives.

The effectiveness of the additive agent was tested in actual vehicles. The results confirmed that supplementing the additives reduced the shocks and prolonged the improvement compared to fluid replacement. Additionally, no adverse side effects were observed. These findings highlight the significant potential of the additive in restoring CVT fluid performance.

1. Introduction

In recent years, as global environmental concerns have grown, reducing CO_2 emissions throughout the product lifecycle and supply chain has become a critical issue for achieving a low-carbon, recycling-oriented society.

The lubricating oil used in continuously variable transmissions (CVTs), called CVT oil, developed and manufactured by our company is designed to be "fill for life" and does not require replacement. However, under certain operating environments and conditions, some performance of CVT oils can deteriorate and necessitate replacement. The waste oil generated during this exchange is typically incinerated, releasing CO_2.

While research into lubricant regeneration technology is ongoing[1], the CO_2 emissions resulting from energy consumption during the regeneration process have been identified as a new environmental concern.

Against this backdrop, restoring the degraded performance of the oil without replacing it is believed to reduce the amount of waste oil and, in turn, contribute to a low-carbon, recycling-oriented society. Consequently, we pursued the development of a technology to restore lubricant performance through additive supplementation.

2. Aims and objectives of this development

CVT oils are required to smoothly engage and release the wet clutch during forward and reverse shifts, as well as when the auxiliary gearbox shifts gears. However, if the oil deteriorates excessively, shocks may occur during engagement and release, leading to driver discomfort. The main cause of this issue is the depletion of CVT-oil additives, which most significantly impacts the friction property of the wet clutch (referred to as "wet clutch friction property ")[2].

Despite oil degradation, other performance aspects, such as the friction property of metal parts, hydraulic performance, and cooling efficiency, remain sufficiently intact. When a degraded lubricant is replaced with fresh oil to restore wet clutch friction property, approximately 8 L of waste oil is generated. This creates a significant burden on customers in terms of replacement costs and work time.

*Hardware System Development Department **Innovative Technology Development Department

Therefore, the present study aimed to develop an additive that moderates the shocks while reducing both the amount of waste oil and the customer burden by diluting the necessary additive to restore wet clutch friction property with base oil and adding it to the CVT oil.

The main technical objectives in this development are as follows.

Objective 1: The goal is to moderate shocks during the engagement and release of wet clutches and to ensure that the improvement (referred to as "durability") lasts as long as it would with a full oil replacement.

Objective 2: To prevent any impact on the friction property of metal components such as belts and pulleys (hereinafter referred to as Steel-on-steel friction property).

Objective 3: To avoid affecting the performance of CVT oil, even when additives are supplemented in excess of the prescribed amount or the amount in the fresh oil.

3. Consideration in solution methods

The types and amounts of the additives were examined by summarizing their functions (Table 1).

Table 1 Main functions of additives

Additives	Function
Friction modifier	Wet clutch friction adjustment
	Steel-on-steel friction adjustment
Detergent dispersant	Disperses contamination
	Neutralize any acid contents
	Wet clutch friction adjustment
	Steel-on-steel friction adjustment
Extreme-pressure additive	Steel-on-steel friction adjustment
	Prevents wear and seizure
Anti-oxidant	Prevents oxidation
Viscosity index improver	Viscosity index adjustment

Solution approach to objective 1

The mechanism of additive depletion is that the oxidized degradation products of the base oil, which are generated by the sliding heat of the components[3), trap the additives and deplete them. Specifically, the detergent dispersant and friction modifier (hereinafter referred to as "FM"), which control the formation of oxidized degradation products and wet clutch friction property, are consumed. Therefore, additives must be added to compensate for this depletion.

However, the formation of oxidized degradation products is accelerated by the catalytic effect of metal ions generated by the sliding of the unit components during driving[4). Therefore, to ensure that the durability is equivalent to that in the case where the oil is replaced with fresh oil, considering this effect is necessary to determine the amount of detergent dispersant to be added.

Solution approach to objective 2

In a lubricating environment where the steel-on-steel friction property is present, the temperature of the sliding surface is high. This condition activates the Brownian motion of FM with low molecular weights, making the adsorption of the FM onto the metal surface difficult.

However, if the FM is present in larger amounts than the extreme-pressure additive that controls the steel-on-steel friction property, the FM is adsorbed on the metal surface, thereby reducing the steel-on-steel friction. Therefore, the ratio of the extreme-pressure additive to the FM must be considered when determining the amount to be added.

Solution approach to objective 3

When additives are supplemented in excess of the prescribed amount or the amount in the fresh oil, the amount of additives in the oil becomes excessive. However, the state in which additives are adsorbed on metal surfaces is determined by the ratio of the additives present. Therefore, if the ratio of the additives in the supplementing agent can be optimized, the performance of the oil can be similar to that of the fresh oil, even if the additive is added to the fresh oil.

The amount of each additive agent was determined as follows: First, the oil with the greatest amount of additive depletion was selected from the recovered oils and those that had completed the durability tests, and was used as the used oil. The additive agents were designed such that, after being added to the used oil, the oil performance would be restored, and its durability would become equivalent to that of fresh oil after an oil change. Subsequently, the amount of the FM was determined by applying a safety factor to the amount required for the used oil. The amount of detergent dispersant was adjusted to match the detergency property of the fresh oil when added to the used oil. Next, the detergent dispersant and FM were added to the fresh oil to create an oil with excess amounts of FM and detergent dispersants. Finally, the amount of the extreme-pressure additive was adjusted through preliminary experiments to obtain the condition where the steel-on-steel friction property was equivalent to that of the fresh oil.

4. Confirmation of effectiveness

The detergency property (test method: JPI-5S-55-99), wet clutch friction property (test method: JASO M349), and steel-on-steel friction property (test method: JASO M358) were examined using CVT oil (fresh oil) and used oil before and after the addition of additive agents.

4.1 Confirmation for objectives 1 and 2

The detergency property and wet clutch friction property of the used oil after additive treatment were comparable to those of fresh oil, and the durability was restored to a level exceeding that of fresh oil (Figs. 1, 2, and 3). Additionally, the steel-on-steel friction property was also comparable to that of fresh oil (Fig. 4).

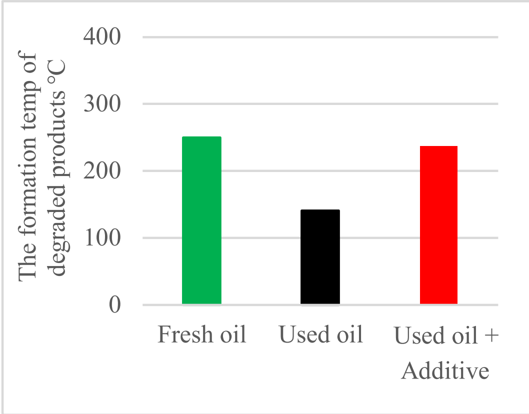

Fig. 1 Detergency test results

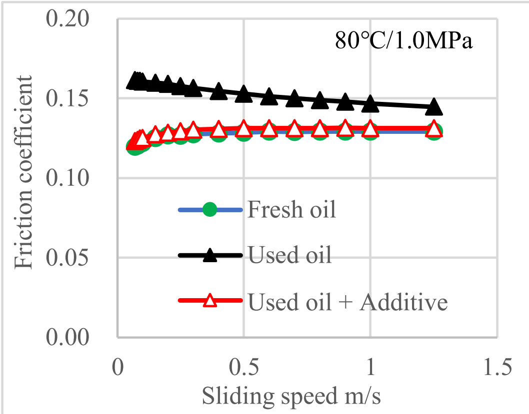

Fig. 2 Wet clutch friction test results

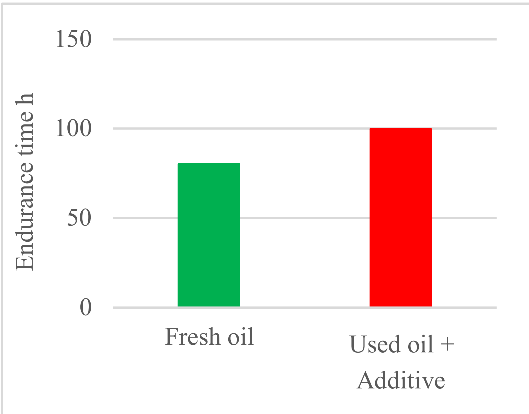

Fig. 3 Wet clutch friction endurance test results

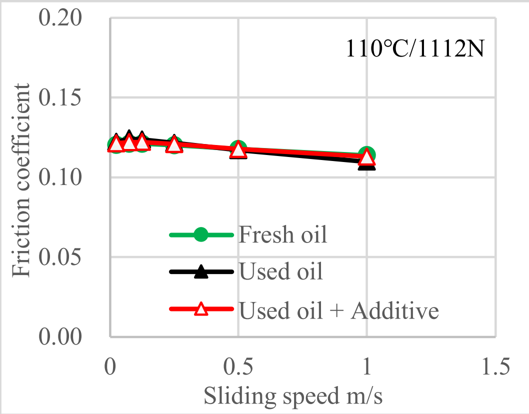

Fig. 4 Steel-on-steel friction test results

4.2 Confirmation for objective 3

The wet clutch friction property and steel-on-steel friction property were comparable to those of the fresh oil, even when the fresh oil was added to the agents (Figs. 5 and 6). The other performances were comparable to those of the fresh oil.

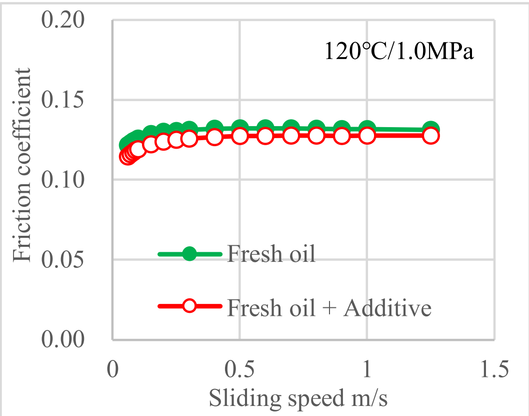

Fig. 5 Wet clutch friction test results

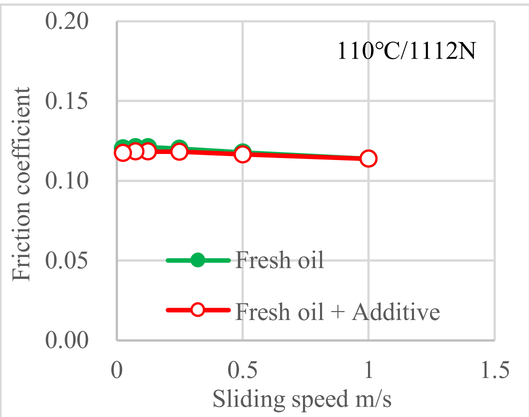

Fig. 6 Steel-on-steel friction test results

5. Verification using actual vehicle

Driving tests were conducted under conditions that accelerated CVT oil degradation, inducing shocks during wet clutch engagement and release. After shocks occurred, the agent was added to the oil, and the additive supplementation was confirmed to reduce the shocks. Continued driving tests demonstrated that the distance between shocks was longer than that with a fresh oil change.

The agent was added again, and further driving was conducted until the next shock occurred. These results confirmed that the effects and durability of the additives were reproducible. Additionally, multiple applications of the agent had no negative impact (such as seizure, wear, or damage) on the performance of the CVT unit (oil pressure, gear shift performance) or any of its components.

6. Summary

The present study developed an additive agent that moderates shocks during the engagement and release of wet clutches and has longer durability than that of a fresh oil change.

By adding the newly developed agent to our CVT oil, its performance can be repeatedly restored without compromising the overall effectiveness of the oil. Furthermore, the use of this agent reduces the amount of waste oil to just 0.5 L, significantly lowering the environmental burden compared to traditional oil changes.

The method of recovering oil performance using the additive agent developed in this study is an effective approach for realizing a low-carbon and recycling-oriented society, thus significantly contributing to the improvement of lubricant design technology.

7. References

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■ Authors ■


Akira SUGIMURA


Gou KATOU


Makoto MAEDA