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Deterioration of High Viscosity Index Hydraulic Fluids During Use in Construction Equipments

W.S. KWON and W.S. MOON

Taedok Institute of Technology, SK Corporation,
140-1 Wonchondong Yusonggu Taejon, 305-712, Korea

This study represents the newly advanced formulation of hydraulic fluids for extended drain interval and introduces the performance results of used oil samples from various excavators. The used oil samples, in this paper, show that there is a sharp change in viscosity drop and moderate additive depletion. For the extension of hydraulic fluid life, it is necessary to improve the stability of viscosity and oxidation. New target properties from the used oil analysis were proposed for extended life. Hydraulic oil with the viscosity index of 140 and improved thermal stability consists of group III base oil, showed the possibility of extension of fluid life

Keywords: extended drain interval, hydraulic fluid, used oil analysis, deterioration, long life

1. INTRODUCTION

Among major requirements for high performance hydraulic fluids, the longer drain interval has become one of their important performances in order to reduce the maintenance cost of construction equipments. Recently, many Japanese manufacturers have extended the drain interval recommendation of hydraulic fluids from 2000 hours to 4000 hours or 5000 hours in some cases to 10,000 hours.

For their applications to construction equipments, the requirements of hydraulic fluids are different from stationary ones because of their difference in operating conditions such as ambient temperature, operating pressure and temperature, tank size etc[1-3]. In case of construction equipments, high viscosity index (HVI) fluids are better for their easy start-up when they operate outdoor, which is usual. However, HVI hydraulic fluids are often accompanied by viscosity drop during use due to breaking down of viscosity modifier. In order to prevent the viscosity drop during use, it is necessary to reduce the concentration of viscosity modifiers by formulating with high viscosity index base oil.

The conventional hydraulic fluids used to adopt and even now use ZnDTP as an antiwear additive, but ZnDTP can sometimes be decomposed to form sludge on parts. In order to prevent the sludge problem, the hydraulic fluids are generally formulated to contain ZnDTP as low as possible. According to a previous study, the addition of proper dispersants can effectively reduce the formation of sludge without other negative effects, such as low oxidation stability, antiwear properties etc[4]. More fundamental approach for preventing sludge is to design the hydraulic fluid as completely ashless, that is, to contain no ZnDTP. For construction equipments, ashless antiwear hydraulic fluid has successfully replaced Zn type hydraulic fluid, but still it is expected that Zn type hydraulic fluid should be used for a while as a main line products.

In this paper, three kinds of Zn type commercial HVI hydraulic fluids were investigated with regard to their performance deterioration with operation time in excavators. While the operation conditions being monitored, used oils were sampled, analyzed and evaluated. Based on the acquired results, it is proposed that some specific improvements are needed to achieve the longer life of hydraulic fluids. Moreover, possible methods of their improvements are also proposed.

2. EXPERIMENT AND SAMPLING

2.1 Hydraulic fluid and test conditions

Three commercial-grade hydraulic fluids were selected for the investigation of the deterioration characteristics with operation. Oil A blended with a group III base oil, a low zinc type additive package and a viscosity modifier and its viscosity index was 168. Meanwhile, oil B of VI 177 blended with a high Zn additive package in a conventional base oil. Oil C of VI 140, a candidate for long life, was formulated with a group III base oil and an additive system with better oxidation and thermal stability.

Oil A and Oil B gathered about 22 samples and 29 samples, respectively, and each sample was collected from different types of newly produced excavators upon different operating time. Operation condition of every excavator differed from one another.

2.2 Changes in hydraulic fluid during use

Analysis and evaluation were conducted for the used oils in terms of viscosity, total acid number, antifoaming tendency, antiwear property by 4-ball wear test, contents of wear metal etc. Figure 1 shows the viscosity change of used oils along with the variation of operating time. At the initial stage of operations, viscosity drops sharply for all the oils tested. Oil B shows sharper change than Oil A because this contains more viscosity index improvers. At some stages, oil B's viscosity is out of range according to ISO 46 viscosity limit. On the contrary, oil C of VI 140 with group III base stock did not show initial drop.

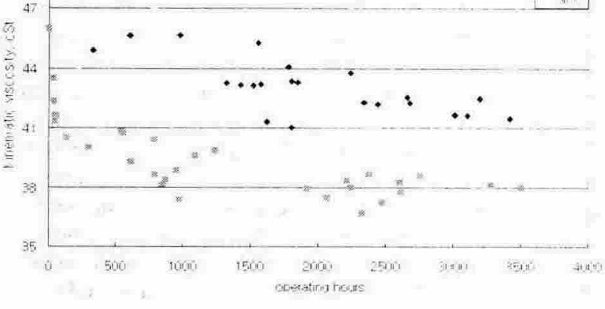

Fig.1 Change in viscosity with operation time

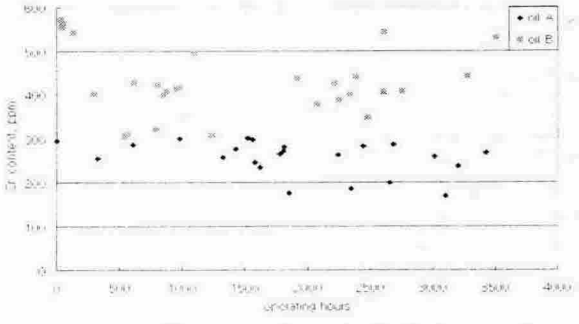

Fig. 2 Change of Zn content in used oils during operation

As shown in Figure 2, depletion of Zn in used oil was moderate and their content were kept at the initial level through the operation. Some sharp change in Zn content was suspected as contamination of R&O type fluid. Zn content was used as a measure for remaining antiwear additive. In 4-ball wear test, wear scar diameters were not changed drastically, which was indicated by the Zn depletion data.

In order to determine their remaining anti-oxidation capability, Rotary bomb oxidation stability test(RBOT) was conducted with the used oils. The results are shown in Fig.3.

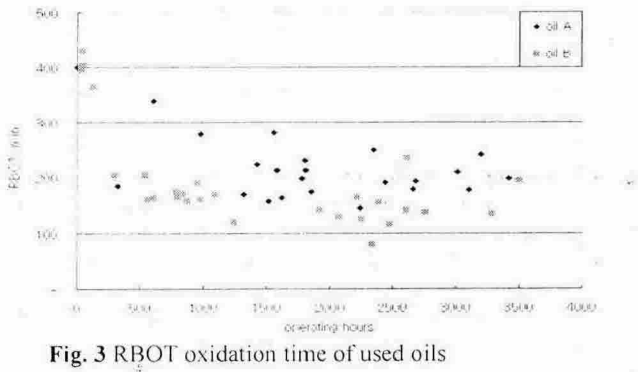

Fig. 3 RBOT oxidation time of used oils

For extended fluid life, improvements in oxidation stability is very important. As shown in the figure, Oil B, blended with a conventional base oil, had more drastic decrease in oxidation time during the early period in RBOT. The decrease of oil A is comparatively slow. Even though all samples did not show critically low levels, improvements in the sustaining antioxidation capacity are requested for longer life. According to the data, it is expected that RBOT would reach 100 min in 3000 hr with these oils. In order to be applied for longer life than 3,000 hr, the improvement of antioxidation capability is critical.

In case of total acid number, all samples did not show considerable increase, which also means there was no viscosity increase caused by oil oxidation. Wear amount of used oils were varied and scattered because wear rate were highly influenced by particles contaminated from outsides. Moreover, concentration of wear metal highly depended on equipments manufactures, i.e. machine design and materials.

In several samples, small amount of settled sludge was observed a... is possibly decomposed materials of additives.

3. IMPROVEMENTS BASED ON OIL ANALYSIS

From the used oil analysis and evaluation, it was found that two critical performance improvements are necessary to make long life hydraulic fluid. That is, stability of viscosity during use and the depletion of antioxidation capability are to be improved to satisfy the requirement longer than 3,000 hr. A new hydraulic fluid was developed based on 100% group III base oil and an additive system with Zn level of 500 ppm. Its viscosity index and RBOT oxidation time are 140 and higher than 700 min, respectively.

This oil could guarantee the minimum 300 ppm Zn after use in Korean construction equipments for 4,000 hours. As additive response of group III base stock was very well, hydraulic fluid with over than 700 min RBOT could be achieved. Oil C presented in Fig. 1 is this new formulation. Another important property was thermal stability. Sludge formation was evaluated using the CM thermal stability test method. As the standard test temperature of 135°C was so mild, both commercial products and the new product produced only less than 10 mg/100cc sludge. Considering that operating temperature of construction equipment is higher than stationary machine, test temperature was increased to 150 °C. Under the new condition , the new product and some Japanese ashless product generated less than 10 mg/100cc, while the other conventional products including low Zn type hydraulic fluid producing deposit over than 10 mg/100cc.

4. CONCLUSIONS

From the used oil analysis and evaluation with hydraulic fluids, the followings are concluded:

1) Conventional hydraulic fluids can not satisfy the recent requirement related to their long life. Two critical performance improvements are necessary to make long life hydraulic fluid. Stability of viscosity during use and depletion of antioxidation capability are to be improved.

2) In order to satisfy the long life requirements, a new hydraulic fluid was developed based on 100% group III base oil and an additive system with Zn level of 500 ppm. Its viscosity index and RBOT oxidation time are 140 and higher than 700 min, respectively.

For construction equipments application of hydraulic fluid, frictional behavior was also important. The use of dispersant should be considered to control sludge. However, friction control additive and dispersant can interact each other in terms of friction characteristics. Balance among additional additives should be considered as a next approach.

5. REFERENCES

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