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# Evaluation and Consideration of Fatigue Life in Mixture of Refrigeration Oil and Refrigerant

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For the prevention of global warming, global regulation of HFC refrigerants has begun. Low GWP refrigerant R1234yf (GWP:1) was proposed as the alternative to R134a (GWP:1430) for automotive air conditioner. In automotive air conditioner, refrigeration oil and refrigerant are mixed and lubricating the bearings. When the type of refrigerant or oil changes, the fatigue life of the bearing could also change. In this report, fatigue life were evaluated by changing the refrigeration oils (PAG, PVE) and refrigerants (R134a, R1234yf). As a result, the bearing fatigue life was longer in PVE than in PAG. It was also found that the fatigue life in R1234yf was shorter than that in no refrigerant or in R134a.

**Keywords:** bearing, fatigue, refrigeration oil, PAG, PVE

## 1. Introduction

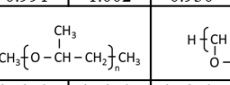
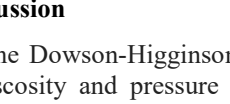
In the lubricating point of the automotive air conditioner, the refrigeration oil and the refrigerant are mixed and lubricating. Various bearings are used for the shaft of the compressor. R134a is being replaced by R1234yf. It is known that the bearing fatigue life is changed by the types of refrigerant and refrigeration oil. Understanding the effects of refrigerants and refrigeration oils on fatigue life is important basic data for compressor design. In this report, the differences in fatigue life were evaluated when the refrigerants or the refrigeration oils changed.

## 2. Materials and Methods

### 2.1. Test oils and test refrigerants

The test oil were polyalkylene glycol (PAG-1, PAG-2) and polyvinyl ether (PVE-1, PVE-2), which were generally used as refrigeration oil. In addition, R134a and R1234yf, which were common in automotive air conditioners, were used as the test refrigerants. (Table 1)

Table 1 Properties of the refrigeration oil and the refrigerants

| Oil | | PAG-1 | PAG-2 | PVE-1 | PVE-2 |
|---|---|---|---|---|---|
| Kinematic Viscosity, $mm^2/s$ | 40°C | 30.46 | 46.26 | 50.14 | 66.57 |
| | 100°C | 7.11 | 9.92 | 6.72 | 8.07 |
| Viscosity, mPa・s at 110°C | No Refrigerant | 5.0 | - | 4.6 | - |
| | In 0.5MPaG R134a/R1234yf | - | 5.0/5.0 | - | -/4.4 |
| Viscosity index | | 209 | 208 | 82 | 84 |
| Density at 15°C, g/cm3 | | 0.991 | 1.002 | 0.930 | 0.937 |
| Base oil Chemical structure | |  | |  | |
| Additives | Anti-oxidant | include | include | include | include |
| | Anti-wear(Phosphate) | include | include | include | include |

### 2.2. Fatigue life evaluation method

Bearing fatigue life was compared in the conditions shown in Table 2. Evaluation was carried out 6 times in the same conditions and weibull plots were created.

Table 2 Test conditions

| | |
|---|---|
| Bearing | INA 81104TN |
| Rotational speed | 1500rpm (2.16m/s) |
| Load | 7900N |
| Hertz pressure | 1.5GPa |
| Temperature | 110°C |
| Refrigerants (10wt%) | None, R134a, R1234yf |
| Oil quantity | 50mL |
| The number of test | n=6 |
| Fatigue detection | Vibration sensor |
| Evaluation | Weibull plots/ L50 |

### 2.3. Test Results

$L_{50}$ of PAG-1 was 44.1hr, and PAG-2/R134a was 40.5hr, which were almost the same results. On the other hand, PAG-2 / R1234yf was 23.4hr, which was shorter than the former two results. PVE generally had a longer fatigue life than PAG. $L_{50}$ of PVE-1 was 81.4hr and PVE-2 / R1234yf was 54.2hr.

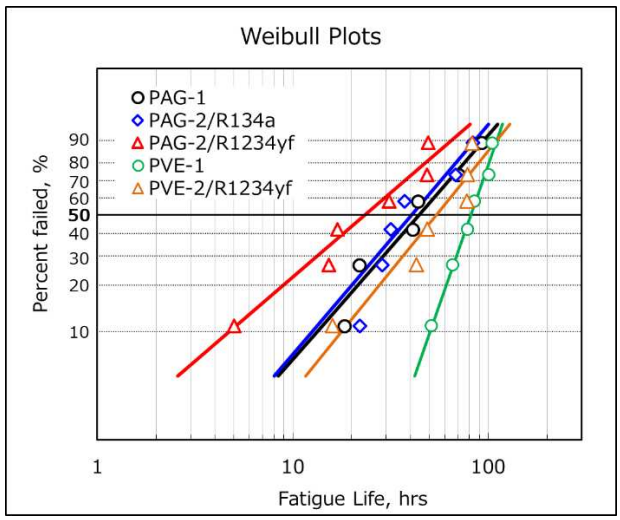



Fig.1 Weibull plots for PAG and PVE

## 3. Discussion

From the Dowson-Higginson equation, it is considered that viscosity and pressure viscosity coefficient α are related to minimum oil film thickness in the EHL region [1], which affects the fatigue life.

PVE had a higher pressure viscosity coefficient than PAG, and in the test conditions, α of PAG-1 is 11.1 and α of PVE-1 is 14.2. The difference of α have contributed to the longer fatigue life of PVE. Fatigue life in R1234yf was shorter for both PAG and PVE than without refrigerant. It is known that R1234yf contains an olefin structure and is easily decomposed and generate an acidic component. It is possible that the acidic component acted on the deterioration of the oil and the friction surface, which affected the fatigue life.

## 4. References

[1] J. C. Skurka : Elastohydrodynamic Lubrication of Roller Bearings Trans. ASME, F(1970) 281