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Abstract. This article analyses the impact of lubricants on engine performance, collates the evaluation criteria of existing engine lubricants, and uses Flowmaster to build model and analyse specific vehicle characteristics and evaluation indicators to obtain a model for the relationship between engine oil viscosity and oil consumption of oil pump. For the R&D goal, this model was used to formulate the lubricant components and prepare them. Vehicle tests show that the consumption of fuel oil for vehicles using research and development engine oil will drop by 12%, and noise will drop by an average of 7dB. The engine oil has the effects of energy saving, noise reduction and emission reduction.

1. Effects of Lubricant Quality on Engine Performance

1.1. Effects of lubricant on the economy of engine
The effect of lubricating oil on the economics of the engine is mainly to reduce the fuel consumption by reducing the friction coefficient of friction components. Taken the piston ring (friction loss accounts for 50% of the engine energy loss) as an example, the oil film thickness of the piston ring and the cylinder wall increases with the increase of the lubricating oil viscosity, the loss caused by the friction is also increased, which in turn increases the engine fuel consumption [1-2]. At present, the average fuel consumption per 100 kilometers of mini-vehicles is approximately 7.58L, and that of medium-sized vehicles is about 11.15L[3]. The friction loss of the moving parts of the engine accounts for 50%-80% of the mechanical loss, and reducing the friction loss of the moving parts can improve the combustion efficiency of the engine and reduce the fuel consumption.

1.2. Effects of lubricant on the engine emission
Under the same conditions of the engine, the lower the engine oil consumption and the lower the emission, the lubricating oil with the cylinder wall, the piston and the piston ring form a seal to the combustion chamber, and the reliable sealing will ensure the normal combustion of the mixture and reduce engine emissions. The current implementation is the fifth phase of the national vehicle emission standards, the fifth phase National standard requirements NOx emission limit of the I type vehicle is 0.06g/km in the type I test (see Table 1), which is less than the fourth standard 0.02g/km, NMHC and PM testing items have also been added. Under strict standards, emission reductions for engines rely mainly on electronic fuel injection (EFI) systems, exhaust gas re-circulation (EGR) systems, turbocharging technology, and gasoline direct injection (GDI). If lubricating oil is used to assist in reducing engine emissions, there will be huge environmental benefits.
Table 1. Emission limits of I type vehicle

| Reference mass (RM)(KG) | I type vehicle | II type vehicle | III type vehicle |
|-----------------------|----------------|----------------|-----------------|
|                       | -              | RM≤1305        | 1305<RM≤1760    | 1760<RM         |
| RM                    | all            | 1.00           | 1.18            | 2.27            |
| CO(g/km)              | 0.10           | 0.10           | 0.13            | 0.16            |
| THC(g/km)             | 0.068          | 0.068          | 0.090           | 0.108           |
| NMHC(g/km)            | 0.060          | 0.060          | 0.075           | 0.082           |
| NOX(g/km)             | 0.0045         | 0.0045         | 0.0045          | 0.0045          |
| PM(g/km)              | 0.0045         | 0.0045         | 0.0045          | 0.0045          |

1.3. Effects of lubricant on the engine noise
When the engine changes in a large working condition, the moving parts inside the engine will be subjected to a large vibration shock. The buffering action of the lubricating oil will absorb a part of the impact and reduce the vibration of the parts. At the same time, under the oil lubrication, the vibration generated during the engine friction is reduced, thereby the mechanical noise of the engine is reduced [5]. Under the cooling effect of the lubricating oil, the lubricating oil assists the engine to dissipate heat, and avoids the knocking due to the excessive temperature of the engine, thereby reducing the combustion noise of the engine. At present, the average indoor noise of small cars is about 65dB, and the average value of medium-sized cars is about 61.63dB [4]. Engine vibration will affect the service life of the engine, and the noise will affect the comfort of the vehicle. If the engine can reduce vibration and noise through the oil, it will improve the service life of engine and comfort inside the car [6-7].

2. Engine oil evaluation criteria
The development of lubricating oils requires corresponding evaluation standards to guide and regulate. Tab.2 is the lubricating oil testing standards established by some countries and organizations. In China's lubricating oil testing and evaluation standards, bench test method of the lubricating oil performance mainly uses the methods of the United States and Europe for reference, and in combination with the actual situation in China, it is modified or directly quoted from the methods in the United States and Europe [8].

Table 2. Lubricating oil testing standards of some countries and organizations

| serial number | Chinese name |
|---------------|--------------|
| GB/T 11145-2014 | Standard test method for measurement of low-temperature viscosity of lubricants-Brookfield viscometer method |
| GB/T 12579-2002 | Determination of foaming characteristics of lubricating oils |
| GB/T 12583-1998 | Lubricants-Determination of extreme pressure properties-Four ball method |
| GB/T 12709-1991 | Lubricating oils-Determination of aging characteristics-Conradson carbon |
| GB/T 2433-2001 | Petroleum products-Lubricating oils and additives-Determination of sulphated ash |
| GB/T 1995-1998 | Petroleum products--Calculation of viscosity index |
| GB/T 260-2016 | Test method for water in petroleum products-Distillation method |
| GB/T 265-1988 | Petroleum products-Determination of kinematic viscosity and calculation of dynamic viscosity |
| Standard | Description |
|----------|-------------|
| GB/T 3536-2008 | Petroleum products - Determination of flash and fire points - Cleveland open cup method |
| GB/T 6538-2010 | Determination of apparent viscosity of engine oils using the cold-cranking simulator |
| ASTM D 6082-2006 | Method for high temperature foaming characteristics of lubricating oils |
| ASTM D 5800-2008 | Standard test method for evaporation loss of lubricating oils by the Noack method |
| ASTM D5133-2005 | Standard test method for low temperature, low shear rate, viscosity/temperature dependence of lubricating oils using a temperature-scanning technique |
| ASTM D 6616-2007 | Standard test method for measuring viscosity at high shear rate by tapered bearing simulator viscometer at 100°C |
| ASTM D7098-2008e1 | Standard test method for oxidation stability of lubricants by thin-film oxygen uptake (TFOUT) catalyst B |
| ASTM D2783-2003(2009) | Standard test method for measurement of extreme-pressure properties of lubricating fluids(four-ball method) |
| ASTM D2984-2004a | Standard test method for low-temperature viscosity of lubricants measured by Brookfield viscometer |
| ASTM D 1091-2000 | Test methods for phosphorus in lubricating oils and additives |
| ASTM D 2711a-2001 | Standard test method for demulsibility characteristics of lubricating oils |
| DIN 51347-1-2000 | Testing of lubricants - testing under boundary lubricating conditions with the Brugger lubricant tester - Part 1: General working principles |
| DIN 51347-2-2000 | Testing of lubricants - Testing under boundary lubricating conditions with the Brugger lubricant tester - Part 2: General working principles |
| DIN 51352-2-1985 | Testing of lubricants; determination of ageing characteristics of lubricating oils; Conradson carbon residue after ageing by passing air through the lubricating oil in the presence of iron (III) oxide |
| DIN 51363-2-2003 | Determining the phosphorus content of lubricating oils and additives by wavelength dispersive X-ray fluorescence spectrometry |
| DIN 51375-2-2001 | Testing of lubricants - Determination of 1,2-ethanediol content of motor oils - Part 2: Gas chromatography |
| DIN 51453-2004 | Testing of lubricants - Determination of oxidation and nitration of used motor oils - Infrared spectrometric method |
| DIN 51834-2-2010 | Testing of lubricants - tribological test in translator oscillation apparatus - Part 3: Determination of tribological behaviour of materials in co-operation with lubricants |
| ISO 11007-1997 | Petroleum products and lubricants - Determination of rust-prevention characteristics of lubricating greases |
| ISO 11009-2000 | Petroleum products and lubricants - Determination of water washout characteristics of lubricating greases |
| ISO 24254-2007 | Lubricants, industrial oils and related products (class L) - Family E (internal combustion engine oils) - Specifications for |
3. Research and Development target

Based on the engine basic parameters of the target model, we developed an engine lubricant that reduces noise by 2--5dB, reduces fuel consumption by more than 10%, and reduces emissions. The target vehicle parameters are shown in Table 3.

| Item                  | Parameter | Item                  | Parameter |
|-----------------------|-----------|-----------------------|-----------|
| Cylinder              | 4         | Displacement          | 1.485L    |
| Cylinder diameter     | 74.7mm    | Stroke                | 84.7mm    |
| Compression ratio     | 10.2: 1   | Rated power           | 78kW      |
| Max. torque           | 139N·m    | Ignition order        | 1-3-4-2   |

According to the lubrication system model established in [9], the data of the same-displacement engine lubricants A (5W-20) and B (5W-30) with the best sales are introduced, and the software Flowmaster is used for modeling. According to GB/T265-88 kinematic viscosity measurement standard, the relationship between the viscosity and temperature of A, B lubricant is gotten at (20-100) °C, as shown in Fig.1. According to GB/T 1885-1998, the relationship between density and temperature of A, B lubricants at (20-100) °C is obtained, as shown in Fig. 2.

**Figure 1.** The curve of the viscosity and temperature
The calculation result is introduced into the equation of dynamic viscosity (1) to obtain the relationship between the dynamic viscosity and temperature of two lubricants A and B (Figure 3), and the relationship between the oil pump flow at different speeds (Figure 4) and the pressure drop of the oil pump (Figure 5).

\[ \eta_t = \nu_t \times \rho_t \]  

(1)

In the equation (1), \( \eta_t \) is the dynamic viscosity of the lubricant corresponding to \( t \) °C, and the unit is mPa·s; \( \nu_t \) is the kinematic viscosity of the lubricant corresponding to \( t \) °C and the unit is kg/m3; \( \rho_t \) is the lubricant density corresponding to \( t \) °C and the unit is g/cm3.

According to the JB/T 8886-1999, the oil pump efficiency is obtained, and the fuel consumption of the oil pump at different speeds is calculated according to the power consumption calculation formula (2), as shown in Fig.6.

\[ W = \frac{Q \times \Delta P}{60 \eta} \]  

(2)
In the formula (2), \( W \) is the power consumption and the unit is kW; \( Q \) is the outlet flow of oil pump and the unit is L/min; \( \Delta P \) is the pressure drop of oil pump and the unit is MPa; \( \eta \) is the oil pump efficiency.

![Figure 4. The relationship between flow and speed of oil pump](image1)

![Figure 5. The relationship between pressure drop and speed of oil pump](image2)

![Figure 6. The fuel consumption of the oil pump at different speeds](image3)

According to figures 3 to 6, it can be seen that, within a certain viscosity range, the low-viscosity oil has better flow characteristics, thereby reducing the energy required for the oil pump to overcome the frictional resistance of the oil pipeline, thereby reducing the energy consumption of the oil pump. That
is, through properly adjusting the viscosity of R&D lubricants, engine fuel consumption, noise, and emissions can be reduced to achieve the effect of energy conservation and emission reduction. Combined with the models in Figures 3 to 6, the main performance parameters for determining lubricants are shown in Table 4.

| item                              | Design parameter |
|----------------------------------|------------------|
| Density, g/cm³                   | 0.87             |
| 100°C kinematic viscosity, mm²/s| 10.3±0.5         |
| 40°C kinematic viscosity, mm²/s  | 55               |
| viscosity index                  | >155             |

| Table 4. The main performance parameters of lubricant |

4. Lubricant formula selection and preparation process

Lubricant formula is composed of base oil and additive. Literature [10] pointed out that poly-α-olefin (PAO) base oil can produce base oil with lower viscosity by means of oligomerization and hydrogenation. Therefore, base oil can be formed from 0%-60% of hydro refining base oil, 20-35% of poly-α-olefin (PAO), and 5-20% of diester, which meets the requirements of the R&D target. According to the R&D goal of lubricant, additives are used to adjust the characteristics of the lubricant, and the composition ratio of the developed lubricant is shown in Table 5.

| name                      | composition                                      | ratio         |
|---------------------------|--------------------------------------------------|---------------|
| Base oil                  | hydrogenated oil, poly-α-olefin, diester         | 81.0%~93.0%   |
| complex antioxidant       | phenol antioxidant, ZDD, ZDDP etc.              | 0.4%~3.5%     |
| viscosity index improver  | Polymethacylate styrene diene copolymer          | 2.1%~8.9%     |
| detergent                 | High base value calcium alkyl salicylate, High base value sulfurized alkyl phenol calcium | 1.4%~3.5%     |
| Pour-point depressant     | Polymethacrylate, alkyl naphthalene              | 0.3%~0.5%     |
| ashless dispersant        | Anhydride ashless dispersant, Polymer Isobutenyl Succinimide | 2.1%~3.8%     |
| friction modifier         | Zinc molybdenum ytterbium ion electromagnetic friction modifier, Nano Molybdenum Friction Improver | 0.2%~1.1%     |

The preparation process is shown in Fig. 7. First, the components of the base oil are put into the blending kettle in proportion, and the stirring is started. After the temperature is heated to 60-70°C, the pour-point depressant is added. After the stirring, a sample test was performed. After the 40°C viscosity, 100°C viscosity, and pour point data of the sample reached the design requirements for the lubricating oil parameters, then the composite antioxidant, detergent, and ashless dispersant were input. After stirring for 20 minutes, the friction modifier was input and continues to stir for 20-30 minutes at the same temperature. And stirred for 15 minutes, then viscosity index improver is added and stirred for 15 minutes. Samples are taken for parameter testing. The sample's detection parameters compares with design parameters. Fine adjustments are then performed until the design parameters are met and stirring is continued for 20-30 minutes. Let stay for 1 hour, wait for the lubricant to settle and conduct a real vehicle test.
Figure 7. Preparation process
5. Vehicle test

5.1. Vehicle test design

The energy-saving and noise reduction effects of the engine can be evaluated by measured noise and dynamic data stream parameters. Noise reduction effects of real vehicle test reference GB/T 14365-1993 for test design. In the test site to meet the standards, the maximum noise is tested when the engine speed is stable in three quarters of the highest speed then rapid declines to idle speed, and the test equipment use the model AR854 Xima handheld sound level meter.

At present, the national standard for fuel consumption of vehicle is GB/T 19233-2008. This standard measures and calculates the CO2, CO, and HC emissions of automobiles under simulated urban and suburban conditions and uses the carbon balance method to calculate the consumption of fuel. Because the research and development of lubricating oil is still in its initial stage, according to the national standard method, so there are certain economic difficulties in the instrument for the measuring of the CO2, CO, and HC emissions. Under the premise of the test method according to the requirements of the national standard, the dynamic data flow method is used to analyze the energy saving effect of the engine.

In OBDII, The formula of load value for the test is:

\[
\text{Load value} = \frac{\text{Actual air flow}}{\text{Maximum air flow (sea level)}} \times \frac{\text{atmospheric pressure (sea level)}}{\text{atmospheric pressure}} \tag{3}
\]

Since the maximum air flow and atmospheric pressure at the test site are basically unchanged, it is equivalent to a constant value during testing. At this time, the smaller the actual air flow, the smaller the load calculation value.

According to the mathematical model of air flow sensor established by Yan Chaoyong [11] etc., in the positive coefficient hot-wire air flow sensor, the relationship between air flow and hot-wire current can be seen as follows:

\[
I_H = \sqrt{\frac{R_H - R_f}{R_H R_f}} \left( A + B \sqrt{V} \right) \tag{4}
\]

Where: \( I_H \) is hot-wire current; \( R_H \) is hot-wire resistance; \( R_f \) is air resistance; \( A \), \( B \) is constant; \( V \) is the average air velocity.

By deriving the equation (4), the variation model is:

\[
\left( \frac{dI_H}{dV} \right) = \frac{R \sqrt{R_H - R_f}}{4 \sqrt{R_H R_f} \left( A + B \sqrt{V} \right)} * V \tag{5}
\]

Since A and B are constants, the change in the hot-wire current \( I_H \) is affected by the average air velocity \( V \), the hot-wire resistance \( R_H \), and the air resistance \( R_f \), that is, the size of the hot-wire current increases as the air flow increases. The size of the hot-wire current is used as the basis for the engine ECU to control the fuel injection. According to the air-fuel ratio formula, in order to maintain the optimum air-fuel ratio of 14.7, the smaller the air flow rate, the smaller the fuel injection amount and the smaller the fuel consumption.

According to GB/T 19233-2008, gasoline engine fuel consumption formula is shown as following:
\[
FC = \frac{0.1154}{D} \left[ (0.866 \times HC) + (0.429 \times CO) + (0.273 \times CO_2) \right]
\]

where: FC is the fuel consumption and the unit is L/100km; D is the density of the test fuel at 15°C and unit is kg/L; HC is measured hydrocarbon emissions and unit is g/km; CO is measured carbonic oxide emissions and the unit is g/km; CO2 is measured carbon dioxide emissions and unit is g/km.

According to formula (6), there is a positive relationship between fuel consumption and hydrocarbon, carbon monoxide and carbon dioxide, that is, the smaller the fuel consumption and the smaller the emissions, if the other conditions are constant.

Combined with the above formulas, by analyzing the change of engine OBDII load calculation value and injection pulse width, the engine fuel consumption and emissions changes are confirmed, and the effect of the development lubricating oil is ultimately determined.

5.2. Vehicle test

5.2.1. Debugging oil and A, B lubricant comparison test. The debugging oil (sample of R&D oil) was compared with A and B lubricants under the same model. The actual vehicle test was selected as a 1.5L displacement vehicle on the market, and A, B lubricants and debugging oils were sold on the market. The results of comparison tests are shown in Table 6.

|                  | A lubricant | B lubricant | debugging oil | Average comparison result |
|------------------|-------------|-------------|---------------|---------------------------|
| The urban road   |             |             |               |                           |
| Load value, (%)  | 25.88       | 26.11       | 24.31         | Drop 0.685                |
| Injection plus width,(ms) | 2.66       | 2.74       | 2.52          | Drop 0.18                 |
| Noise, dB        | 70          | 71          | 66            | Drop 4.5                  |
| The suburban road|             |             |               |                           |
| Load value, (%)  | 24.23       | 24.68       | 23.86         | Drop 0.595                |
| Injection plus width,(ms) | 2.56       | 2.59       | 2.48          | Drop 0.095                |
| Noise, dB        | 71          | 71          | 64            | Drop 7                    |

5.2.2. Universal test of debugging oil. The actual vehicle uses the model with the same displacement as the benchmark vehicle. Lubricating oil respectively are the original oil of the benchmark vehicle and debugging oil. The comparison test results are shown in Tab.7.

|                  | original oil | debugging oil | comparison result |
|------------------|--------------|---------------|-------------------|
| The urban road   |              |               |                   |
| Load value, (%)  | 19.2         | 18.8          | Drop 0.4          |
| Injection plus width,(ms) | 2.43       | 2.35          | Drop 0.08         |
| Noise, dB        | 70           | 65            | Drop 5            |
| The suburban road|              |               |                   |
| Load value, (%)  | 18.8         | 18.2          | Drop 0.6          |
| Injection plus width,(ms) | 2.27       | 2.21          | Drop 0.06         |
| Noise, dB        | 71           | 64            | Drop 7            |

6. Conclusion

It can be seen from Tab.6 that it is compared with the A, B lubricants, the calculated value of load is reduced by 0.685% in the urban driving conditions; the fuel injection pulse width is 0.18ms and the
noise is 4.5dB. In suburban driving conditions, the calculated value of load decreased by 0.595%; the pulse width was 0.095ms and the noise was 7dB.

It can be seen from Tab.7 that it is compared with original oil, the calculated value of load is reduced by 0.4% in the urban driving conditions; the fuel injection pulse width is 0.08ms and the noise is 5dB. In suburban driving conditions, the calculated value of load decreased by 0.6%; the pulse width was 0.08ms and the noise was 7dB.

Combining the data obtained in Table 6 and Table 7 with the formula 3-6, it can be seen that the developed lubricating oil has certain effects and advantages on energy saving, emission reduction and noise reduction of the engine, and also has practicality and versatility.

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