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May 21-25, 2017

EFFECT OF URBAN MODE VEHICLE RUNNING PARAMETERS ON ENGINE OIL PROPERTIES

TRACK OR CATEGORY

Lubrication Fundamentals I (Session 3G): Additives & Additive Degradation

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INTRODUCTION

Engine oil provides wear protection, thermal management, and corrosion inhibition functions that are critical to engine performance and longevity. Oil properties degrade with the prolongation of service time, and need to be drained to maintain the quality necessary to protect the engine [1]. Running mileage and time were commonly used to evaluate the oil quality. While the oil deterioration is a complex process affected by driving style, climate environment and oil types, etc. The mileage and time may cannot reflect the oil properties completely and effect the scientific determination of engine oil drain interval. Jagammathan et al. [2] considered the engine speed and load conditions to predict the oil properties deterioration with a network/fuzzy classification algorithm and a micro-mechanical system. Wang et al. [3] combined engine parameters (fueling rate, engine speed and engine load) with a special algorithm to indicate the oil quality. Jun H. B. et al. [4] used the engine running parameters obtained by engine mission profiles and engine oil viscosity to predict the oil properties with principal component analysis and regression method. However, the number of vehicle running parameters were limited and the relationship of vehicle running parameters and oil properties were not illustrated in above methods. Thus, the effect of vehicle running parameters on oil deterioration remains to be explored.

On-board diagnostics (OBD) system is a good method to obtain abundant and accurate vehicle running parameters. It original designed to monitor emissions with numerous vehicle sensors which are also capable of providing vehicle running information such as engine speed, mileage, running time, idle ratio, and number of starts, etc. [5]. In order to study the relationship of driving behavior and engine oil deterioration, OBD method was used to obtain complete and accurate vehicle real-time running information of an urban mode experimental car. The synchronous physical and chemical properties and composition change characteristics of two different engine oils were tested. The improved grey relational analysis method was used to study the effect of vehicle running parameters on lubricating oil degradation. The impact order of vehicle running parameters on oil deterioration can be obtained, which can provide a helpful reference for determining the oil drain interval scientifically.

EXPERIMENTAL DETAILS

The experimental engine oils were commercial Mobil Super 2000 SN 10W-40 semisynthetic oil (semisynthetic oil) and SL 5W-40 mineral oil special for Citroen engine (mineral oil). The experimental vehicle was Citroen-Triomphe 2006 civilian car with 2.0 L displacement, 200 N·m maximum torque and 11 compression ratio. The semisynthetic oil and the mineral oil serviced 4655 km and 3883 km, respectively.

The experimental car was driven by one driver in urban mode condition to retain the same driving habits. Lubricating oil samples were collected about every 30 days. The total acid number (TAN), kinematic viscosity (KV) of oil samples were tested according to ASTM D974-2014 and ASTM D445 standard. Initial oxidation temperature (IOT) of oil samples were determined with NETZSCH HP204 Differential Scanning Calorimetery (ASTM E 2009-02). The soot, oxidation, nitration, sulfation, gasoline, water, glycol and ZDDP (zinc dialkyl dithiophosphate) relative change values of engine oils were tested by Integra configured in NICOLET iS10 infrared spectrum. The vehicle running parameters included speed, idle time, idle ratio, mileage, engine running time and number of starts were acquired by OBD system.

RESULTS AND DISCUSSION

The running status of semisynthetic oil and mineral oil were shown in Fig. 1. The idle ratio (Fig. 1(a)) of both semisynthetic and mineral oil was mainly concentrated at 15% to 20%. Most of the vehicle speed (Fig. 1(b)) was less than 40 km/h. The single running mileages (Fig. 1(c)) was mainly less than 10 km. Most of single running time (Fig. 1(d)) was less than 60 min. The distribution characteristics of idle ratio, average speed, single running mileage and single running time of two kinds of engine oils were similar. They were high idle ratio, low running speed, short distance and short running time, which was the typical urban running condition.

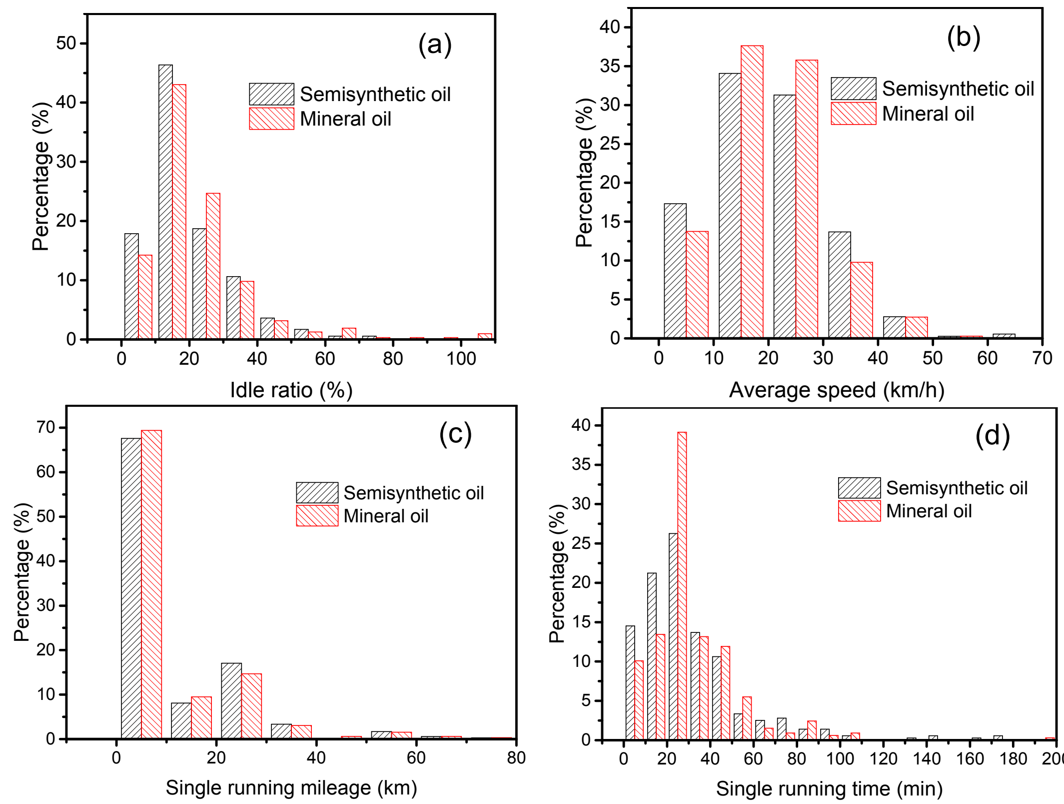

Fig. 1 Driving conditions distribution of experimental vehicle. (a) idle ratio, (b) average speed, (c) single running mileage, (d) single running time

The correlation degree determined by reference of reported grey analysis method [6]. The correlational degree of semisynthetic oil properties and running parameters were shown in Tab. 1. The correlational degree of each driving conditions to TAN were [γ (TAN, Monthly average speed), γ (TAN, Engine running time), γ (TAN, Mileage), γ (TAN, Idle time of engine), γ (TAN, Number of starts), γ (TAN, Monthly average idle ratio)]= [0.6305, 0.6061, 0.6061, 0.6047, 0.5572, 0.5819], where γ (TAN, Monthly average speed)> γ (TAN, Engine running time)= γ (TAN, Mileage)> γ (TAN, Idle time of engine)> γ (TAN, Number of starts)> γ (TAN, Monthly average idle ratio). It indicated the influence of the monthly average speed on the TAN was the highest. Other impact order of running parameters on semisynthetic oil properties could be obtained similarly. The correlational degree order illustrated that TAN, KV at 100ºC and IOT of semisynthetic oil had highest correlational degree with monthly average speed and monthly average idle ratio was the second. Oxidation and Nitration of semisynthetic oil were correlative with monthly average idle ratio most. Sulfation and ZDTP of semisynthetic oil had highest correlational degree values with engine running time. Overall, the influence of monthly average speed, monthly average idle ratio and engine running time on semisynthetic oil properties were the highest.

The correlational degree of mineral oil properties and running parameters were presented in Tab. 2. As Tab. 2 shown, the impact order of each running parameters on mineral oil properties can be calculated. The correlational degree order suggested that TAN, IOT, Soot and Gasoline of mineral oil had highest correlational degree with monthly average speed and the monthly average idle ratio was the second. Oxidation, Nitration and Sulfation of mineral oil were related with idle time of engine closely. ZDTP of mineral oil was affected most by mileage.

CONCLUSIONS

In this paper, the OBD system and synchronous test of lubricating oil assured the accuracy and real-time of vehicle running parameters and oil properties. The relationship of vehicle running parameter in urban condition and the lubricating oil properties were analyzed by improved grey relational analysis method. The results can be concluded that:

(1) The properties of semisynthetic oil and mineral oil are closely related with the monthly average speed, monthly average idle ratio and idle time of engine. Scientific of commonly used oil drain interval which was determined by mileage needs to get further researched. The running speed, idle time and idle ratio are the non-negligible important factors while determine the oil drain interval.

(2) The lubricating system of vehicle is complicated. The degradation of lubricating oil is coupled with mechanical and chemical action. The results of this study focused one vehicle, two different lubricating oils and typical urban driving conditions, more common results needs to enlarge the number of vehicles, kind of oils and driving conditions. OBD technology and lubricating oil properties analysis method in this paper can give some reference to determine the oil drain interval scientifically.

Table 1. Correlational degree of semisynthetic oil properties and running parameters

Correlational degree	Monthly average speed	Mileage	Engine running time	Idle time	Monthly average idle ratio	Number of starts
TAN	0.6305	0.6061	0.6061	0.6047	0.5572	0.5819
KV at 100ºC	0.6192	0.5815	0.5759	0.5710	0.6049	0.5656
IOT	0.6990	0.5821	0.5728	0.5712	0.6540	0.5582
Oxidation	0.5770	0.5566	0.5497	0.5365	0.5947	0.5346
Nitration	0.5492	0.5722	0.5634	0.5462	0.5855	0.5466
Sulfation	0.6133	0.8100	0.8109	0.7894	0.5881	0.8071
ZDTP	0.5716	0.6288	0.6333	0.6208	0.5550	0.6308

Table 2. Correlational degree of mineral oil properties and running parameters

Correlational degree	Monthly average speed	Mileage	Engine running time	Idle time	Monthly average idle ratio	Number of starts
TAN	0.5545	0.5233	0.5216	0.5213	0.5335	0.5242
IOT	0.6959	0.5276	0.5272	0.5241	0.6523	0.5279
Soot	0.6613	0.5994	0.5988	0.5996	0.6537	0.5981
Oxidation	0.5809	0.6979	0.6872	0.7106	0.5678	0.6757
Nitration	0.5804	0.7471	0.7397	0.7487	0.5699	0.7264
Sulfation	0.5631	0.7485	0.7374	0.7563	0.5486	0.7165
Gasoline	0.7001	0.6027	0.6011	0.6026	0.6953	0.5986
ZDTP	0.5889	0.7106	0.7032	0.7049	0.5937	0.6885

ACKNOWLEDGMENTS

The authors are grateful for the financial support from National Natural Science Foundation of China (No. 51575402) and National Basic Research Program of China (No. 2013CB632303).

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KEYWORDS
Vehicle running parameters; Grey relational analysis; Lubricating oil properties; Oil drain interval