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CHARACTERIZATION OF FRESH AND USED DIESEL ENGINE OILS BY DIFFERENTIAL SCANNING CALORIMETRY

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ABSTRACT

The characterization of fresh and used diesel engine oils by differential scanning calorimetry is described. It is shown that the oil stability decreases as the running distance increases. A significant relationship is observed between the amount of the heat evolved (ΔH) for fresh and used diesel engine oils and the corresponding values of the total base number (TBN), total acid number (TAN) and the viscosity measured at 100 °C.

INTRODUCTION

Thermal methods such as differential scanning calorimetry (DSC), differential thermal analysis (DTA) and thermogravimetry (TG) are applied successfully for rating the thermo-oxidative stability of automotive lubricating oils [1–4]. These methods have been used extensively to evaluate the performance quality of engine oils [5,6]. Oil degradation and contamination are the result of acidic combustion products (soot), in addition to the presence of dust and water which cause changes in oil properties [7,8]. An attempt was applied to evaluate diesel engine oil during its performance using differential scanning calorimetry, and the data obtained were correlated with some of its physico-chemical properties.

EXPERIMENTAL

Field test program

Oil samples were fully drained from the bus vehicles at 1000, 3000 and 5000 km running distance (manufacturer's recommended interval, 5000 km). The selected buses were subjected to normal maintenance at their depot. The main properties of the fresh and used diesel engine oils, which were the

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TABLE 1

The main properties of fresh and used diesel engine oils

Property	Analysis method	Fresh oil	1000 km	3000 km	5000 km
Flash point (°C)	IP 36/75	242	231	227	223
Viscosity at 100°C (cst)	IP 71/75	11.99	11.84	11.70	11.50
Total base number (mg KOH g^{-1})	IP 177/64	5.80	3.05	2.70	2.20
Total acid number (mg KOH g^{-1})	IP 177/64	1.70	1.80	2.33	2.80

average of results obtained from the three buses, were measured according to Institute of Petroleum (IP) standard methods, and are listed in Table 1.

Differential scanning calorimetric measurements

The measurements were performed in a Heraeus TA-500 analyser. A 10-mg oil sample was heated in an aluminium crucible at a rate of 10°C min^{-1} to 350°C in a static air atmosphere. Aluminium oxide was used as reference material, and duplicate measurements were made for each sample.

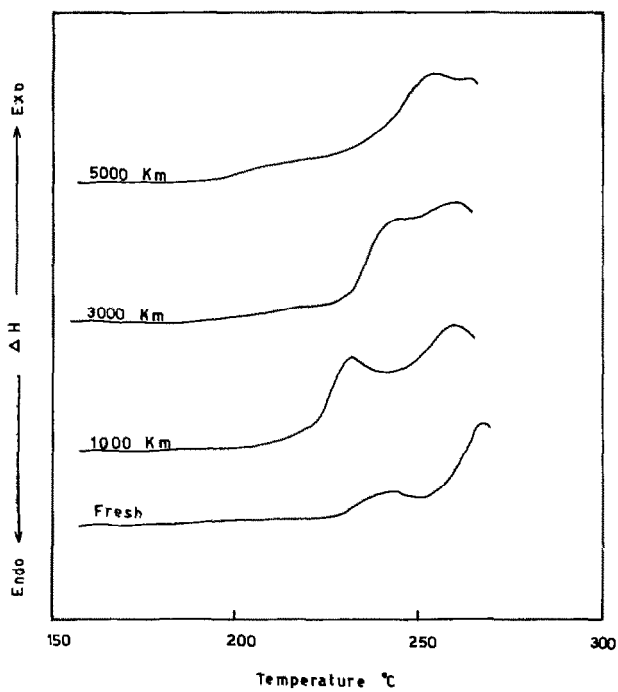

Fig. 1. DSC curves of fresh and used diesel engine oil in buses.

TABLE 2

Thermal data of fresh and used diesel engine oils

Thermal property	Fresh oil	1000 km	3000 km	5000 km
Initial degradation temperature T_i (°C)	222	204	201	184
Heat of degradation ΔH (kJ g^{-1})	11.2	13.0	14.8	15.2

RESULTS AND DISCUSSION

Figure 1 shows the differential scanning calorimetric thermograms which were obtained for the fresh and used diesel engine oils. It is clear from the figure that fresh diesel oil exhibits a higher thermal stability, and that degradation commences at 222 °C. It is observed that the thermal stability of the oil is inversely proportional to the running distance.

The initial temperature of the degradation (T_i) and the enthalpy values (ΔH) of the fresh and used diesel engine oils are shown in Table 2. In the temperature range 150–350 °C, the enthalpy values which are directly proportional to running distance could be attributed to degradation of the oil into lighter components, i.e. ΔH increased from 11.2 to 15.2 kJ g^{-1} as the oil was used, up to its 5000 km running distance.

A relationship was noted when plotting the viscosities at 100 °C of the fresh and used diesel engine oils against the enthalpy values (see Fig. 2). Figure 3 shows the relationship between the total acid number (TAN) and the corresponding enthalpy values of fresh and used diesel engine oils. It is clear from the figure that there is a non-linear and a directly proportional relationship.

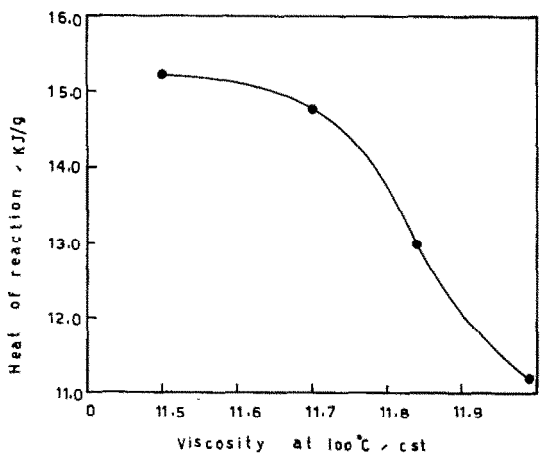

Fig. 2. Relationship between viscosity at 100 °C and ΔH.

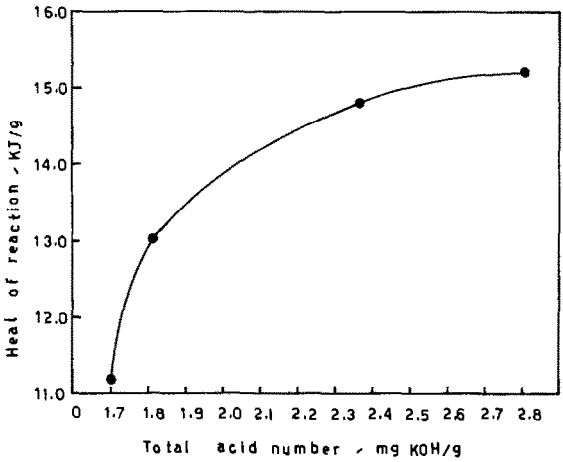

Fig. 3. Relationship between TAN and ΔH.

Figure 4 shows the non-linear relationship between the total base number (TBN) and the enthalpy values of fresh and used diesel oils.

From the results obtained, it is clear that differential scanning calorimetry can be applied successfully in characterizing lubricating oils during performance, and could be used as an indicative method in studying acidity, total base number (detergency), change in viscosity and oil degradation while in service.

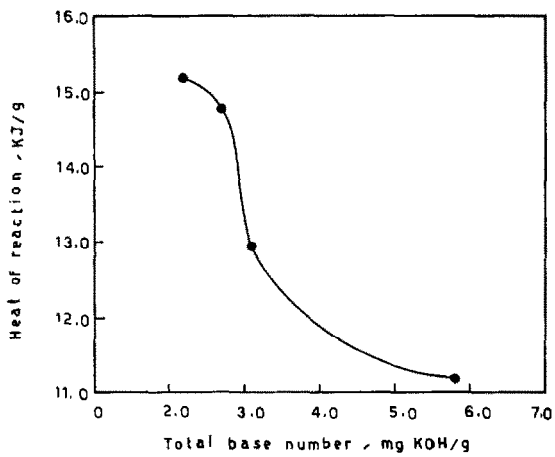

Fig. 4. Relationship between TBN and ΔH.

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