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Review

Lubricity assessment of gasoline fuels

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ABSTRACT

This paper presents the lubricity measurements of the three commercial gasoline types, unleaded gasoline (95 RON), new super or LRP (96 RON) and super unleaded gasoline (98 RON) and the effects of various physicochemical properties on lubricity. The results indicate that the nature of the fuel is an important factor for the lubrication properties of each type of gasoline fuel. The potassium content takes an active part in this and the amount that is added to the fuel doesn't seem to affect the final result of CWSD1.4 proportionally. A careful statistical approach to the data identified that, the composition, the sulfur and nitrogen contents, the oxygen content that is mainly contributed from the MTBE content and the viscosity, do affect the lubricity but in a different degree for each type of fuel. This differentiation of the properties' effect on lubricity, reinforces the idea of the complicated wear mechanism that takes place under the specific conditions of the experiments and the important role of the compositional characteristics of the fuel. Oxygen content and MTBE seem to maintain or even increase the wear mechanism. Chlorine was also detected on the metal surface of the specimens after scanning with electron microscopy (SEM).

Contents

1. Introduction

In the 1960s, the term "lubricity" was defined by Appeldorn and Dukek [1] as; "If two liquids have the same viscosity, and one gives lower friction, wear or scuffing, it is said to have better lubricity". It should be noted, however, that this definition was not strictly applied and many workers carried out lubricity researches on aviation fuels based on their own understanding of the concept [2–10].

In the late 1980s and early 1990s, environmental concern about the toxic and harmful emissions from diesel and gasoline engines led to large reductions in the amounts of sulfur content and the development of reformulated gasoline fuels.

The lubricating ability of fuels, because of their very low viscosity, depends mostly on their boundary film-forming properties. The history of fuel lubricity is associated with problems in engine performance as liquid-hydrocarbon based fuels must possess a modicum of lubricating ability to be able to protect high-pressure injection pumps and related fuel supply equipment from wear. The topic of gasoline lubricity has recently become more urgent with the introduction of direct-injection gasoline engines, which will necessitate high-pressure gasoline injection pumps, a development that is most likely to place considerably more emphasis on the lubricating ability of gasoline, accelerating wear

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Table 1
HFRR test conditions.

Test load	200 g
Test temperature	25 °C
Frequency	50 Hz
Stroke length	1 mm
Test period	75 min
Test ball	6 mm in diameter, 800 VPN (kg/mm^2), 0.1 μm CLA
Test flat	Mild steel, 190–210 VPN (kg/mm^2)

especially in rotary distributor fuel pumps [11, 12]. According to pump manufacturers this loss of lubricity may be the difference between fuels from a controlled laboratory environment and a cost-conscious production environment [13].

The modern processes of hydrotreating gasoline fuel to remove sulfur may reduce the fuel lubricating capability (from the year 2009, Euro 5 emissions specifications have defined the limit of 10 ppm S for the member states of E.U.). The lubricity of aviation kerosene and diesel fuel appears to arise from very small quantities of polar, quite high boiling point components. It is realized that the overcoming increase in the severity of treatment of gasoline fuels makes the analysis and identification of these components very difficult, as they vary greatly depending upon the origin of the fuel.

By the early 1980s, the antiwear properties of aromatic nitrogen compounds in lubricants had been observed by several workers [14]. However, their action mechanism was little understood.

Diesel fuel work has revealed that humidity, which reflects environmental water vapor pressure, can have an important influence on the friction and wear, although this was not taken into account in test work until very recently.

Humidity, different from relative humidity, is an absolute measure of the amount of water vapor or degree of dampness in the air [15, 16]. Relative humidity (RH) is the ratio of the actual vapor pressure of the air to saturation vapor pressure, usually expressed as a percentage. Unfortunately, humidity is often misused as a popular term for relative humidity, leading to incomparable results. In this study, water vapor pressure (WVP) was adopted as an index to represent the amount of water vapor, or humidity.

It is possible to eliminate, at least in a large extent, the influence of humidity on test repeatability of friction, wear, and film formation by carefully controlling humidity in a relative narrow range of 0.9–1.2 kPa.

The repeatability is thus quite good. It must be emphasized that test repeatability depended not only on test method, but also on test fuel. The wear behavior of some gasolines was found to be sensitive to the time of exposure to air in that the wear values obtained fell slightly after the fuel container had been opened several times. This may be due to the oxidation of gasoline components. Gasolines containing olefins, and dienes, in particular, have very poor oxidation stability [17–21].

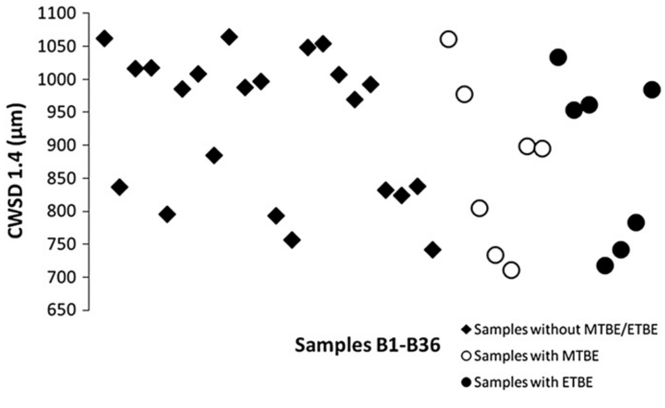

Fig. 1. Lubricity mean values (CWSD1.4 — corrected wear scar diameter at 1.4 kPa water pressure) for the non-additized gasoline samples B1–B36.

A survey of 35 low sulfur diesel fuels (sulfur content ranged from 1 to 498 ppm) has showed that in spite of high refinement most low sulfur diesels still contain considerable residual polyaromatics (0.3–2.2 wt.%) and diaromatics (2–11 wt.%) [14, 22]. A detailed analysis of correlation data has suggested that even in low sulfur diesel fuels, polyaromatics may still play an more important role than diaromatics in determining diesel lubricity.

In the case of gasoline, however, polyaromatics are absent due to the lower boiling range and only a few thousandths by vol. of diaromatics, i.e. naphthalenes, are found in gasolines. More than 99% of aromatics present in gasoline are monoaromatic, i.e. benzene and alkylbenzenes [17–21].

Fuel composition is a key factor in determining the lubricity of fuels. Fuel composition depends not only on the crude oil the fuel is prepared from, but also on the refinery process, finishing process, and blending method. The gradually increase in severity of refinement in recent years to meet tightening environmental regulations has simultaneously reduced the concentration of many potential lubricity agents and thus made fuel lubricity poorer and poorer [17–21].

Study of the lubricity of current gasolines has demonstrated that all non-additized gasolines tested gave clearly higher wear than that of a Swedish Cass I diesel fuel and much higher wear than those of other diesel fuels. There are considerable differences in wear between non-additized gasolines, which must arise from the difference in gasoline composition. Some retail, unleaded gasolines give very high wear but others produce lower wear, marginally lower than a Swedish Class 1 diesel fuel. Further analysis is difficult since details of composition and origin of these commercial gasolines were not available [17–21].

Gasoline lubricity is a complex phenomenon, involving many complicated and interconnecting factors, such as the presence of water, oxygenates diolefins, diaromatics, the effect of viscosity and the synergistic effect of different wear mechanisms. The lubricity mechanism of gasoline is quite different from that of diesel fuels that leads to severe adhesive wear. With low-sulfur fuels, adhesive wear is observed instead of corrosive and mild oxidative wear, and deposits build up on top land [17–21].

Metallurgy and mechanical properties of test specimens have important effects on the lubricating mechanisms of fuels. When the hardness of the lower specimen in an HFRR test is not enough to support the generated oxide films formed by the reaction between surfaces and dissolved oxygen and the adsorption films formed on top of the oxide films by gasoline polar impurities, severe adhesion and metal transfer occur [17–21].

Fuel quality in recent years became increasingly important, not only for its role in the actual performance of the vehicles, but also for its impact on the emissions. However, the fuel pump at the service stations is the point at which the actual specifications of the fuels should be ascertained. This paper presents results of a survey in gasoline samples obtained from pump service stations in Athens and Salonika, where the public buys its fuel.

In Greece, three main types of gasoline are available in the service stations: new super or LRP gasoline with a Research Octane Number of 96 (96 RON) for the non-catalytic cars, unleaded gasoline with a Research Octane Number of 95 (95 RON) and super unleaded gasoline with a Research Octane Number of 98 (98 RON) for newer cars equipped with a catalyst. Some service stations also sell super unleaded with a Research Octane Number of 99 or 100 (99 + RON) but the market share of this product is very small. Unleaded gasoline is the cheapest gasoline and it is marked with quinizarin, while new super and super unleaded gasolines have similar prices (and they are quinizarin free). This price difference is the main motive to mix the cheaper with the more expensive fuel. Most gasoline adulteration cases involve the illegal mixing of the cheaper unleaded into the LRP or super unleaded gasoline. Less common is the mixing of much cheaper heating fuel into the