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ADVANTAGEOUS AND DISADVANTAGEOUS PROPERTIES OF DIESEL FUELS OF LOW SULPHUR AND REDUCED AROMATIC CONTENT

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In the paper the different quality grades of diesel fuels of low sulphur and reduced aromatic content are summarized (on the base of various degrees of reduction in sulphur and aromatic content). The effects of reduction in sulphur and aromatic content on exhaust gas emissions, fuel consumption and wear of fuel pump and other parts of engine are presented. The possibilities for reducing and eliminating the disadvantageous properties (wear of the fuel pump and injection system, excess fuel consumption, etc.) by using different types of additives (cetane number improver, lubricity improver, etc.) are discussed. The improvement in lubricity of reformulated and additive containing diesel fuels is presented on the base of results of High Frequency Reciprocating Rig (HFRR) test.

Keywords: diesel fuel, hydrotreating, lubricity, biodiesel

Introduction

To achieve the requirements of the more and more stricter exhaust gas emission standards of diesel engines is only possible by combining improvement of fuel quality, enhancements of in-engine performance (for example: improvement of fuel injection systems, redesign of the combustion chamber, control of charge air temperature, etc.), and development of more effective exhaust gas treating systems (for example: particulate filter, lean NO_x catalyst, lean NO_x traps, etc). This paper only deals with the fuel quality improvements and their advantages and disadvantages. The present (year 2000) and expected (years 2005 and 2010) diesel fuel quality requirements are summarized in Table 1 (1).

Advantages and Disadvantages of Reformulated Diesel Fuels

The advantages of the application of diesel fuels of low sulphur and aromatic content can be summarized in the following manner [1 – 9]:

- reduction in the emission of acid rain precursor substances (SO_2, NO_x) and particulates
- reduction in the rate of the decrease in the total basic number of lubricating oil by lowering the amount of combustion products of nitrogen and sulphur compounds having acid character
- reduction in the rate of increasing the viscosity by lowering the formation of particulates which can get into the lubricating oil
- longer lubricating oil drain intervals are possible because of the lower solids formation and by reserving the base content of the lubricating oil for an extended period
- by applying diesel fuels of low sulphur content, the total base number (TBN) of the lubricating oil can be reduced, consequently ash containing detergent-dispersant additives may be applied in lower level and the lower ash level contributes to operating of the exhaust treating catalysts and particulate filters more effectively and for a longer period
- the lubricity improver additives are applied to diesel fuels not merely for reducing the wear of the fuel pump but it results in the same effects on different parts of the combustion chamber increasing the lifetime of the engine
- the reduction in the NO_x content of exhaust gases contributes to decreasing the ozone problems in the upper air (where the problem is the ozone depletion)

Table 1
The present and the future quality requirements of diesel fuels

Properties	EN-590: 2000	Requirements in the European Community EC 2005 January	EP 2005 January	E CA 2005 January	EC 2010
Density at 15°C, kg/m^3, max.	820 - 845	845	825	-	825
Distillation					
85 vol.% point, °C, max.	350	-	-	-	-
95 vol.% point, °C, max.	360	350	340	d	330
Cetane number, min.	51	53	58	d	58
Sulphur content, ppm, max.	350	200	50	50	50
Total aromatic content, %, max.	-	-	-	-	-
Polyaromatic content, %, max.	11	8	1	d	1

EC: European Council, EP: European Parliament,
E CA: EU Conciliation Agreement on Fuels and Vehicles, d: debated

and in the near ground air (where the problem is the ozone content increasing)

- the lower sulphur content leads to keeping the activity of catalysts used in the exhaust gas treating system for extended period, which contributes to lower emission of harmful substances
- reduction in the corrosion of different parts of engine and of exhaust gas system.

However, beside the many advances of application of reformulated diesel fuels their use causes some disadvantages, too. Some examples are summarized in the following:

- the sulphur containing compounds are generally considered as components providing some anti-wear properties, and the reduction of their amount and that of other compounds providing lubricity results in numerous problems in fuel pumps of diesel engines
- aromatic compounds have higher heat of combustion than paraffin hydrocarbons having same carbon numbers, so if their portion is decreased, the energy content of the diesel fuel will decrease, too, increasing the fuel consumption
- reduction in the aromatic content of the diesel fuel its density will be lower, too, and this leads to higher fuel consumption and higher emission
- the formation of gel and sediments in the type of in-line fuel injection pumps lubricated by the crankcase oil, causes interactions between the lubricity improver additives of diesel fuel and of crankcase lubricants, and this leads to wear in the fuel pump, contributing to worse driveability, blocking of fuel filters, unsteady fuel pumping, and increase in regulated emission.

The objective of this study was the production of gas oils having different sulphur and aromatic contents. The disadvantageous effects of the reduction in sulphur and aromatic content of the products on the lubricity were investigated, and the possibilities of reducing this negative effects were summarized.

Experimental

The hydrodesulphurization and hydrodearomatization experiments were carried out at the University of Veszprém, Department of Hydrocarbon and Coal Processing. The experiments were carried out in a high pressure twin reactor system. This system consists of a tubular reactor free of back mixing and having 100 cm^3 efficient volume, as well as equipments and devices applied in the reactor system of hydrotreating plants (pumps, separators, heat exchangers, temperature and pressure regulators, gas flow regulators). The experiments were carried out on catalysts of constant activity level and by continuous operation. The repeatability of the experimental results was higher than 95% considering the ensemble errors of both the technological experiments and the test methods. The hydrodesulphurization (HDS) experiments were carried out on Co-Mo/support catalyst and the hydrodearomatization (HDA) experiments on metals/support catalyst. The applied operating conditions are summarized in Table 2.

The properties of the feedstock and products were determined by standard test methods which are summarized in Table 3.

Results and Discussion

The results of HDS experiments are summarized in Table 4. These data display well that reduction in the sulphur content of the products causes decrease in lubricity, shown by the HFRR test results. However, the product having the lowest sulphur content also satisfies the requirements of the EN 590 standard (scar diameter max. 460mm).

The results of HDA experiments are summarized in Table 5. We applied a product of HDS experiment as feed for HDA experiment. These data display that both the sulphur and the aromatic content of the products were reduced. So, it cannot be established whether the reduction in the aromatic content of the products is

Table 2 The applied operating conditions

Parameter	HDS	HDA
	experiment	
Temperature, °C	300-330	280-320
Pressure, bar	40	50-80
Liquid hourly space velocity, h^{-1}	1,5-3,0	1,0-1,5
H_2-to-hydrocarbon volume ratio, m^3/m^3	200	800

Table 3 The applied test methods

Properties	Standards
Density, at 15°C	MSZ EN ISO 12185
Sulphur content	ASTM D2622-98
Aromatic content by HPLC*	IP 391:1995
Distillation data	ASTM D86-97
Lubricity (HFRR**), at 60°C, μm	MSZ ISO 12156-1

* HPLC: High Performance Liquid Chromatography
**HFRR: High Frequency Reciprocating Rig

Table 4 The main properties of feedstock and products of HDS experiments

Property	Feed	Experiments			
		A/1	A/2	A/3	A/4
Density, kg/m^3	859	857	856	855	855
Sulphur cnt., ppm	188	118	64	45	24
Total aromatic cnt., %	37,7	37,1	36,8	36,5	36,2
Nitrogen cnt., ppm	193	77	49	45	38
Lubricity, HFRR, at 60°C, μm	323	381	387	410	413

Table 5 The main properties of feedstock and products of the HDA experiments

Property	Feed	Experiments			
		B/1	B/2	B/3	B/4
Density, kg/m^3	855	828	822	818	812
Sulphur cnt., ppm	24	21	17	12	11
Total aromatic cnt., %	36,2	16,8	14,8	12,3	9,3
Lubricity, HFRR, at 60°C, μm	413	520	573	595	615
HDS activity, %	-	12,5	29,1	50,0	54,2
HDA activity, %	-	53,6	59,1	66,0	74,3

contributed to reducing of the lubricity, and how it is influenced by such an effect if it exists at all.

The data of Table 5 show that on the examined catalyst within the applied process parameters not only the saturation of aromatic compounds occurred in considerable level but also the reduction of the sulphur content. The maximum of HDS activity is about 54% which shows that the reduction of the sulphur content is not the main function of the examined catalyst. Accordingly, the hydrodesulphurization of sulphur compounds having the lowest reactivity (e.g. dialkyl dibenzothiophenes) presumably did not take place on the applied catalyst of given composition. The maximum of HDA activity is about 75%, but higher aromatic saturation level was not obtainable probably owing to the sulphur content of the feed which reduced the efficiency of the relatively low sulphurtolerant catalyst.

The lubricity of products of the HDA experiments does not satisfy the specified limit. In order to meet the requirements of the standard, 1% biodiesel, the properties of which meet the requirements of the standard (DIN 51606), or 400 ppm commercially available lubricity improver additive were added to the products, and the HFRR tests were repeated. The new lubricity data of the products were less than 300 mm.
The data of Table 4 and Table 5 also show that the lubricity highly depends on the type of the gas oil fraction applied as feedstock in the experiments.

Conclusion

The application of diesel fuel of low sulphur and aromatic content has many advantages and also disadvantages. The advantages mainly arise from the aspects of the environmental protection (lower exhaust gas emission) and the disadvantages from the reduced lubricity of the diesel fuel. However, the disadvantages can be eliminated relatively easily by applying additives even in low level.

The results of the experiments of the study confirmed that reduction in the sulphur content of the gas oils causes loss in lubricity. The definite answer concerning the effect of the reduction in the aromatic content on the lubricity can be given by carrying out further experiments. The results also confirmed that application of additives or blending with biodiesel can give satisfying solution to eliminate this disadvantage.

This paper also displayed that lubricity became one of the most important specifications of reformulated diesel fuels.

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