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POTENTIAL NON-TOXIC AQUEOUS EMULSION AS A DIESEL FUEL

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Abstract

Natural processes occurring on Earth (fires, volcanic eruptions) and human activity in the area of acquisition and processing of energy, is the cause of the continuous contaminating the atmosphere of combustion products. The combustion of fuels is and will be in the near future primary means of generating energy, including for transportation purposes. Transport is the cause of many environmental threats - emits dust and particles along with many of gaseous harmful substances and also noise and vibration. Power sources used for transport are almost exclusively equipped with internal combustion engines, among which is dominated by a diesel engines. In view of the known advantages of these motors such as high efficiency and relatively low emissions of toxic compounds in the exhaust gas, they have been accepted as the most preferred source of power motor vehicles in the coming decades, assuming that meet the requirements of future regulations regarding environmental protection. The problem to be solved in internal combustion engines is the emission of nitrogen oxides. In this paper are contained an overview of proven methods and results in the reduction of nitrogen oxides in exhaust gases by means of emulsion fuels, and forming an opinion concerning of the usefulness of such solutions in the future

Keywords: *emulsions, water, diesel engine, nitrogen oxides, emissions,*

1. Introduction

Widespread use of internal combustion engines in various forms of transportation of people and goods is the result of mastering the production of internal combustion engines, their operation

but also the use of petroleum-based fuels, with an attractive energy density. The operation of such means of transport causes known for many years the threat in the form of emissions to the atmosphere of aggressive chemicals and noise. These problems and the methods of reducing their negative impact on the environment are well known and will not be considered in this study, with the exception of the declared discuss reducing emissions of nitrogen oxides by means of emulsion fuel.

An important factor affecting the formation of nitrogen oxides in the combustion chamber is the oxidation of carbon and hydrogen (as a petroleum fuel component) by oxygen in the air, which contains about 78% nitrogen. The greatness determining the intensity of the formation of nitrogen oxides in the combustion chamber are temperatures circulation. Reduction of NO_x within the cylinder can be achieved by influencing on the course of mixing of the fuel with air of combustion and then taking into account the distribution of concentrations of oxygen and temperatures.

The methods used to limit nitrogen oxide emissions from diesel engines are a reduction in the intensity of their formation in the engine and / or reducing their concentration in the exhaust gas catalytic methods. The effectiveness of these methods is very different and, as practice shows, not enough efficient [16].

Introducing water into the combustion space – fuel emulsion. The group of methods to interfere with the combustion process are treatments for entering into the combustion space of water in natural or bound in the water-fuel emulsion [5, 9, 10, 13, 14, 16-25]. Addition of water into motor fuel is not a new solution has been used because of its ability to improve the energy and ecological indicators of the engine. Water injection was used in the thirties, in order to increase the engine power by increasing the compression ratio. During the Second World War, water injection has been widely used in aircraft engines and for short-term overloading of tank engine. Water is also used as an additive in the manufacture of fuel – water emulsion. The water content of the emulsion affects the combustion process affecting the growth efficiency of the engine in the case of increasing the compression ratio; and to reduce exhaust emissions [8].

Water alone may create oil emulsion oil/water, but such an arrangement has a satisfactory stability only when the dispersion of the oil phase is about 0.1 microns and the oil concentration does not exceed 0.1%. For an emulsion containing oil and water only, it takes a large energy input to overcome the surface tension forces existing between the aqueous and oil phase. Obtaining permanent emulsion systems of both types of rowing a high concentration of the dispersed phase becomes easier through the use of compounds called emulsifiers. Emulsifiers are surface-active compounds, which facilitate passage of oil and water in the disperse system by lowering the interfacial tension and fit emulsion stability [10].

Adding water sprayed ultrasonically. An alternative to a water emulsion fuel oil is the introduction of water into the combustion space. One technique uses ultrasonic waves [5, 16]. When either appear the need for additional components, regardless of the fuel, to the engine intake system or directly into the exhaust constructors tend to look for other solutions that provide adequate spraying liquid. One of these new techniques, it is possible to use in internal combustion engines can be ultrasonics. Strong ultrasonic waves caused in the liquid cause the disintegration of the free surface. From the liquid surface detach fine droplets are expelled into the environment. With appropriate frequency and wave, power can be obtained a liquid aerosol having a relatively small diameter drops, large homogeneity and the desired concentration of the drip phase.

Ultrasonic aerosol can be achieved in two different ways:

– spraying a layer of the liquid applied to the surface of the vibration at the frequencies most often 20-100 kHz (low-frequency spraying),
– spraying the surface of the so-called “fountain ultrasonic” resulting from directing the beam of ultrasonic waves at a frequency of 2-3 MHz thick film from the liquid to the liquid surface (high frequency sputtering).

Hypotheses to explain the phenomenon of atomization ultrasonic cavitation suggested his character. According to these hypotheses, the liquid is sprayed by the action of the free liquid

surface shock waves resulting from the implosion of cavitation bubbles vibrating in accordance with changes in the pressure of the acoustic wave. Another theory, assumes that a drop detaches itself from the crests standing capillary waves generated on the free surface of the liquid and are carried by the stream flowing medium.

This method is characterized by uniform and homogeneous distribution of the water in the engine cylinders. Although this method of connection to the combustion chamber does not provide adequate conditions (the right place right time) to maximize water in the process of reduction of the NO_x formation, it results in a measurable decrease in emissions of oxides of nitrogen [16].

2. Novel way production of microemulsion

Microemulsions are thermodynamically constant, stabilized on the border of phases by compounds surface active, usually surfactants [3, 9]. Microemulsions differ from common emulsions transparency, low viscosity, big durability, and first of all with small dimensions of particles, within the range from approx. 10 nm to 200 nm. Microemulsions are characterized besides with very values of surface tension. Besides microemulsions have large area interaction of water in diesel oil and diesel oil in water. Components of the microemulsion are exactly dispersion; create the mixture close to the molecular mixture. This means that every molecule of the component of the phase dispersion is found in relative to its ambience phase of the second component. The preparation of the microemulsion according to applied method consists in bring in of the special component modified surfactants Invex. In opposition to the previous emulsification and the microemulsion, this process does not demand mixers, or other special devices. Process of production of the microemulsion takes place in temperature of 40°C. It consists in mixing diesel oil and Invex surfactant on these conditions, with the mechanical mixer during 30 minutes. Then suitable quantity of demineralized water to the founded concentration is moved in. The concentration of water carried out 10, 20, 30 and 40%. After bring in of water, the received microemulsion was mixed mechanically during 30 minutes, then it was cooled to the ambient temperature. Stand microemulsion at the use of this method was obtained for the content of water carrying out of 25%. Microemulsions of content of water 30 and 40% were subject to cloudiness after 60 minutes. Microemulsions of the content of water to 25% are characterized with the thermodynamic stability. [9]

Typically, the use of water-fuel microemulsion in a diesel engine is connected with reduction in emissions of NO_x. Fig. 1 shows emission level of NO_x versus water content in microemulsion of water-diesel oil. As is clear from Fig. 1, linear decrease in NO_x emissions was obtained with a water increase in microemulsion.

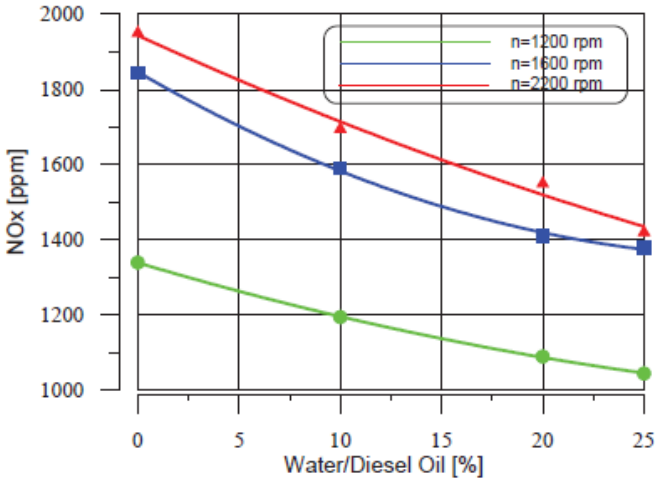

Fig. 1. Effect of water content in the diesel oil-water microemulsion on the emission of NO_x

3. Commercial fuels

Emulsified fuel with mixed water gets recognition in Europe and US, as evidenced by CARB endorsements. Emulsified fuel is being recognized in Europe and US as a new diesel fuel although it is not an oil alternative fuel as in the case of GTL or biomass fuel. When two different types of liquids (that are insoluble together) are mixed and agitated quickly, one becomes small particles and is dispersed in the other. This process is called emulsification. Water and oil, known as typical mutually insoluble substances, can be emulsified but are soon re-separated into water and oil. However, with the addition of a small amount of emulsifier, the re-separation can be prevented. The mixed fuel consisting of water and oil with the addition of an emulsifier is called the emulsified fuel. It is old knowledge that an emulsion fuel contributes to improvement of combustion. In fact, people used to add water to diesel fuel since the turn of the 20th century. Special efforts were made by the industries after the first oil crisis in 1973 to develop emulsion fuels. Then, as the crude oil price became stabilized, it was found that emulsion fuel cost more than it saved the fuel cost, and the industrial efforts ended.

In early 1990s, an American venture business called A-55 (later renamed as Clean Fuel Technology) started a research and development project of emulsion fuel with the cooperation rendered by Caterpillar. Some of the major oil companies joined the project and turned out to be successful as evidenced by favourable taxing and permission by engine manufacturers to use emulsion fuels in Europe. Necessary work was started shortly toward the technical standardization of the emulsion fuel. The project's contribution to reducing NO_x and PM has been endorsed by the California Air Resources Board (CARB).

Emulsion fuel is receiving new attention as a new diesel fuel because, among others, PM and NO_x are reduced simultaneously, it does not require engine modification and it can be used with existing vehicles.

Emulsion fuel, used in a diesel engine, not only reduces PM and NO_x emissions but also contributes to 5 to 10% improvement of fuel efficiency net (without water). While the exact mechanism of combustion improvement by emulsion fuel is yet to be identified, the following explanation is generally accepted:

PM reducing effect. Microscopic explosion of water drops: Water drops introduced into the engine are heated and volumetrically expanded quickly resulting in microscopic explosion, which, in turn breaks the oil in the fuel into small particles. Steam reforming reaction: The temperature of the compressed gas inside the diesel engine reaches as high as 1000°C at the time of fuel injection.

This leads to steam reforming reaction of hydrocarbon and water in the fuel:

$$C_nH_m + n\,H_2O \rightarrow n\,CO + (m/2 + n)H_2. \tag{1}$$

Hydrogen and carbon monoxide resulting from the reaction are easily flammable gases and thus are burnt completely without creating soot (PM).

NO_x reducing effect. As the combustion gas inside the engine reaches a temperature of 1700 degrees Celsius, this dissociates the molecular nitrogen and oxygen and turns them into atomic nitrogen and oxygen. The dissociated nitrogen and oxygen atoms are bound to each other generating nitrogen oxides (NO_x). This reaction occurs more easily at higher temperatures. Water absorbs an evaporation heat of 2250 kJ/kg as it changes from a liquid to a gas (steam). The evaporation heat of water is much greater than that of other liquids. This means that water has a greater cooling capacity. Emulsion fuel, containing water, thus lowers the maximum temperature of the combustion gas and contributes to reducing the generation of NO_x as a result.

Fuel efficiency improving effect. During the combustion of emulsion fuel, the absorption of evaporation heat by water should cause a large loss of energy, but improvement of fuel efficiency is often found in experiments. This is because the generation of NO_x itself is also a significant heat absorption reaction and the NO_x suppression effect of water is larger than the loss of evaporation heat by water and, as a whole, a higher thermal efficiency is realized as a result.

A-55.s projects triggers re-evaluation of emulsion fuel and encourages major oil companies as well. The re-appearance of industrial interest in emulsion fuel owes to the American Company, A-55 (Clean Fuel Technology) that, with the cooperation of Caterpillar, announced a technology in 1993 for running a diesel engine using emulsion fuel with 55% water content. A French oil company, TOTAL, and other major oil companies soon entered this market which is now about to become a new fuel category.

Tab. 1. Manufacturers of emulsion fuels in Europe and US

Fuel manufacturer	Product name	Marketer	Water	Yrs. in market
Clean Fuel Technology (U.S.)	Aquadiesel Aquadyn (U.S.)	IPLOM S.p.A, Shell Australia*	13%	11 years
TOTAL (France)	Aquazole™	TOTAL's gas stations	14~17%	9 years
CAM Tecnology (Italy)	Gecam™	AGIP, Petrofuel S.p.A, RA.M.OIL S.p.A, ERG, SARAS	10~11%	6 years
Lubrizol (U.S.)	PuriNOx™ Qwhite Aspia	BP, Q8, Blanco Petroli, Green Oils, Kuwait Petroleum Italia	10~20%	5 years
	Proformix™	Chevron		

4. Conclusions

If the fuel such as microemulsions is produced in commercial quantities, it means that there is meaning to their use. The results of empirical test, on the engine test stand, additive ultrasonically atomized water in an amount up to 20% by weight of fuel consumption reduces NO_x emissions about 0.5% for every 1% added water.

Lack of effect of the addition of water (to 20%) for energy parameters of the engine under test operation (Me, Ne, pe) and the lack of effect on the concentrations of carbon monoxide, hydrocarbons and carbon dioxide as well as particulate emissions in the exhaust.

The reduction of NO_x by addition of water measured in the 13-mode test of ESC reaches 11% with the addition of water, with no changes in carbon monoxide, hydrocarbons and particulates.

The water content in diesel must be optimized due to the overall efficiency of the engine operation, the degree of opacity and changes in toxic exhaust emissions. Addition of water affects most to reduce emissions of nitrogen oxides and this effect is maintained with the increase of percentage of water content.

However, emissions of CO, CH and PM initially decrease and then increases when the proportion of water exceeds 20%. When a water content greater than 30% of the emulsion may comprise a mixture of structure of the water-oil or oil-water, which results in deterioration of useful ratios of engine operation [8]. In addition, the water content significantly affects the basic properties of the fuel such as the pour point and flash point of which increases with increasing viscosity of the emulsion.

The biggest problem associated with the use of emulsion as a fuel is to obtain a stable emulsion of water and diesel oil, which determines the reliability of the engine operation. A stable emulsions requires the use of added emulsifier, the emulsion stability will depend on the type and the content of the emulsifier used. The rate of phase separation also increases significantly with increasing temperature [11].

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