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The use of animal fats in the diesel fuelled engine

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Abstract. The decrease in the reserves of non-renewable oil products has led to the search for alternative solutions to ensure the replacement of petroleum products used in internal combustion engines and a reduction of the pollution imposed by international regulations for the limitation of greenhouse gases, of NO_x, HC, CO and smoke. So, a good solution is the use of preheated animal fats used at the compression ignition engines in mixture with the diesel fuel. The properties of animal fats are similar to diesel fuel, and therefore animal fats preheating and blending with diesel fuel is a simple, cheap method and their use in compression ignition engines does not require engine modifications. The main advantages of animal fats are the cetane number and the inferior calorific power which have values that are very close to those of diesel fuel, but have the disadvantages of high viscosity and poor vaporization characteristics, the preheating of animal fats being required. When animal fats are preheated to a temperature of about 40^{o}C and mixed with diesel fuel, they are totally soluble in blend which is completely homogeneous, with no limit of dissolution.

1. Introduction

Continuous reduction of non-renewable oil reserves, prices volatility, the more severe regulations of pollutant emissions and greenhouse gases and the raw materials availability leads to the intensification of the preoccupation for the use of alternative fuel obtained from renewable sources, [1], animal fats having a high potential also due to their good combustion properties and large reserves. Used animal fats capitalization for biofuels production is also recommended it by their higher energetically value.

Animal fats may represents an energetically source with large capitalization possibilities, either as raw material or even as oils obtained by transesterificantion, with large perspectives of use. Biodiesel fuel is manufactured from oils plant, animal fats and recycled cooking oils and is an alternative to fossil fuel. The main advantages of biodiesel fuel are: it is renewable, it is energy efficient, can replace diesel fuel, it can be used as 20% blend in most diesel equipment without major modifications, it can reduce global greenhouse gas emissions and it is not toxic being biodegradable. Biodiesel is an oxygenated fuel, non toxic, sulphur free and contain more oxygen compare to diesel petroleum and lower calorific power slightly lower than diesel [2]. Animal fats are secondary products of the leather industry and due to their good combustion properties they can be use as fuels for diesel engines [3]. Animal fats are lipid materials derived from animals. Physically, animal fats are solid at room temperature (20…25^{o}C) and are constituted from tryglicerides of saturated monocarboxylic fat acids with even number of carbon atoms (C_{12}-C_{18}) in which palmitic and stearic acids are predominant [4]. Animal fats have a composition similar to that of diesel fuel but with a lower content of carbon and

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hydrogen and higher oxygen content. The most important difference between animal fats and diesel fuel is the viscosity value which is ~20 times greater than diesel fuel, at 40^{o}C [5]. At lower temperatures the kinematics viscosity depends on the type of animal fats and their composition because they are a mixture of fatty acids and glycerine esters, linolenic acid, stearic acid and other acids with different properties (ex :linolenic acid had a flow temperatures -14^{o}C and 70^{o}C for stearic acid) [6], [7]. The caloric power of animal fats is around 10% lower than that of diesel fuel and the engine power decreases in comparison to that with diesel fuelling. The oxygen content of animal fats is higher than that of diesel fuel (~12% versus 0.33%) [8]. For the same air/fuel ratio, the cyclic fuel dose can be increased at the use of the animal fats and the engine power can be maintained, but emissions of particles and unburned HC can increase [9]. The main problems associated with the use of animal fats as fuel in diesel engines are represented by their high viscosity and poor volatility. That's way different methods (like: transesterification; diesel fuel-biodiesel blends use, use of blends between biodiesel-alcohols blends, use of the biodiesel-alcohol-water emulsion, preheated animal fats-diesel fuel blends use) can be used in order to provide a proper animal fats fuelling solution for diesel engines [8], [9], [10]. Preheating animal fats and blending with diesel fuel is a simple, cheap solution and does not require major engine modifications. When animal fats are preheated (at temperature of 40^{o}C) and mixed with diesel fuel, animal fats becomes totally soluble in diesel fuel and a homogeneous blend is achieved [6], [11]. For diesel engines, raw animal fats can be use as single fuel or in blends with diesel fuel only if the animal fats are preheated, at relative high temperatures, so that their viscosity to be closer to the diesel fuel viscosity [6], [11], [12], [13]. The emulsification with alcohols (methanol, ethanol) can be another solution [6]. Experimental investigations of Kumar [14], carried out on a single cylinder diesel engine with direct injection fuelled with preheated animal fats, show the increase of the minimum specific energy consumption, the decrease of in-cylinder peak pressure and maximum pressure rise rate, the increase of the ignition delay, the decrease of the maximum heat release rise rate and the decrease of smoke emission. The HC and CO emissions level are increased [14]. The results of experimental investigations carried out on the CFR-IT9-3M diesel engine fuelled with animal fats-diesel fuel blends (with 15%vol. animal fats content) show the reduction of in-cylinder maximum pressure with 10% comparative to classic fuelling [15]. The use of animal fats in blends with diesel fuel requires the preheating of animal fats at a temperature of min. 38°C [15], [16]. At this temperature, the animal fats are completely soluble in diesel fuel and an extremely homogenous blend is obtained. But, atomisation and combustion processes impose the limits up to 40% animal fats in mixture with diesel fuel due to the viscosity [15], [16]. For the same engine adjustments, the NO_x emission level decreases with 30%, the smoke emission level decreases with 65% and the HC emission level raises with 58% [15]. If the engine adjustments are changed, like the injection timing, the decreases of the specific energy consumption, NOx, smoke and CO_2 emission levels are achieved [16].

In the paper are presented some experimental results of raw animal fats-diesel fuel blends use at diesel engine.

2. Description of the experimental test bed and methodology

The diesel engine used for experimental investigation is a D2156 MTN-8 truck diesel engine, turbocharged, with 6-cylinder and a 10.35-liter swept volume which develops a nominal output of P_e = 188 kW and a maximum torque of 890 Nm. The diesel engine is fuelled by a type A Bosch injection pump which operates at injection pressure of 250 bar.

The engine is equipped with a second two-chamber fuel tank used to supply the fuelling system with animal fats-diesel fuel blends. This second reservoir has an inner part in which the diesel fuel is mixed with preheated animal fat, and an exterior part constituted by a water chamber. At temperatures above 40°C the diesel fuel-animal fats blend becomes completely homogeneous. The setup temperature (45°C) is obtained by using two 800 W electric resistances, mounted in the water chamber of the second reservoir. The temperature of the animal fat - diesel fuel blend was monitored by a digital thermometer mounted inside the fuel tank. Determination of pollutant emissions is done using

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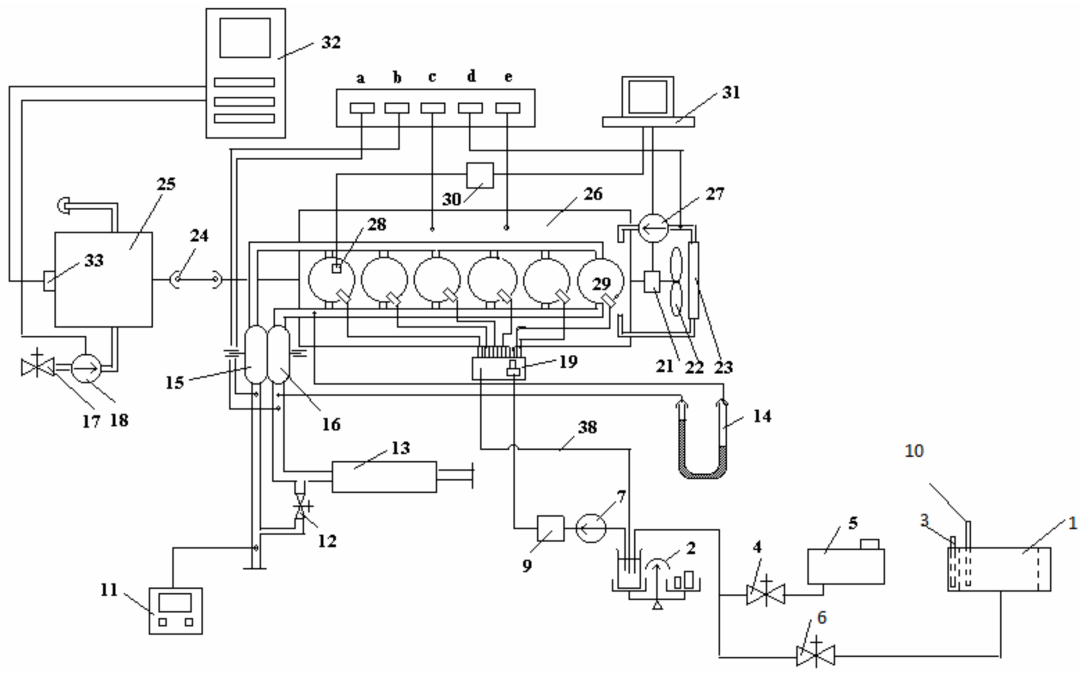
an AVL DiCOM 4000 gas analyzer that measures the level of CO, HC, CO_2 and NO_x emissions. Smoke emission level is measured with an AVL DiCOM 4000 opacimeter. The engine is mounted on a test bed equipped with a Hoffman eddy-current dynamometer and AVL data acquisition system. The engine is instrumented with flowmeters, thermometers, thermocouples, thermoresistances and manometers in order to monitor the air and fuel consumption, fluids temperatures and inlet pressure.



Notes:
1. Animal fat emulsion tank - motor; 2. Gravimetric balance (Sibiu Precision); 3. Electrical resistance; 4. Diesel fuel valve; 5. Diesel fuel tank; 6. Petroleum-diesel fuel emulsion valve; 7. Diesel fuel pump; 9.Diesel fuel filter; 10. Animal-diesel fuel emulsion thermometer; 11. AVL Digas 4000 Gas Analyzer; 12.EGR valve; 13. Meriam air flowmeter; 14. Mercury differential pressure gauge measuring pressure of overcharging; 15-16. Turbocharger Holset Group; 17. Line valve for brake cooling; 18. Dyno cooling water circulation pump; 19.Diesel injection pump; 21. Kubler's incremental speed transducer; 22.Ventilator; 23. Coolant radiator; 24.Cuplaj; 25. Hoffman I3d Eddy Curent Electric Dyno; 26. Diesel engine D2156 MTN8; 27. Motor cooling water circulation pump; 28. Kistler piezoelectric pressure transducer; 29. Diesel Injector; 30. Kistler charge amplifier; 31. Calculator and AVL acquisition board; 32. Electric brake controller; 33. Electric dyno speed encoder and power cell; 38. Diesel return pipeline; a) Exhaust gas temperature indicator; b) air intake temperature indicator; c) Lubricant oil temperature indicator; d) Engine coolant temperature indicator; e) Lubricant oil pressure indicator.

Figure 1. The experimental test bed schema [2].

As fuel blend preparation method it was used the method of preheated animal fats which are further mixed with diesel fuel in volumetric percents of 5% and 10%. The main properties of the animal fats versus diesel fuel, or some different biodiesel fuels, are presented in the table 1.

The experimental investigations carried out at the regime of 40% engine load and 1450 rev/min engine speed, at constant engine power and constant value of injection timing. For diesel fuel, 5% and 10% of animal fats-diesel fuel blends the pollutant emissions level, fuel consumption, effective power, in-cylinder pressure, air consumption were recorded. The reference is defined by all the parameters registered for only diesel fuel operation.

Table 1. The physic-chemical properties of diesel fuel and animal fats. [12, 13]

No.	Specific properties of the fuels	Diesel *	MEGA	EEGA	Animal Fats
1	*Density [g/ml]*	*0.8495*	*0.874*	*0.869*	*0.92*
2	*Viscozity at 40 °C [mm²/s]*	*2.96*	*4,814*	*5.036*	*45*
3	*Thick point [°C]*	*-12*	*16*	*14*	*6*
4	*Congealing point [°C]*	*-16*	*16*	*12*	
5	*Ignition point [°C]*	*74*	*160*	*185*	*170*
6	*Boiling point [°C]*	*191*	*313*	*327*	*344*
7	*Water and sediments [% v]*	*<0.005*	*<0.005*	*<0.005*	*<0.005*
8	*Coke number [% m]*	*0.16*	*0.056*	*0.052*	
9	*Ash [% m]*	*0.002*	*0.001*	*0*	*0*
10	*Sulphur [% m]*	*0.036*	*0.01*	*0.009*	*0*
11	*Iodine number [g/100g ,fuel]*		*49.1*	*47.2*	*54*
12	*Cetane number CN [-]*	*49.2*	*72.7*	*72.4*	*56*
13	*Caloric power Hi [MJ/kg]*	*42.9*	*37.25*	*37.63*	*39.77*
14	*Carbon [% m]*	*86.67*	*76.42*	*76.58*	*77.6*
15	*Hydrogen [% m]*	*12.96*	*12.59*	*11.57*	*12.3*
16	*Oxygen [% m]*	*0.33*	*10.98*	*11.84*	*12.5*
17	*Nitrogen [ppm]*		*9*	*10*	
18	*Oxygen for combustion O_t [kmol/kg fuel]*	*0.1045*	*0.0917*	*0.0890*	*0.0915*

**Diesel fuel for comparison produced by American company Philips 66, MEGA methyl ester of beef fat, EEGA ethyl ester of beef fat*

3. Results

Figure 2 presents the variation of in-cylinder pressure for diesel fuel and blends of diesel fuel-animal fats. Comparative to diesel fuelling, the maximum pressure value decreases for x_c =5% with 5.5% and with 12% for x_c=10%, because of aggravation of the fuel atomization, figure 3. Also, the angle of maximum pressure tends to occurs later on cycle with around 16% comparative to diesel fuelling.

The maximum pressure rise rate registers values around 1.9 bar/°CA at diesel fuel fuelling and begins to decrease, once with the rise of the animal fats content in blend with diesel fuel, till 1.7 bar/°CA for x_c=5%, and 1.3 bar/°CA for x_c=10%, the general decreases in combustion noise being around 31%, figure 4.

Because the animal fats has a lower caloric power value comparative to diesel fuel, and the injection timing is maintained constant, at the rise of animal fats content in blend with diesel fuel the effective specific energy consumption starts to increase, figure 5.

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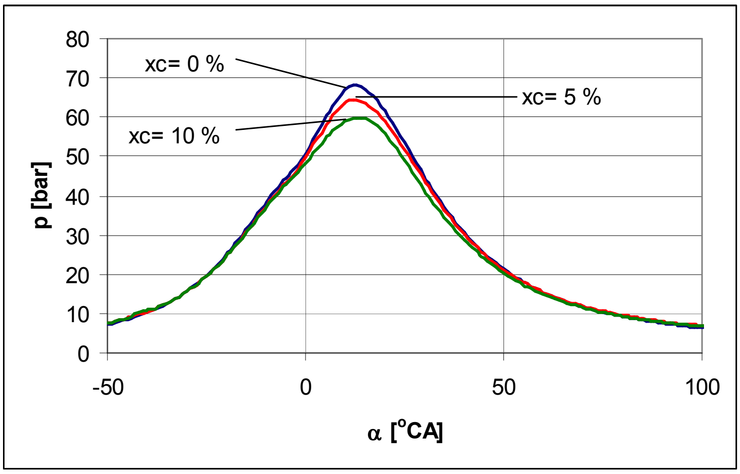

Figure 2. Pressures diagrams at different substitute ratios x_c.

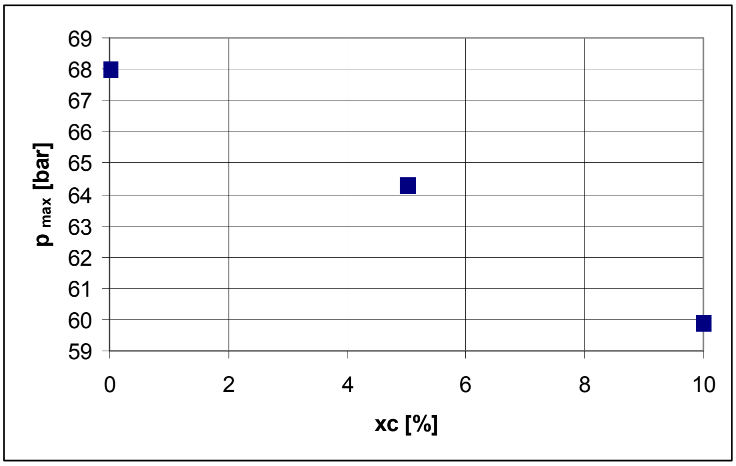

Figure 3. Maximum pressure versus at the 40% engine load.

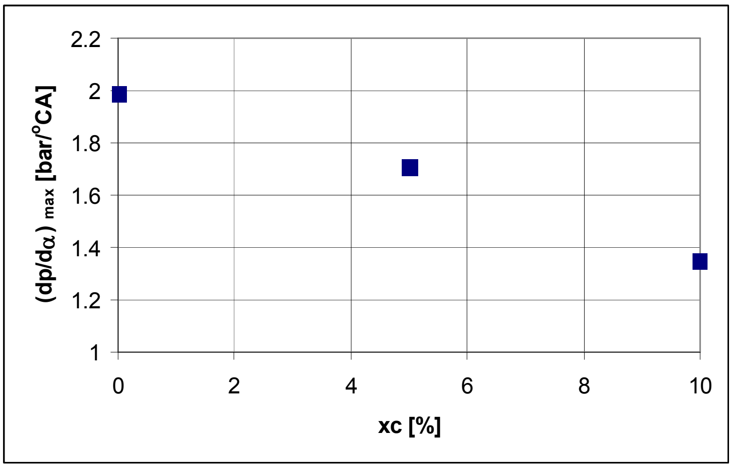

Figure 4. Maximum pressure rise rate versus different substitute ratios.

In figure 6 is presented the NO_x emissions level variation with percent of substitute ratio of diesel fuel by animal fats. NO_x emissions level decreases with 20.4 % for x_c=5% and 20.8% for x_c=10%.

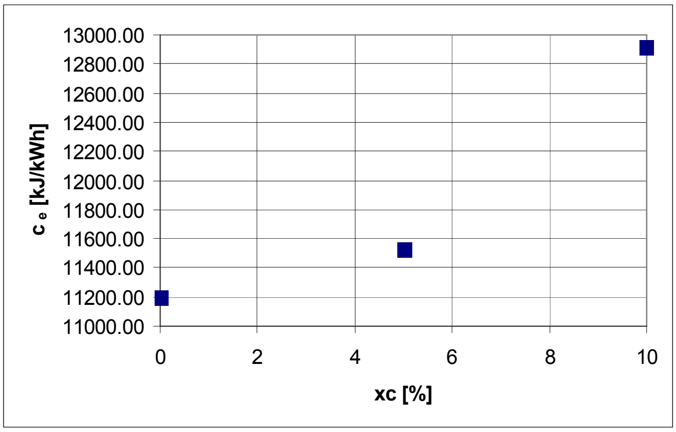

Figure 5. Effective specific energy consumption versus different substitute ratios x_c.

In figure 7 is presented the HC emissions level variation with percent of substitute ratio of diesel fuel by animal fats. HC emissions level increases with 54 % for x_c=5% and 27.3% for x_c=10%.

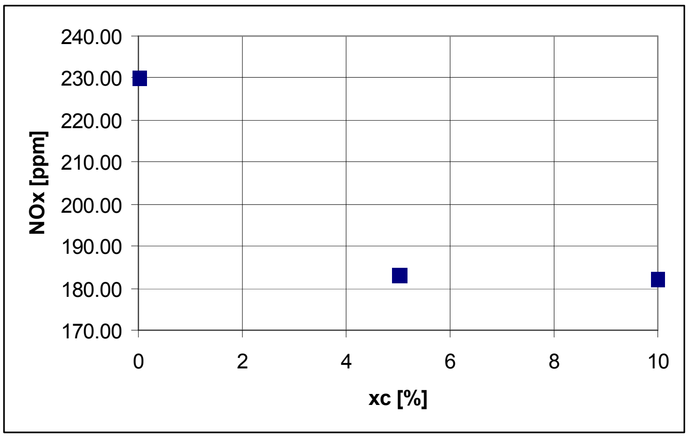

Figure 6. NO_x emissions level versus animal fats content.

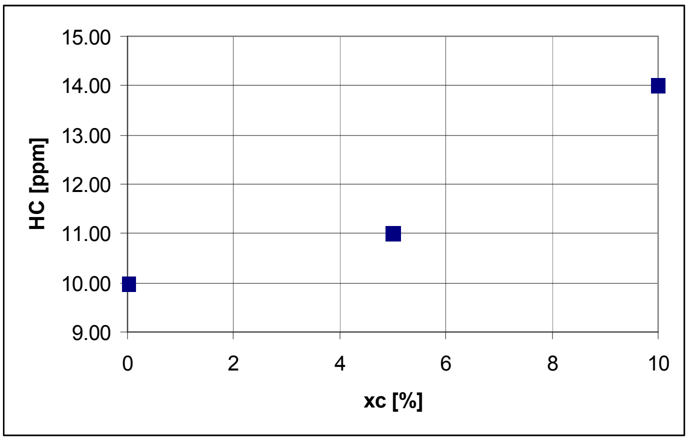

Figure 7. HC emissions level versus animal fats content.

Regarding the smoke emission, at the animal fats content increase in mixture with diesel fuel a decrease in the level of the smoke emission concentration is observed, figure 8. This reduction in of smoke emission concentration at animal fats use is explained by the decrease of carbon content and by the increase of the oxygen content. Thus, for x_c=10%, smoke concentration decreases with 60%.

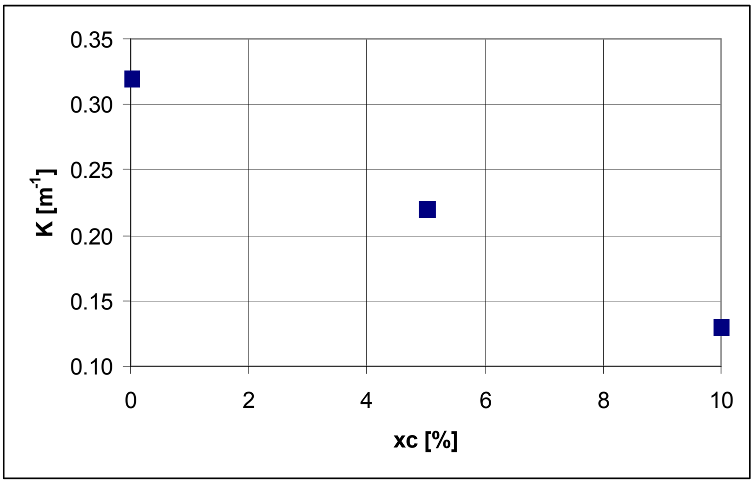

Figure 8. Smoke emission level defined by smoke number versus animal fats content.

4. Conclusions

For the same engine adjustments the increase in the animal fats content in mixture with diesel fuel leads to in-cylinder maximum pressure decrease. Comparative to diesel fuelling, the maximum pressure value decreases for x_c =5% with 5.5% and with 12% for x_c=10%, because of aggravation of the fuel atomization. The angle of maximum pressure tends to occurs later on cycle with around 16% comparative to diesel fuelling. The maximum pressure rise rate registers values around 1.9 bar/°CA at diesel fuel fuelling and begins to decrease, once with the rise of the animal fats content in blend with diesel fuel, till 1.7 bar/°CA for x_c=5%, and 1.3 bar/°CA for x_c=10%, the general decreases in combustion noise being around 31%. The effective specific energy consumption increase due to the increase of the auto ignition delay and the move of the combustion in the expansion stroke, because the animal fats has a lower caloric power value comparative to diesel fuel, and the injection timing is maintained constant, at the rise of animal fats content in blend with diesel. The NO_x emissions level decreases with 20.4 % for x_c=5% and 20.8% for x_c=10% and the HC emissions level increases with 54 % for x_c=5% and 27.3% for x_c=10%. At animal fats use the smoke emissions level decreases with 60% (at x_c=10%), due to the decrease of carbon content and by the increase of the oxygen content. Finally, the use of animal fats as alternative fuel for diesel engine offers the advantages of direct use of raw waste materials from tanneries as fuel and of doesn't require significant modification of engine design.

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