TECHNICAL UNIVERSITY OF CLUJ NAPOCA
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PHASE 2009

3.1. DETERMINATION OF FUNCTIONAL PARAMETERS OF AN INTERNAL COMBUSTION ENGINE BY EXPERIMENTAL TESTING ON TEST BENCH

3.1.1. Determination of functional parameters of the engine using diesel fuel

In order to carry out research on the use of diesel-biodiesel-bioethanol blends as alternative fuel in diesel engines, laboratory facilities of Internal Combustion Engines and Biofuels laboratory were used, both of the Department: Road Vehicles and Agricultural Machinery of the Mechanics Faculty, Technical University of Cluj Napoca. These laboratories have fully equipped test benches, with hydraulic brakes, sensors for determining the main operating parameters of the engine, control and measurement systems, experimental data acquisition and processing, etc.

The experimental test bench (Fig. 3.1), equipped with a D-2402.000 engine, hydraulic brake and data acquisition system, is capable of measuring speed, braking force, fuel consumption, test length and coolant temperature. Fuel supply is made from fuel tanks (Fig. 3.2). Using commercial diesel, variations of power, timing and fuel were high.

Fig. 3.1. experimental test bench equipped with D-2402.000 engine (Photo - Biofuels Lab - Department: Road Vehicles and Agricultural Machinery, Faculty of Mechanical Engineering of the TUC-N).

Fig. 3.2. Fuel tanks unit.

3.1.2. Determination of functional parameters of the engine running on research fuels (biodiesel-diesel-ethanol blends)

List of investigated mixtures is presented in Table 3.1. Tests performed were repeated for each mixture. Sample characteristics are shown in Figures 3.3-3.6.

Tabel 3.1. Mixtures investigated and some of their properties

Nr.	Fuel code	Biofuel, % (v/v)	Kinematic viscosity, mm^2/s	CC	Density, kg/dm^3	Flash point, °C	CFPP, °C	Calorific power, MJ	Fuel equivalent
1	B25M70E5	30	2.7560	52.60	0.852	18	-3	41.10	0.96
2	B20M70E10	30	2.4796	49.70	0.847	16	-3	40.45	0.95
3	B20M75E5	25	2.6447	51.85	0.850	17	-3	41.24	0.97
4	B15M75E10	25	2.3739	48.95	0.845	15.5	-3	40.59	0.95
5	B15M80E5	20	2.5269	51.10	0.847	16	-3	41.38	0.97
6	B10M80E10	20	2.2746	48.20	0.843	15	-3	40.74	0.96
7	B10M85E5	15	2.4205	50.35	0.845	14	-3	41.53	0.97
8	B5M85E10	15	2.1759	47.45	0.843	15	-3	40.88	0.96
9	B5M90E5	10	2.4353	49.60	0.841	17.5	-3	41.67	0.98
10	M100	0	2.4853	51.00	0.843	69	0	42.60	1.00

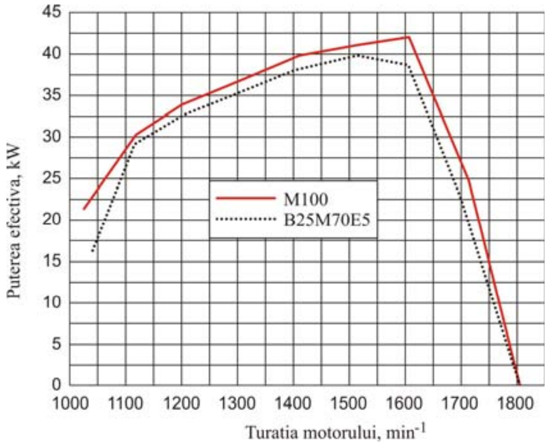

Fig. 3.3. Power variation depending on engine speed.

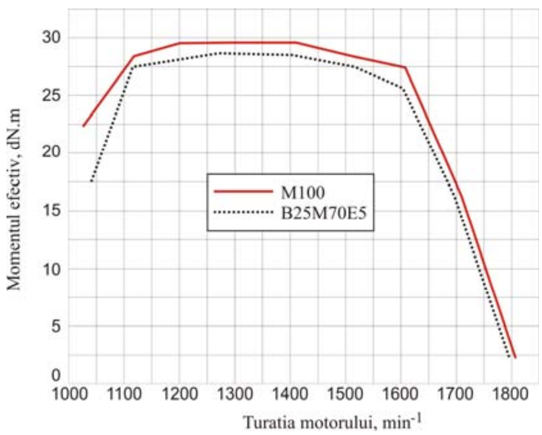

Fig. 3.4. Torque variation depending on engine speed.

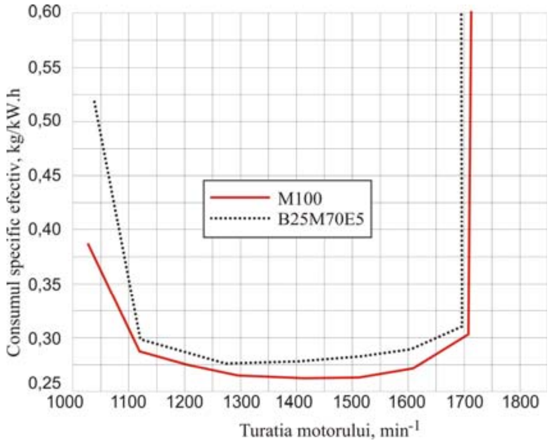

Fig. 3.5. Specific fuel consumption variation depending on engine speed.

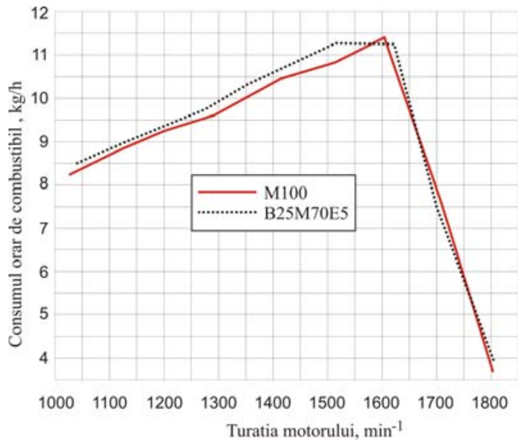

Fig. 3.6. Hourly fuel consumption variation depending on engine speed.

Also, for four types of fuel were raised by task characteristics (Fig. 3.7).

3.1.3. Critical-comparative evaluation of results

Engine power and actual torque of the engine decreases with 5-9% using the researched mixtures versus base diesel fuel. Also found that the engine speed corresponding to the maximal power decreases with 70-100 rot / min when engine is fuelled with diesel-biodiesel-ethanol blends.

The specific fuel consumption is actually higher at small loads, but is reduced at part and high loads. Lowest values were found for diesel. For mixtures specific fuel consumption is higher because their calorific value is lower. The order is M100, D85B10E5, M80B10E10 and M70B25E5, this order is maintained through all the load scale of the engine. Greater increase is noticed at small loads (32.4% for M70B25E5) at medium and high loads the values for mixtures are comparable to those found for diesel, ranging between 6.2 and 15.8%.

Depending on engine load, efficiency, as expected, decreases using mixtures, similar trends were observed for specific fuel consumption. Efficiency reduction is between 0.4 and 21.7%.

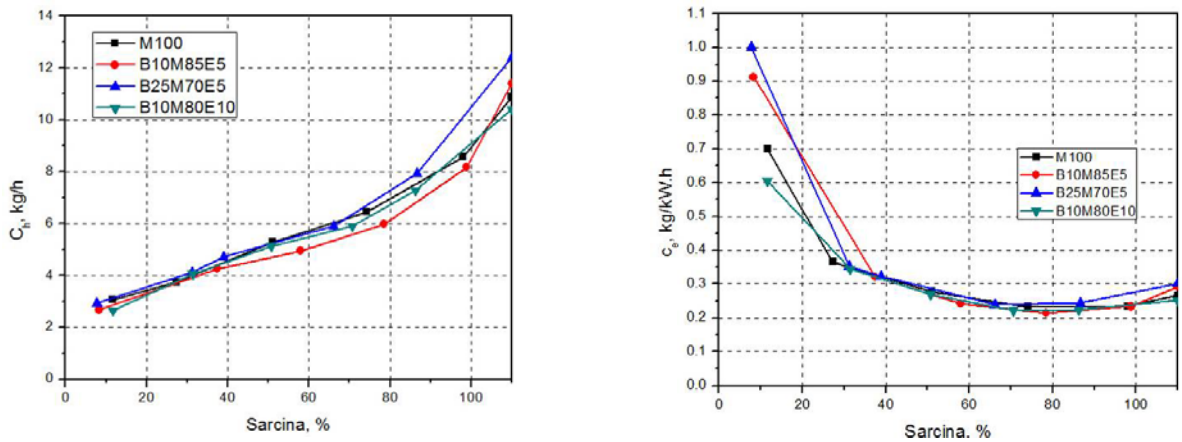

Fig. 3.7. Load characteristics.

3.2. POLLUTION DETERMINATION OF THE INTERNAL COMBUSTION ENGINE BY EXPERIMENTEL TESTING ON TEST BENCH

3.2.1. Determination of parameters of pollution control engine fuel (diesel)

To determine the compression ignition engine's pollutants, appropiate measuring devices were used (BOSCH BEA 350 diagnostic station for measuring CO, CO2, HC, NOx, O2; and RTM 430 smoke analyzer to determine the absorption coefficient, the most modern equipment available within the Department of Road Vehicles and Agricultural Machines). To provide conclusive results, calibrations were performed to the diagnostic station.

3.2.2. Determination of pollution parameters of the engine, using research fuels (diesel-biodiesel-bioethanol blends)

Examples of featured obtained are shown in Figures 3.8-3.11.

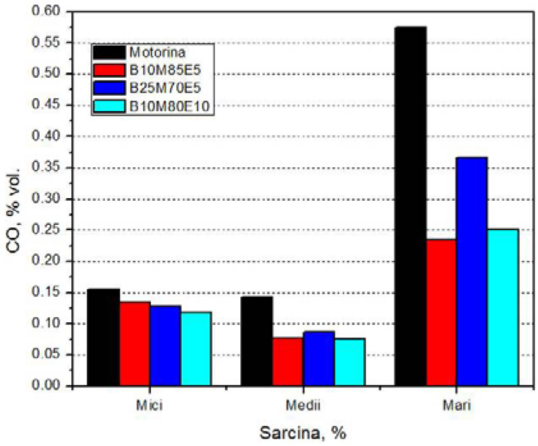

Fig. 3.8. CO emission variation, depending on load.

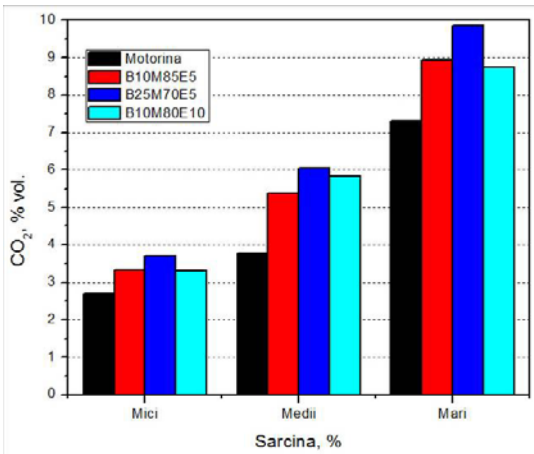

Fig. 3.9. CO_2 emission variation, depending on load.

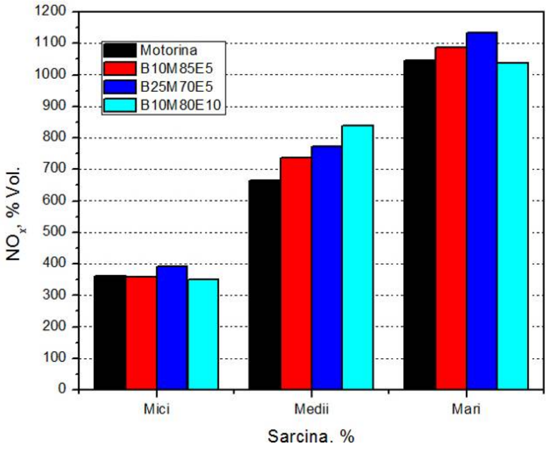

Fig. 3.10. NO_x emission variation, depending on load.

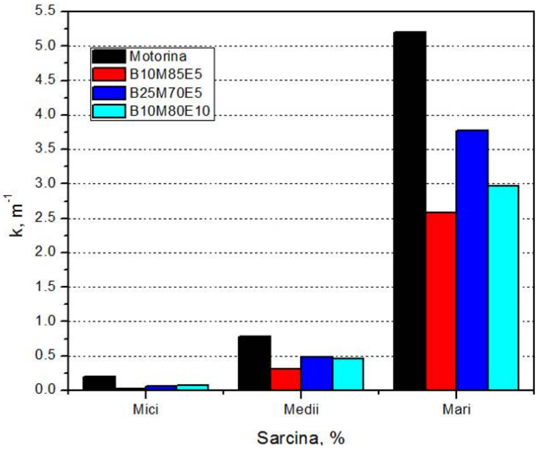

Fig. 3.11. Smoke emission variation, depending on load.

3.2.3. Critical-comparative evaluation of results

Carbon monoxide emissions vary by the used fuel and by load. Thus, for small and medium loads, the highest emissions were measured for oil and lowest for D80B10E10 mixture. As expected, with heavy load, CO emissions increase, being lower for investigated mixtures with about 50%. This is explained by the high oxygen content of biodiesel and ethanol, which supports the process of oxidation during the exhaust stroke. The experimental results showed that at high engine loads, the lowest CO emission has the D85B10E5 mixture (0.234% vol), which compared with diesel (0.575% vol), represents a 59% reduction.

CO_2 emissions in the case of the investigated mixtures, are higher than those measured for diesel engine at all three load schemes considered in this paper. CO2 increase can be attributed to the CO decrease , which oxidizes further because of the high oxygen content in fuels i, providing a more complete burn. Also, excess amount of oxygen allows the oxidation of CO all the way in the exhaust, including exhaust path of combustion. This explanation is supported by the reduction of CO to those observed for diesel. Increasing CO_2 can not be regarded as a negative consequence because they are re-used (consumed) in the photosynthesis of plants from which biofuels are produced.

NOx emissions of diesel engine tested at small loads usually have a slight discount. But at medium and heavy loads NOx emissions are higher than those noticed for diesel with 10-26%. Increased NOx emissions at medium and heavy loads can be explained by higher fuel combustion temperatures, because the oxygen content of biodiesel and ethanol, which enables more complete combustion and thereby increase combustion temperature, which favors the formation of nitrogen oxides. Also, because of ethanol’s low cetane number, the mixture’s cetane number is reduced. This leads to an increase in fuel ignition delay and the accumulated fuel / air mixture will burn faster, resulting in a faster heat release at the beginning of the combustion process, resulting in a higher temperature which supports the formation of nitrogen oxides.

HC emissions for blends of 5% ethanol are significantly reduced compared to diesel in all three domaines of engine load. Blends with higher ethanol percentage generates higher HC emissions and those with a higher content of biodiesel emit less HC. This suggests that the presence of ethanol in the mixture is a growth factor for HC emissions, while biodiesel decreases their presence. One explanation might be the cetane number: high cetane number diesel with biodiesel promotes easy ignition and complete combustion of the mixture, while low cetane ethanol act opposite. Because of low cetane, ethanol will be lit and will later burn incompletely, thus increasing the content of unburned hydrocarbons in exhaust gas composition. The most significant reduction can be found at heavy loads of 50%.

Smoke emissions of internal combustion engines were evaluated by measuring the opacity of the exhaust, highlighted by light absorption coefficient. Exhaust opacity was significantly reduced (by 50%) for all mixtures, especially at small and medium loads. At heavy load this reduction varies from 27.6% for D70B25E5 and 50.3% for D85B10E5 mixture. Although it is known that the use of oxygenated blends reduce particulate emissions of compression ignition engines, the mechanism by which this occurs has not yet found a plausible explanation. Smoke formation occurs in fuel-rich zones of the chamber, especially in the injected liquid jet. Considering that the oxygen in the biofuels provides oxidizerfor the pyrolysis processes of the burning jet, would result in a reduction of solid particle formation.

3.2.4. Defining the optimum value of air excess coefficient based on experimentally measured pollutants

Because both biodiesel and ethanol contain a substantial quantity of oxygen, combustion of diesel-biodiesel-ethanol mixture in compression ignition engine - keeping the same dose of fuel - will take place with a higher oxygen excess, compared with diesel combustion, resulting in a more complete combustion. Also, by increasing the fuel dosage, the lower calorific value of biofuels can be offset, without reducing the oxygen excess found in diesel combustion.

3.3. DEFINING THE INFLUENCE OF RESEARCH FUELS ON THE RESEARCH ENGINE’S TECHNICAL CONDITION

3.3.1. Comparative evaluation of deposits on the engine parts

Tests were performed on a BMW car, type TD 524, equipped with an E34 type engine with six cylinders in line, with maximum power of 86 kW at 4800 rpm rot/ min and maximum torque of 220 N • m at 2400 rot / min engine speed. Deposits on the injectors (Fig. 3.12) and piston head were evaluated. There was no significant change in deposits found on inspected parts.

Fig. 3.12. Deposits on injectors: Diesel combustion, cleaned injectors.
After running onB25M70E5.

3.3.2. Evaluation of engine parts wear

In the evaluation of wear five components of the engine were assessed: injector needle (tip wear), injector body (flow rate), cylinder, piston skirt and con rod bolster (Fig. 3.13). The pieces were removed and evaluated three times during the ca. 300 hours of engine operation with biodiesel-diesel-ethanol blends.

Fig. 3.13. Components evaluated for wear

There were no abnormal wear of parts inspected and no significant modification of the nozzle flow coefficient.

3.3.3. Assessment of lubricating oil quality evolution

For tests a range of lubricants recommended by the engine manufacturer was used, with classifications: SAE - 10W40, API - SJ / CG-4 and ACEA - A3/B3. The fuel used was a mixture of 70% diesel, 25% biodiesel made from rapeseed oil and 5% ethanol, the composition is expressed in percent volume. During the tests were taken and assessed eight oil samples.

To determine the density and viscosity of lubricating oil, SVM-3000 type device was used. Oil density was determined by the oscillating U-tube SR EN ISO 12185, and the methodology to determine viscosity was the one described in EN ISO 3104. Viscosity index was determined respecting the methodology contained in STAS 55 and ISO 2909. Flashpoint was determined by Pensky-Martens device, with closed crucible, HFP type 339, according to EN ISO 2719.

Density of the lubricating oil increases during use, indicating contamination with soot and oxidized substances, but no fuel contamination and dilution is observed. You can also find a more pronounced increase for diesel, compared with diesel-biodiesel-ethanol mixture, due to its more complete combustion.

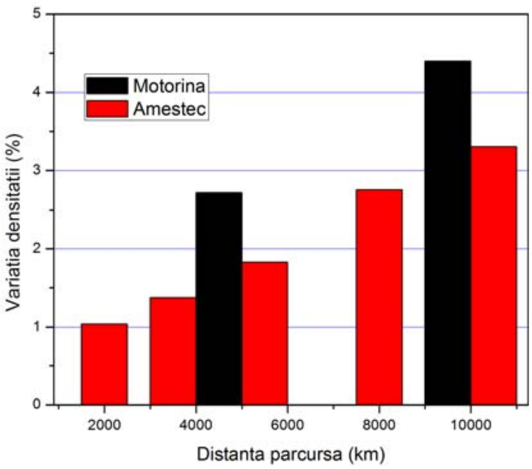

Fig. 3.14. Changes in relative density of lubricating oil.

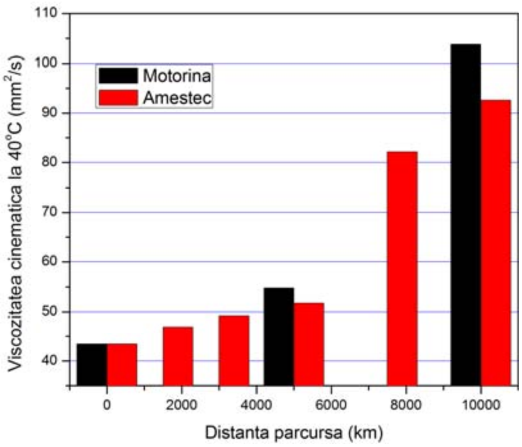

Fig. 3.15. Kinematic viscosity at 40 ° C of the oil samples

It can be also found a growing vizcozity of the lubricating oil during use, indicating no contamination with soot or fuel either. Lube oil viscosity increases more when using diesel fuel, indicating a lower contamination in the case of use of diesel-biodiesel-ethanol mixture.

Changes in oil viscosity in low temperature domain increases considerabely, both when used with diesel and diesel-biofuel-ethanol blend, the increase being lower for the mixture. This may make it difficult to start the engine and give inadequate lubrication in low temperatures. At high temperatures (> 60 ° C) viscosity increase is more modest, it does not raise significant change in viscosity for engine operation at normal operating temperature of lubricating oil.

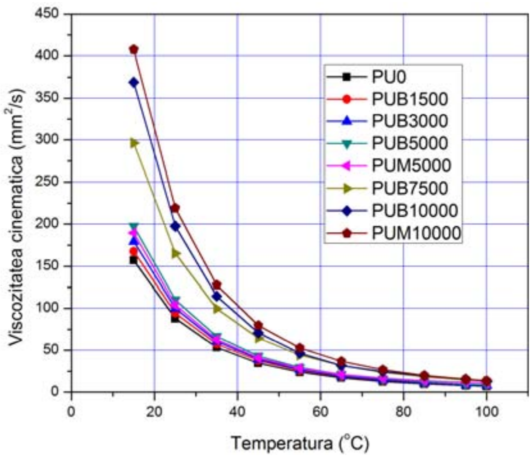

Fig. 3.16. Kinematic viscosity variation with temperature.

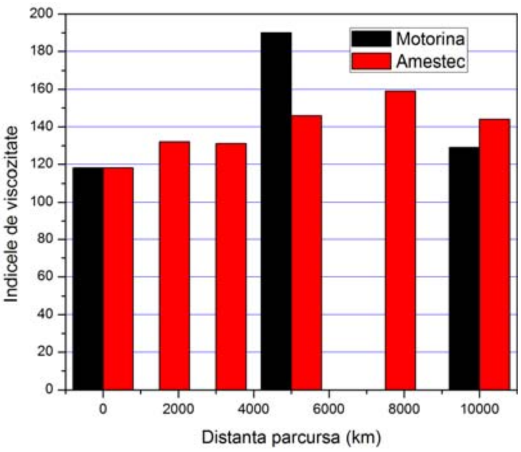

Fig. 3.17. Viscosity index of oil samples.

Viscosity index increases at the beginning of use due to the contamination of lubricating oil with solids, then decreases because of its thermal cracking resulting from the fractions with lower viscosity. Flash temperature of oil samples rise during operation, indicating loss of lighter fractions of oil and confirming that the extent of contamination with fuel is reduced.

In **conclusion** we can state that:

– Due to the lower calorific value of the biofuels, engine performance is reduced, especially at small loads.
– significantly lower CO emissions on account of rising CO_2 emissions as a result of further oxidation including the exhaust path, it is possible because the investigated mixtures contain oxygen up to 4.55% m/m.
– NO_x emissions increase, especially atmedium and heavy loads, which can be attributed to a more complete combustion and combustion temperature increase due to the oxygen in the fuel.
– HC emissions decrease in all regimes of engine load.
– Regarding to smoke emissions, was found that these emissions decrease compared to those found when running with diesel, being higher for blends with high biofuel content.
– In general it can be concluded that mixtures investigated emit less pollutants, especially at medium and heavy engine load, except CO_2 and NO_x , which are found to be higher than those determined for diesel.
– The experimental results presented demonstrate the viability of using biodiesel-diesel-ethanol blends to supply compression ignition engines.
– Following these were not found significant differences in the quality of the lubricating oil when biofuel-diesel blends were used, opposed to diesel supply.
– diesel-biodiesel-ethanol mixtures as fuel for compression ignition engines can be used without drawbacks on the progress of deposition, wear or lubrication oil quality in terms of the evaluated properties.