THE INFLUENCE OF BIOFUELS BASED ON RAPESEED OIL USING IN DIESEL TRACTOR ENGINE D-2402 TYPE ON EFFECTIVE POWER AND TORQUE PERFORMANCE, COMPARED TO DIESEL FUEL

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Abstract: *The idea that has conditioning this paper was the use of biofuel based on rapeseed oil on a medium-power diesel engine, alternative power supply being used, both as with diesel fuel and with rapeseed oil mixed with diesel in various proportions. This paper presents experimental results on a diesel engine effective power and torque performance of fueled with fuels based on rapeseed oil compared with diesel fuel. Fuels used in experimental research were mixtures of rapeseed oil, rapeseed methyl ester and diesel in different proportions: 80% diesel fuel - 20% rapeseed oil, 50% diesel fuel - 50% rapeseed oil, 25%diesel fuel - 75 % rapeseed oil, 100% rapeseed oil, 100% rapeseed methyl ester (RME) and 100% diesel fuel as (reference fuel). Because the researches were focused on the use of fuels derived from rapeseed oil on the existing Romanian engines, the work initially focused on those factors that do not involve changes or adjustments to diesel engine. International researches conducted so far have highlighted the effective power and torque performance differences of fuels based on rapeseed oil in comparison with diesel fuel. In Romania there have been intensive studies on different biofuels used in diesel engines. BIOCOMB consortium of the Technical University of Cluj-Napoca in collaboration with University of Agricultural Sciences and Veterinary Medicine, from the researches made possible that Cluj-Napoca to be the first city in the country where buses fueled with biodiesel from from rapeseed oil. The novelty of these experiments refers to the fuel blends used in the experimental tests and to the importance of results of effective power and engine torque performance. Practical implications of the work are found in the immediate applicability in the possibility of increasing the performance of agricultural tractors powered by biofuels and also open new directions in applied research on ways of streamlining the use of biofuels. The theme and direction of approach in this paper represents an innovation in the field of national research. Results and conclusions issued in the work are possible due to the support of the research project co-funded by the European Social Fund through Sectoral Operational Programme Human Resources Development 2007-2013.*

Key words: *rapeseed oil, rapeseed metyl ester, diesel fuel, effective power, torque*

INTRODUCTION

The use of vegetable oils as fuel is not new but dates back in the late 19th century, when Rudolph Diesel, the inventor of the diesel engine (DEMIBRAS A., 2002; HEBBAL OD et. al., 2006) at the International Exhibition in Paris in 1900 presented and demonstrated the functionality of a diesel engine, being fed then by peanut oil (KRAWEZY T., 1996).

The growing demand for energy, the depletion of petrol, the instability of world fuel prices and concerns about global warming are factors that focus the interest in renewable energy sources, bioenergy, in particular. Frequently bioenergy is presented as an environment friendly and locally available source of energy. Therefore bioenergy is emerging as a key factor in both developmental and environmental terms. Biofuels are an essential component of bioenergy because transport plays an important role in the world's total energy demand.

Diesel engines are widely used in the transport, electricity generation and shaft power.

These sectors are heavy consumers of petroleum oils which can be partially or totally replaced by vegetable oils and their derivatives which are derived from agriculture and thus of renewable origin.

There are four ways to use vegetable oil as fuel for diesel engines. One is to convert vegetable oil in a product with similar properties to diesel fuel (oil change chemical structure). This process is called transesterification. Another method is to use pure vegetable oil (filtered only) and mixed with different proportions en standard fuel, diesel fuel. Another method is the diesel fuel mixture with methyl ester of rape oil and the fourth method is to use pure vegetable oil (filtered) in diesel engines. This method requires implementing diesel engine changes because of higher viscosity of vegetable oil (eg. fuel heater).

Growing of energy crops depends directly on climatic conditions of different areas in the world. Thus, in the USA and Canada is predominant in soybean crop in south-east Asia (Malaysia, Indonesia and Thailand) and palm oil crop in Europe is growing especially the rape crop. In Romania is predominant rape as energy crops.

The flash point of rapeseed oil is 220 ^{o}C, which is much higher than that of diesel. It makes the ignition relatively difficult, but the transportation and handling is much safer. The calorific value is 10–15% less in comparison to diesel, but because of higher density the volumetric content of heat value is nearly about the same as that of diesel (EJAZ M., et. al. 2007). Straight Vegetable Oils (SVOs) have a chemical composition that corresponds in most cases to a mixture of 95% triglycerides and 5% free fatty acids, sterols, waxes and various impurities (VAÏTILINGOM G., 1992; WANG YD et al., 2006).

From previous studies it is evident that various problems are associated with vegetable oils being used as fuel in diesel engines due to the high viscosity, high density and poor non-volatility, which lead to problems in pumping, atomization and poor combustion inside the combustion chamber of a diesel engine (VELLGUTH G., 1983, LABECKAS G., et. al., 2003).

The transesterification is an extensive, convenient and most promising method for reduction of viscosity and density of vegetable oils [9]. However, rapeseed oil methyl ester (RME) mixing with diesel fuel reduces the calorific value of the fuel blend. That may result in engine power losses and increase in brake specific fuel consumption (BSFC) (NWAFOR OMI., 2004).

In Germany test with pure rapeseed oil as a diesel fuel has made by SCHOEDDER C., 1981. Short term engine tests indicated rapeseed oil had comparable energy outputs to diesel fuel. The tests showed that difficulties arose in engine operation after 100 h, due to deposits on piston rings, valves, and injectors. He indicated that further investigations are required to prepare the fuel, which is suitable for continuous running of engine and suggest the required modifications in the engine.

WAGNER and PETERSON, 1982 used rapeseed oil as a diesel fuel extender to study the long term effects of using vegetable oil as a fuel. They used a blend of 70% rapeseed oil and 30% diesel fuel, successfully to operate a small single cylinder engine for 850 h with the excellent results.

The purpose of this work is to investigate the effect of biofuels based on rapeseed oil on the engine performance (effective power and torque) compared with diesel fuel.

MATERIAL AND METHODS

In this study, the D-2402 compression ignition engine type was fuelled with 6 different fuels blends: 100 %diesel fuel;100% rapeseed metyl ester (RME); 80% diesel fuel - 20% crude rapeseed oil (80D_20R); 50% diesel fuel - 50% crude rapeseed oil (50D_50R); 25% diesel fuel 75% crude rapeseed oil (25D_75R); 100% crude rapeseed oil.

The main properties of the blends have been determined and are presented in Table 1.

Table 1

The main properties of the tested fuels

Property parameters	**Diesel fuel**	**80D_20R**	**50D_50R**	**25D_75R**	**RME**	**Rapeseed oil**
Density at 20, ^{o}C, g/cm3	0.834	0.855	0.880	0.897	0.883	0.915
Viscosity at 40, ^{o}C, mm2/s	2.346	4.424	9.654	17.859	4.466	34.358
Oxidation stability, h	>58	>58	9.5	7.79	6.84	5.92
Acid value, mg KOH/g	0.04	0.625	1.358	1.904	0.292	2.008
Peroxide number, mmol•O_2/kg	0	2.132	5.202	6.333	3.138	13.590
Coke content, max wt%	0.009	0.078	0.183	0.259	0.022	0.4
Water content, mg/kg	37	138	297	405	77	535
Cetane number	57.6	56	53.8	49.3	50.3	48.1

The experimental stand equipped with a diesel engine D-2402 type, hydraulic brake and data acquisition system, allows measurement of engine speed, braking force, fuel consumption, testing duration coolant engine temperature, oil temperature and ambient parameters.

The main features of the engine subjected to experiment are shown in Table 2.

Table 2

The main technical characteristics of the engine used in experimental tests

Engine type	**D-2402**
Number of cylinders	4
Cylinder diameter, mm	110
Stroke, mm	130
Engine capacity, cm^3	4760
Compression ratio	17:1
Injection pressure, daN/cm^2	175±5
Injection timing advance	24°
Effective power, kW	51,5
Nominal speed, rpm	1800
BSFC – Brake Specific Fuels Consumption, g/kWh	244

In order to perform this study different load engine was considered.

Methodology of the research program has been developed based on completing the following algorithm:

- establishment installations and equipment used for experiments and giving metrological and functional of these (to ensure conclusive results obtained);

- establishment of entry / exit data from the experimental stand, respectively the aquisition and transfer of data;

- record and analyze necessary data to establish experimental research findings related to the theme.

Thus was established the lifting several loads (regimes) of biofuels in several engine speeds, for better coverage of the loads beaches respectively engine speed. Diesel engine test requires measuring of a large number of parameters, processing of results value and their comparison with the values of the manufacturer imposed. Those tasks are handled by computer from the experimental stand, which much improved efficiency, objectivity and overall quality of the testing process. Experimental stand and positioning of sensors that measure the instantaneous values of the some parameters that describe qualitatively the engine subjected to experimentation are presented in Figure 1.

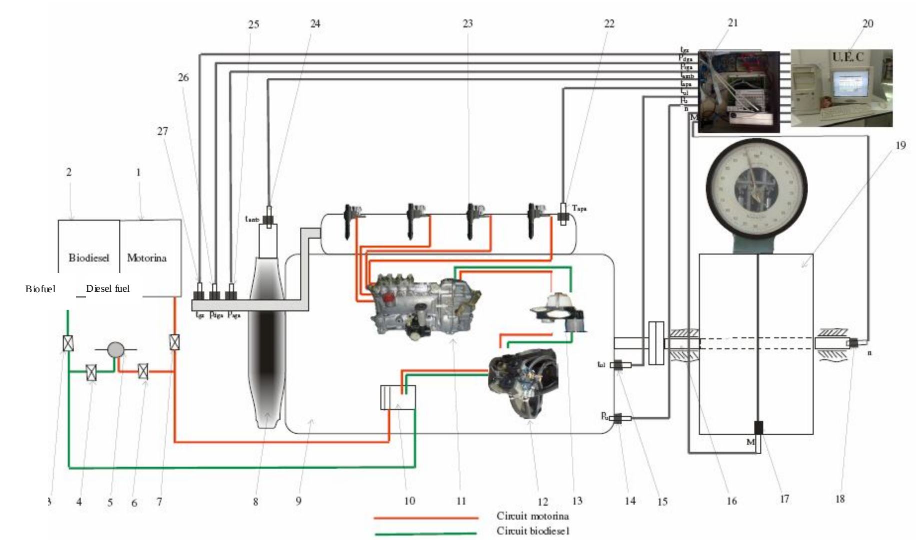

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Figure 1. Experimental stand a... positioning scheme
Diesel fuel flow
Biofuel flow

1- diesel fuel tank; 2- biofuel tank; 3-biofuels valve ...lves; 8- engine radiator; 9- diesel engine; 10- switch distributor; 11- in-line pump injection; 12- biofuel heating element; 13- pump supply; 14- oil pressure sensor; 15- oil temperature sensor; 16- hydraulic brake shaft; 17 – engine torque sensor; 18- rotation sensor; 19-brake stand; 20- electronic computing unit; 21- electronic block(multiplexer module); 22- ater temperature sensor; 23- injector; 24- ambient temperature sensor; 25- exhaust static pressure sensor; 26- exhaust gas dynamic pressure sensor; 27- exhaust gas temperature sensor

System functions that acquisition and processing the data of the experimental stand are:

- conditions consist of sets values for the following parameters: speed, time of robust test duration;
- the sensors are use to measure and record simultaneously the instantaneous values of the parameters that describe qualitatively the engine function (Figure 1)

Based on experimental results obtained is presented a comparative study of the main parameters of D-2402 engine fueled with new types alternative fuels based on rapeseed oil and diesel.

The experiments have been performed at partial loads (χ=0.92, χ=0.86, χ=0.82, χ=0.78, χ=0.73, χ=0.68), using different types of fuel based on rapeseed oil (mixture with diesel fuel and rapeseed methyl-ester) and having diesel fuel as witness. Experimentation of each type of fuel was preceded by emptying the entire fuel supply system and replace the fuel filters. Tests were conducted at the nozzle opening pressure specified by the manufacturer (p_{inj}= 175 ± 5 daN/cm^2).

RESULTS AND DISCUSSIONS

As a result of experimental research for the 6 load regimes specified above, the calculations were performed and curves were drawn according to the actual parameters variation graphs as shown in the figures 4-9 for effective power, and Figures 10-15 for engine torque.

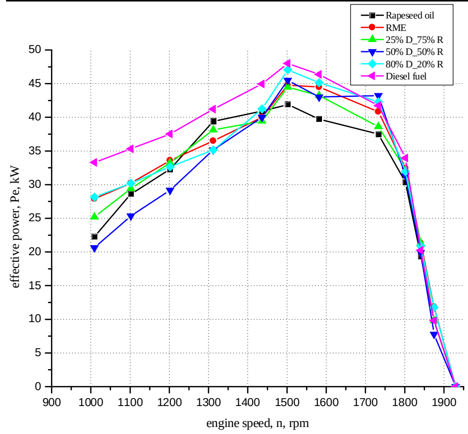

Figure 2. Variation of effective power depending on engine speed, for the load regime □=0.92

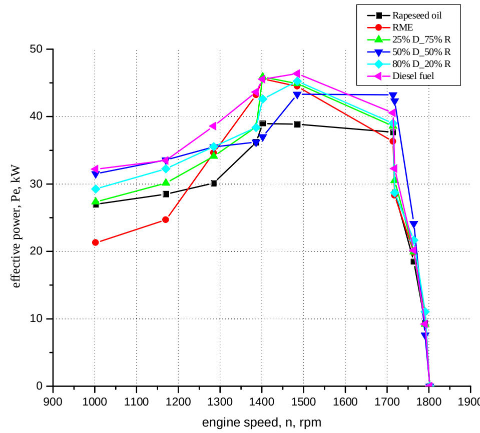

Figure 3. Variation of effective power depending on engine speed, for the load regime □=0.86

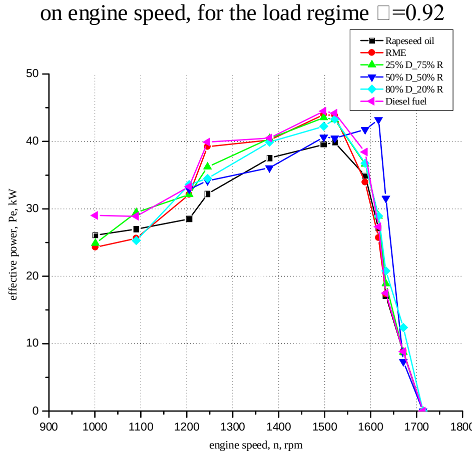

Figure 4. Variation of effective power depending on engine speed, for the load regime □=0.82

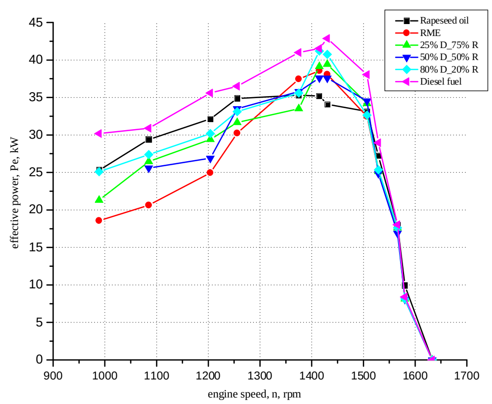

Figure 5. Variation of effective power depending on engine speed, for the load regime □=0.78

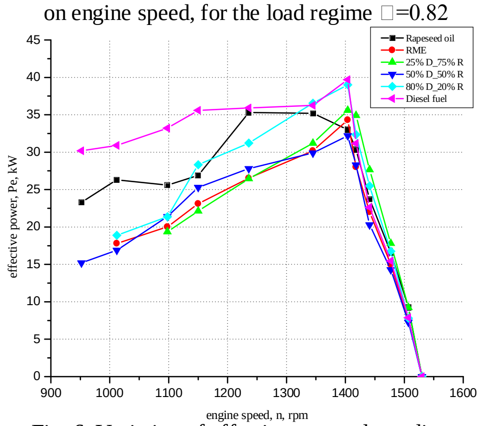

Fig. 6. Variation of effective power depending on engine speed, for the load regime □=0.73

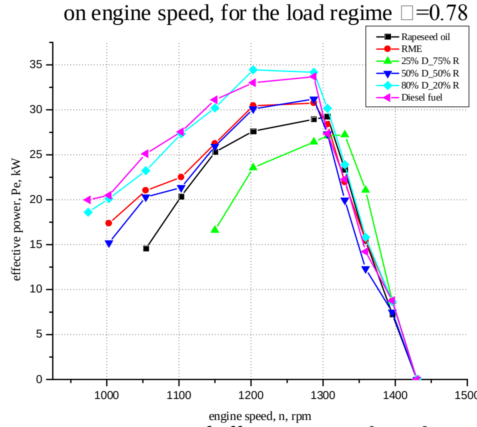

Fig. 7. Variation of effective power depending on engine speed, for the load regime □=0.68

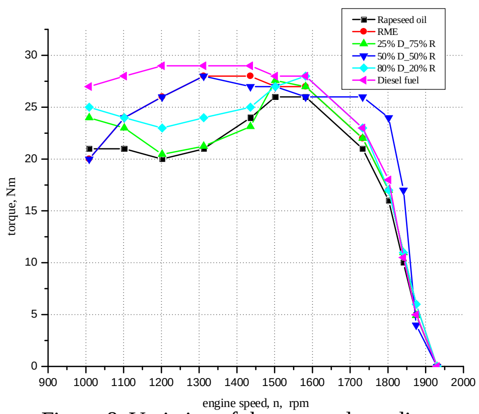

Figure 8. Variation of the torque depending on engine speed, for the load regime □=0.92

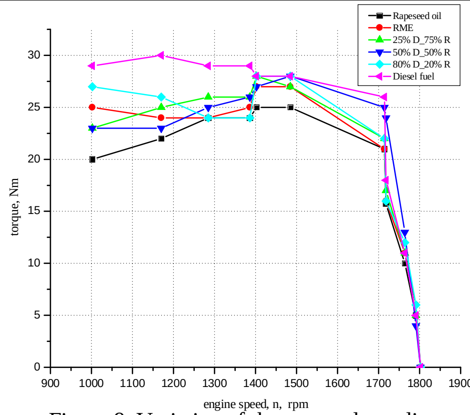

Figure 9. Variation of the torque depending on engine speed, for the load regime □=0.86

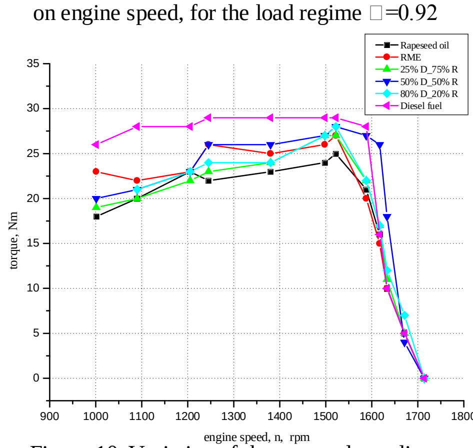

Figure 10. Variation of the torque depending on engine speed, for the load regime □=0.82

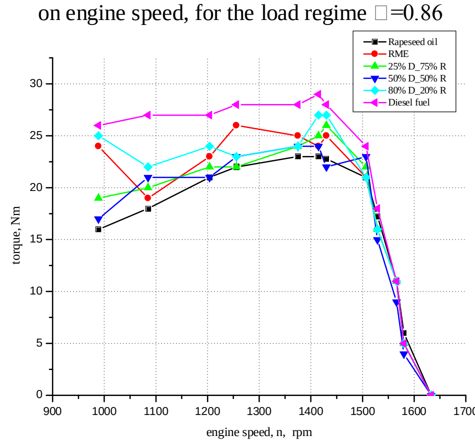

Figure 11. Variation of the torque depending on engine speed, for the load regime □=0.78

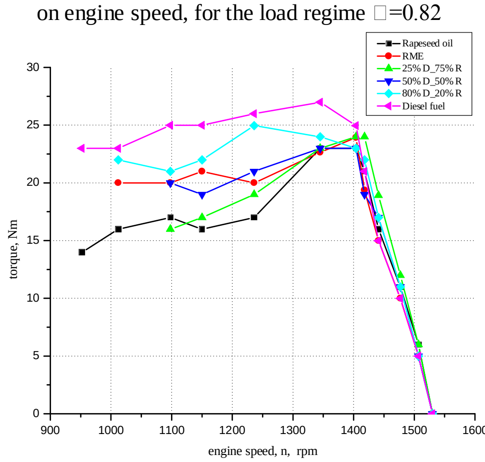

Figure 12. Variation of the torque depending on engine speed, for the load regime □=0.73

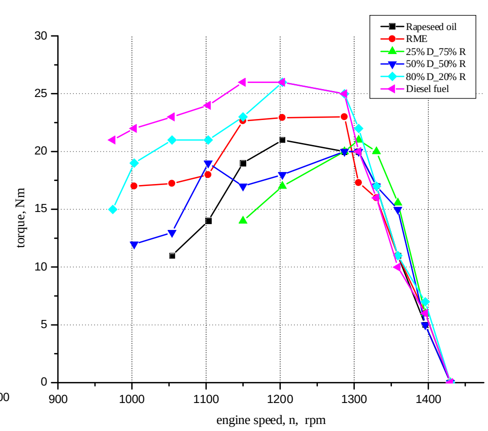

Figure 13. Variation of the torque depending on engine speed, for the load regime □=0.68

Table 3 summarizes the evolution of effective power values and the torque engine of fuels based on rapeseed oil compared to diesel fuel.

Table 3

The evolution of effective power and torque of biofuels based on fuels rapeseed oil compared with diesel fuel

Load (regime)	Fuels	Effective power [%]	Effective torque [%]
	Crude rapeseed oil	- 12,81	- 17,10
	RME	- 7.72	- 7,27
□=0.92	25D-75R	- 9.52	- 13,01
	50D-50R	- 13,09	- 2,16
	80D-20R	- 6,63	- 8,45
	Crude rapeseed oil	- 14,07	- 17,72
	RME	- 9.61	- 11,59
□=0.86	25D-75R	- 6,67	- 9,87
	50D-50R	- 2,25	- 6,44
	80D-20R	- 5,38	- 8,58
	Crude rapeseed oil	- 9,75	- 19,46
	RME	- 5,03	- 13,61
□=0.82	25D-75R	- 2.82	- 15,57
	50D-50R	+ 4,82	- 4,27
	80D-20R	- 1,74	- 11.26
	Crude rapeseed oil	- 10,62	- 19.92
	RME	- 17,03	- 12,75
□=0.78	25D-75R	- 13,09	- 15,54
	50D-50R	- 12,56	- 19,13
	80D-20R	- 9,91	- 10.36
	Crude rapeseed oil	- 10.44	- 20,04
	RME	- 22,17	- 12,37
□=0.73	25D-75R	- 12,97	- 10.64
	50D-50R	-25,09	- 11,72
	80D-20R	- 10,72	- 4,94
	Crude rapeseed oil	- 13,92	- 21,60
	RME	- 8,52	- 13,57
□=0.68	25D-75R	- 11,62	- 11,97
	50D-50R	- 13,31	- 21,20
	80D-20R	+ 1.16	- 5,48

The engine's functional parameters that have been obtained experimentally in the case of fuels based on rapeseed oil are diminished in comparison with those obtained for diesel fuel, but they mainly insure the exploitation requirements of the vehicle that has that engine. The maximum value of the moment when using fuels based on rapeseed oil is close to its value when using diesel fuel. Meanwhile, the fuels with a higher superficial tension and density, form a jet with a diversity of drops and a superior penetration, thus creating better conditions for self ignition, as well as for the control of mixture and burning [13]. The first drops that form have bigger dimensions, creating optimum flying conditions for the following drops, which maintain their kinetic energy for a longer period of time.

It can be noticed that the engine develops a smaller power when using rapeseed oil (P_{emax} = 41.9 kW) than the case of using diesel fuel (P_{emax}=48.02 kW). The corresponding curves for RME and the other fuels can be usually found between them (RME - P_{emax}=44.8 kW; 25D_75R - P_{emax}=44.5 kW; 50D_50R - P_{emax}=45.5 kW; 80D_20R - P_{emax}=47.04 kW).

This can be explained by the smaller value of the mass caloric power of biofuels in comparison to diesel fuel: with 13.8 % for rape oil and with 10.3% for RME less than diesel fuel.

Still, the difference of power is not high (for a load regime of □=0.88), being only 12.81 % in the case of rape oil, 7.72 % for RME, 9.25 % for the mixture 25D_75R, 13.9 % for the mixture 50D_50R and 6.63 % for the mixture 80D_20R, due to the one fact that, the difference between the value of volume caloric power of biofuels and diesel fuels is lower than in the case of their mass caloric power and on second the influence of their oxygen content is being felt.

The smallest difference between powers is for the load regime □=0.82, where the difference between rapeseed oil and diesel is only 9.75%, 5.03 % for RME, 2.82 % for the mixture 25D_75R and 1.74 % for the mixture 80D_20R. For the mixture 50D_50R it can even be noticed an increase in power with 4.82 % (see Table 2.)

For the regime □=0.68, within the interval of revolutions 1.200-1.300 rpm, the fuel 80D_20R has a value of the effective power with 4% higher than diesel fuel.

The considerations presented within the analyses of the variation of effective power with respect to the type of fuel remain also valid in the case of the analyses of the variation of the engine's torque. In this case it is noticeable the fact that the type of fuel influences the engine speed at which the maximum effective moment is being achieved. For the engine that has been used during the experiments with diesel, the engine speed at the maximum moment is: n_{max}=1.202 rpm and for rape oil n_{max}=1.500 rpm.

For the mixture 50D-50R, the revolution at the maximum moment is n_{max}=1.312 rpm, and for the mixture 80D-20R, the engine speed at the maximum moment is n_{max}=1.582 rpm. RME, has the engine speed at the maximum moment: n_{max}=1.312 rpm, and the mixture 25D_75R at the same engine speed when it reaches the maximum power, that is n_{max}=1.500 rpm.

CONCLUSIONS

- Higher the rapeseed oil percentage in diesel is, more the power of engine decreases. This can be explained by the lower value of caloric power of rape oil (37.6 MJ/kg) in comparison with diesel fuel (41.8 MJ/kg).
- The fuel that is closest to the diesel's fuel values is the mixture 80D-20R, due to the high level of diesel fuel within it. It can also be noticed that for the load regime □=0.73, rape oil has an appropriate behaviour to diesel fuel, within the engine speed interval 1.250-1.350 rpm.
- A good behaviour has RME, having results of the effective power that are very close to those obtained for diesel fuel.
- The torque is influenced by the percentage of rape oil within the fuel. Thus, diesel fuel has the highest value of the torque, and rape oil the smallest one in the majority of the loads regimes.
- When using mixtures with a low content of rapeseed oil there is a slight decrease in the value of the torque in the area of the usual engine speed of the engine. The increase of the rapeseed oil percentage leads to a more important decrease of the engine torque.
- The mixture 80D-20R is the closest as value to the engine torque that has been obtained when using diesel fuel. This can be noticed from the 6 load regimes to which the experiments have been achieved.
- The values of the effective moment for RME are close to the ones for diesel fuel.
- The values of the engine torque that are very close to the ones for diesel fuel can be noticed in the case of the load regime □=0.92 for the fuel 50D–50R, where the difference is only 2.16 % favouring diesel fuel (Table 3)

Based on the analyses of the main functional parameters of the compression ignition engine supplied with biofuel, it can be concluded that its supply with fuel based on rapeseed oil can insure comparable performances with those achieved when supplying the Romanian tractors with diesel fuel.

Acknowledgements

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