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CERCETAREA FACTORILOR CAUZALI DE UZURĂ ȘI A CARACTERISTICILOR ULEIULUI ÎN CAZUL ALIMENTĂRII CU BIOCOMBUSTIBILI A MOTOARELOR PENTRU MAȘINI AGRICOLE

Lucian FECHETE, Doru-Laurean BĂLDEAN, Adela-Ioana BORZAN

RESEARCH OF WEAR CAUSING FACTORS AND LUBRICANT CHARACTERISTICS IN CASE OF BIO-FUEL SUPPLY TO THE AGRICULTURE MACHINE'S ENGINE

Lubricants and fuels are used in over a billion machines. All of them are used in different operating regimes. Because the viscosity and density of engine's fluids are different in each case, operating conditions are significantly changed. This idea underlines the specific engine operating conditions when performing actual tasks in agriculture. The fuel-lubricant interaction study leads to solutions regarding the wear problem. Experiments show the problems and also the optimal solutions. Agricultural machine lubrication takes part in determining the reliability and durability. Biofuel-adds in commercial fuel is now common practice and an actual task on agricultural engineering is machines life span. Biodiesel may be used alone or in mixtures with other fuels, either fossil diesel or alternative solutions. The content of biodiesel in commercial fuels throughout the European Union is under 15 percent, but it is supposed to increase toward 20 percent. So, we have to analyse the influence that biodiesel has in lubrication and in component wear. In this study were developed experiments concerning the biofuel use and influence on lubricants in various situations, determined by complex analyse of available data from applied research. There were changes in carbon deposits and quality of lubrication. Biodiesel influenced the lubricant composition.

Keywords: agriculture, biodiesel, biofuel, engine, machine
Cuvinte cheie: agricultură, biodiesel, biocombustibil, motor, utilaj

1. Introduction

In the past three decades there were analyzed and documented many methods for pollution reduction and machines efficiency improvement (Bățaga et. al., 1995). One of the most significant methods consists in optimizing the “hardware” mechanisms (Burnete, 1998) and fluid supply (Burnete et. al., 2009) to the engine (regarding fuel, coolant and lubricant), as well as processes investigation capabilities (Burnete et. al., 2015). But wear causing factors and the main fluids (lubricant and fuel) that enter the engine may even more be detailed or analyzed in order to gain knowledge.

Developing high quality machines for agricultural engineering, (Gheres, 2007) is possible by understanding the kinematic parameters (Gheres, 2013) and energy consumption (Gheres, 2014) as well as the repair costs when the tractor reach service interval or repair state (Lorencowicz, 2015).

By analysing through numerical investigations (Mariasiu, 2015) and after external energy conditioning (Mariasiu and Burnete 2010) researches tend to improve the overall possibilities for reaching alternative solutions in implementing biofuels and biolubricants at different stages of agricultural complex system operation regarding the load level as well as cold start process (Mariasiu and Varga 2010). On this path researchers have developed simulation models for computational fluid dynamics when supplying the engine with biodiesel (Moldovanu and Burnete 2013) and lubricant flow in tractor’s sub-assembly (Noh et. al., 2017). Yet there are few studies concerning actual tasks in agricultural engineering concerning machines management (Papageorgiou, 2015) and the alternative materials (Popescu et. al., 2011) for economic and efficiency reasons. Concerning waste reduction by transforming some materials as polyethylene (Popescu and Filip 2010), polymers (Popescu et. al., 2011) and polyolefins (Popescu et. al., 2014) into alternative fuels there were recorded also achievements and results.

The last but not least there were developed studies related to biodiesel quality, standards and properties in order to positively impact the environment and society (Barabás and Todoruț 2011). This significant idea brings the light to one of the most important criteria for fuel and lubricant match with the targeted machines both in agricultural and other commercial applications. Lubricating and injection system from an engine has an important role in creating all of its dynamic behavior. Smoke opacity and power output from all thermal engines correlate with the proper development of its injection and lubrication processes as well as the fluids' significant properties.

The present study expands the field of research concerning the alternative solutions for fuel and lubricant supply to compression ignited engines (from category 3LD510 Lombardini manufacturer) equipping agricultural tractors and machines in order to improve power, torque, smoke opacity diminish, efficiency, reduce waste and to also increase components life span as well as maximize the profit in the process if possible.

Through the present paper and the developed research the main objective is to identify an alternative solution (if any) for fuel (from which we studied at least 4 different solutions), lubricant (in mixture with fuel and after a certain period of engine exploitation) and operational process in order to cut down energy costs (by improving power output and torque), diminish pollution (regarding smoke opacity) and recycle waste materials (vegetable oils and polluted water) meanwhile the mechanical components still perform optimally (meaning that injectors and high pressure fuel pump still operates and the wear level doesn't takes it out of the operation which happens during the water injection).

2. Materials and method

The materials used consist in a test bed with Lombardini tractor engine 3LD510 (single cylinder research unit) and corresponding fluids (fuels and lubricants) according to table 1 (Materials for applied research). The base model diesel fuel was prepared in such a specific manner in order to be biodiesel free and making no impact upon fatty acid methyl esters in the initial fuels. For study development there were used mixtures of different substances.

Table 1

Substance	Origin
Diesel fuel	Diesel standard - SF – 43 (EN ISO 3170 sau EN ISO 3171)
Biodiesel	Methyl ester rapeseed oil, ICIA, Cluj-Napoca
Lubricant	Castrol 15 W 40 – motor oil
Water	Standardized water source from public network - SR EN ISO 17025:2005

The mixtures were obtained by volumetric dosage in multiple instances combining the fuel with oil and water, according to table 2 (Mixtures used for applied research), in order to study engine performances and fluid properties.

Table 2

Substance	D100	D65W35	D5L95	D2L98	B100	B65W35	B5L95	B2L98	L100
Biofuel, % v/v	0	0	0	0	100	65	5	2	0
Diesel, % v/v	100	65	5	2	0	0	0	0	0
Oil, % v/v	0	0	95	98	0	0	95	98	100
Water, % v/v	0	35	0	0	0	35	0	0	0

The methods used are presented in table 3 (Methods, equipment and tests), along with some of the equipment and tests performed.

Table 3

Testing	Equipment	Apparatus series	Analyzing method
Penetrating tension at industrial frequency 50 Hz;	OTS 100AF/2, brass electrodes	6410-836/00090/1362	SR EN 60156:1997
Dielectric rigidity, kV/cm	OTS 100AF/2	6410-836/00090/1362	SR EN 60156:1997
Water content, ppm	Coulometer AVO KF, 2000	6111-441/001100/1071	SR EN 60814:2002
Density/20°C, g/cm^3	Densitymeter with liquid	18/2002	STAS 35-81, p.2
Flame point, p=972 bar	Pensky-Martens AF3	A090116	SR EN ISO 2719:2003
Mineral acidity	Cylinder with stopper	with separation funnel	STAS 22-1964
Torque load curve	Lombardini C.I.E.	3LD510	ISO 789-8

3. Experimental test bed setup

The experimental test bed schematic is presented in figure 1. The compression ignited engine C.I.E. 20 is operated in order to reach different load and speed regimes, being each time supplied with one of the proposed fuels (Diesel, Biodiesel and their mixture with water) and lubricated with Castrol oil 15W40. The inside cylinder pressure of the compression ignited engine from Lombardini tractor was monitored with the pressure sensor 13, reaching maximum values of 130 bar. All used fluids (fuels and lubricant) were stored in specific tanks 6-9. The mixtures were realized with measuring vessels 5 and temporary stored in the daily tank 25. From this point the current fuel solution is transferred trough low pressure pipe line 26 and tap 27 to the pump assembly (low pressure and high pressure pump). Through a high pressure steel pipe line the fuel is sent to the injector in order to be sprayed into the combustion chamber. The chemical energy of each fuel in various proportions is transformed into thermodynamic parameters (gas pressure and force on top of the piston head) which lead to the piston displacement, connection rod cranking of the engine main shaft (the crankshaft). After developing the engine characteristic diagrams by using the hydraulic dynamometer 21 and after measuring the torque and engine speed a specific quantity of 500 milligrams of lubricant was taken apart in order to be analyzed with the specialized equipment available in order to highlight the changes.

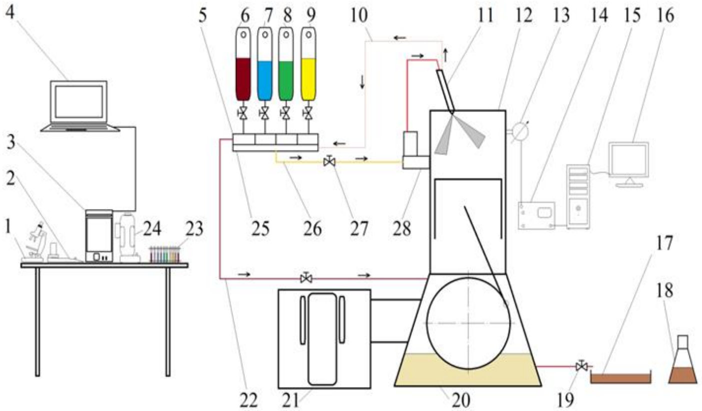

Fig.1 Experimental test bed setup for inspecting the fuel and lubricant characteris-tics. 1-micros-cope; 2-OTS 100AF/2; 3-Coulo-meter AVO KF, 2000; 4-Data recording/storage station; 5-measuring vessels; 6-lubricant tank; 7-water tank; 8-biodiesel (R.M.E.) tank; 9-diesel fuel tank; 10-fuel return; 11-fuel injector; 12-3LD510 Lombardini cylinder head; 13-pressure sensor; 14-analog/digital convertor unit; 15-storage and post processing digital unit; 16-display for pressure-volume characteristic diagrams; 17-oil tray; 18-erlenmeyer glass; 19-oil tap; 20-oil tank/case; 21-dynamometer; 22-oil supply pipe line; 23-glass tubes; 24-cylinder with stopper; 25-daily tank; 26-fuel line; 27-fuel tap; 28-fuel pump assembly

4. Results and discussion

Testing results with diesel fuel on the engine-dynamometric bench are presented in table 4 (Testing results with D100 – standard diesel fuel), correlating the hourly fuel consumption (Ch) with power output (Pe) in order to determine the specific fuel consumption (Ce). Lowest Ce was at 2700 rpm and 20.1 Nm. The output measurements determined with biodiesel fuel (canola oil or rape methyl ester) supplied to the engine test bench are presented in table 5 (Testing results with B100 – Biodiesel (Rape Methyl Ester)), being highlighted the greater smoke opacity level in comparison to the diesel standard operation.

Table 4

Diesel							
C.I.E. speed	C.I.E. Torque	Hour Cons.	C.I.E. Power	Specific Consumption	Power coefficient	Torque coefficient	Opacity
D100.n	D100.T	D100.Ch	D100.Pe	D100.Ce	D100.χP	D100.χM	D100.k
[rpm]	[Nm]	[l]	[kW]	[kg/kWh]	[-]	[-]	[1/m]
2985	1.66	0.77	0.518	1.25	0.078	0.051	0.027
2900	5.04	0.897	1.527	0.49	0.231	0.154	0.038
2850	10.13	1.345	3.028	0.37	0.459	0.309	0.050
2825	15.09	1.390	4.5	0.26	0.682	0.460	0.150
2700	20.1	1.530	5.728	0.22	0.868	0.613	0.610
2195	25.5	1.621	5.853	0.23	0.887	0.777	1.640

Table 5

Biodiesel							
C.I.E. speed	C.I.E. speed	C.I.E. speed	C.I.E. speed	C.I.E. speed	C.I.E. speed	C.I.E. speed	C.I.E. speed
B100.n	B100.n	B100.n	B100.n	B100.n	B100.n	B100.n	B100.n
[rpm]	[rpm]	[rpm]	[rpm]	[rpm]	[rpm]	[rpm]	[rpm]
2976	2976	2976	2976	2976	2976	2976	2976
2885	2885	2885	2885	2885	2885	2885	2885
2826	2826	2826	2826	2826	2826	2826	2826
2773	2773	2773	2773	2773	2773	2773	2773
2691	2691	2691	2691	2691	2691	2691	2691
2405	2405	2405	2405	2405	2405	2405	2405

Suppling the engine with biodiesel obtained from vegetable canola oil leads to a better specific fuel consumption (Ce) and by its higher lubrication index creates the proper condition for the tractor engine to perform longer, though it has a little higher smoke opacity. So one of the wear causing factors may be the fuel composition and combustion. The tests were conducted even further results with standard diesel fuel blended with 35 % water in volume/volume ratios and the engine coupled to the dynamometric bench was operated in similar loading conditions and charging regime, thus the obtained results were gathered on the same structure but with some significant differences regarding the values.

Results of biodiesel+water blend (B65W35) are presented in table 6 (Analyses results for all the blends of fuels). It is observed that the biodiesel performs better than the rest of tested fuels on the tractor engine with compression ignition both in hourly fuel consumption and specific fuel consumption which means it leads to increased energy efficiency.

The main characteristics (which are operationally influential) and results of laboratory analyze for fuel and lubricant blends regarding the specific properties are shown in table 7 (Analyze results for all the blends of lubricants).

Table 6

Substance	D100	D65W35	B100	B65W35
Penetrating tension, at 50 Hz frequency, [kV]	47	39	50	40
Dielectric rigidity, [kV/cm]	190	98	200	101
Water content, [ppm]	2	$3.5*10^4$	3.2	$3.5*10^4$
Density at 20°C, [g/cm^3]	0.834	0.8921	0.9	0.935
Flame point trough Partens-Martens method, at p=972 mbar, [°C]	>55	150	210	245
Accidity and alcalinity	7	6.6	7.6	7

Table 7

Substance	D5L95	D2L98	B5L95	B2L98	L100	L100 after supply D100, for 15h	L100 after supply B100, for 15h	L100 after supply B65W35, for 15h
Penetrating tension, at 50 Hz frequency, [kV]	47.8	47.9	47.7	47.8	52	47.9	47.8	48
Dielectric rigidity, [kV/cm]	193.7	195.9	210	215	240	191.6	191.2	191.8
Water content, [ppm]	1.1	1	1.4	1.2	0.9	6.5	7	9
Density at 20°C, [g/cm^3]	0.8825	0.884	0.886	0.8853	0.885	0.88	0.882	0.872
Flame point trough Partens-Martens method, at p=972 mbar, [°C]	170	182	203	196	190	191	191	191
Accidity and alcalinity	7.2	7.4	7.3	7.45	7.5	7.4	7.4	7.4

Consumption test results with tested fuels on the engine test bed are presented in figure 2 and 3.

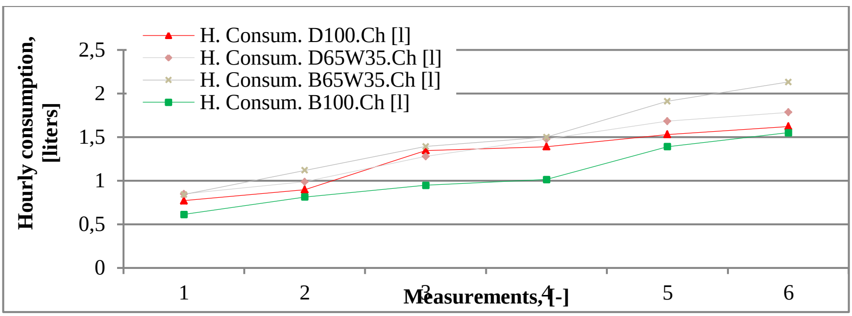

Fig. 2 Experimental test results concerning hourly fuel consumption

5. Conclusions

Researching in the Laboratory of Internal Combustion Engines “Nicolae Bățaga” from Technical University of Cluj-Napoca through applied experimental means of laboratory testing with engines from agricultural machines installed on dynamometric bench to determine the most influential parameters (as temperature, power, torque, fuel and lubricant main characteristics) regarding tractor’s energy and propulsion supply component, as well as the observations concerning the results in the present paper, have lead our efforts to issue some conclusions, as

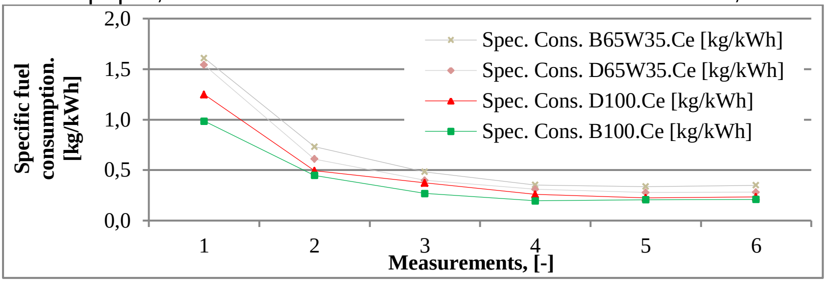

Fig. 3 Experimental test results concerning specific fuel consumption

follow: after supplying a specific fuel to the injection system of the engine it presents signs of influence upon the lubricant; the measurements made on the engine showed some advantages and higher fuel economy when using biofuels; when mixing the conventional or alternative fuels (biodiesel) with water through a process of high speed fragmentation of molecules the resulting fuel (D65W35 and B65W35) was used in injection supply system of the compression ignited engine in order to analyze the operation conditions and some data were recorded, the engine was working and it could be loaded to some point although the power and torque output are lower than in the case of reference fuel; the measurements outline the influence of fuel type (diesel, biodiesel or blends) and lubricant gross composition at least upon the agricultural machine’s engine power and torque outputs, due to the combustion and component lubrication processes through laboratory applied means; wear causing factors are linked both to the performance output and to main fluids (fuel and lubricant) composition (water content and acidity); when the engine was supplied with fuel-water blends the injector and the high pressure pump has been clogged up and terminated few times, especially when the fuels was stored for minimum 3 days; thus, the lubricating capability of the fuel is at least as equally important as the engine's lubricant. The engine works properly with its adjusted fuel.

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Lucian FECHETE
Doru-Laurean BĂLDEAN
Adela-Ioana BORZAN
Departamentul de Autovehicule Rutiere şi Transporturi,
Facultatea de Mecanică, Universitatea Tehnică din Cluj-Napoca
e-mail: dorubaldean@yahoo.com; doru.baldean@auto.utcluj.ro; 0752083337
adela.borzan@auto.utcluj.ro; lucian.fechete@auto.utcluj.ro;