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IMPROVING DIESEL ENGINE OPERATION FOR A GREENER ENVIRONMENT USING HYDROGEN FUELLING

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Abstract: *The objective of the paper is the improvement of energetic and pollution performance of a truck diesel engine which operates fuelled with hydrogen and diesel fuel. The authors recommend hydrogen addition within the intake manifold of the engine, a method also known as diesel-gas method. In order to conduct the experiments a 10.34 l turbocharged truck diesel engine was equipped with an external gas injection system for hydrogen fuelling. The maximum hydrogen quantity was limited to keep the maximum pressure rise rate as low as possible and to limit the smoke emission level. The results of experimental investigations show both the increase of the thermal efficiency of the engine and the reduction of the* NO_x *and smoke emissions level.*

Key-Words: *pollution, diesel-gas, NOx, combustion, fuel, consumption.*

1. INTRODUCTION

With the drastic increase in regulations as far as pollution is concerned for the diesel engines, the researchers in the field must find viable and sustainable solutions to supply the engines with fuel in a more efficient and less polluting way. A well known and excellent solution is the use of alternative fuels. Among these fuels a very good variant is hydrogen. Hydrogen can be used as an alternative fuel for both types of internal combustion engines, with spark ignition and compression ignition. In the case of spark ignition engines, the use is relatively easy, the air-hydrogen mixture can be made in the intake manifold and ignited by a spark plug. In the case of diesel engines, the most common supply method is "Diesel-Gas" [1], the injection of hydrogen in the gaseous state being made in the intake manifold, and the ignition is carried out in safe conditions by the diesel fuel jet flames. The use of hydrogen as a single fuel in compression ignition engines is difficult and requires major modifications of the injection and ignition systems, due to the high self-ignition temperature and very low cetane number, which make it virtually impossible to ignite the air-hydrogen mixture. In the table 1 some important properties of hydrogen are presented in comparison with diesel fuel properties.

Dual-fuel powered diesel engines produce less pollutant emissions than conventional ones, and no major engine modification is required. Smoke and particulate emissions are much lower in the case of dual diesel-hydrogen fuelling than in the case of the standard diesel-only engine [2]. The reduction of the amount of air introduced into the engine, due to the presence of gaseous fuel leads to a slight decrease in the level of HC and carbon monoxide emissions [3], [4]. At low loads, there is a decrease in the effective power and the indicated efficiency, compared to the diesel only supply mode.

Varde et al. [5] studied the effects of hydrogen fuelling by introducing hydrogen into the intake manifold of a diesel engine. The main objective of this research was to reduce the level of particulate matter in the exhaust gases by introducing small amounts of hydrogen. The degree of substitution of diesel with hydrogen was equal to 10% in energy percentages and led to a reduction in the level of smoke emission at partial load. However, at full load the reduction in smoke emission was more modest most likely due to the small amount of air available in the cylinder.

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It has also been found that very low hydrogen flows have had adverse effects on the thermal efficiency of the engine, but notable improvements in efficiency have been obtained by increasing the percentage of hydrogen supplied.

Table 1.
Properties of diesel fuel and hydrogen [1]

Property		Diesel fuel	Hydrogen
Molecular mass, [kg/kmol]		226	2.016
Theoretical air-fuel ratio, [kg air/kg fuel]		14.7	34.32
Density		820-860	0.0899
Flammability limits in air, at 20 °C and 760 mm Hg	λi….λs	0,34…1,68	0.136…10.12
Flame velocity in air (λ=1), at 20 °C and 760 mm Hg [m/s]		-	2.37
Cetane Number		45-55	-
Min. ignition energy in air [mJ]		0.2-0.3	0.15
Heat of Vaporization [kJ/mol]		250-314	458.1
Boiling temperature, °C, la 101300 Pa		180-359	-253
Autoignition temperature, [K]		473...493	845
Lower Heating Value	[kJ/kg]	41800	119 600

In [6] the influence of the hydrogen fuelling with different degrees of substitution of diesel fuel with hydrogen on the pressure in the cylinder of a diesel engine was studied and with the increase of the degree of substitution of diesel fuel with hydrogen at low engine loads the maximum pressure and the maximum pressure rise rate was lower due to the reduction of the diesel dose and the increase of the self-ignition delay [6].
Haroun A.K. Shahad and Nabeel Abdul-Hadi performed an experiment on a diesel engine fuelled with hydrogen injection in the intake, observing an increase in thermal efficiency by (~ 40%) to 60-80% engine load. At higher loads the thermal efficiency decreases dramatically due to incomplete combustion, the air excess coefficient being substantially lower [7].
The paper [8] presents the effects of hydrogen addition on the energy and pollution performance of a diesel engine powered by diesel as a pilot fuel and methane. The effect of gaseous fuel on the maximum pressure inside the cylinder and on the heat release is relatively low at low and medium loads [8]. At high loads, however, the addition of gaseous fuel contributes to increasing the efficiency of the combustion process and increasing the maximum pressure inside the cylinder. Also, the increase in the amount of hydrogen led to an increase in the maximum pressure. Also at high load the burning process has become unstable and difficult to control [8]. This is also confirmed by Gatts et al. [9], which suggests that the efficiency of the combustion process is dependent on engine load and to increase the effective thermal efficiency of the engine hydrogen should be added at high loads [9].
By using dual fuel operation, the level of CO, HC and smoke emissions decreases due to improved combustion, but there is a slight increase in CO_2 emission [3], [10].

2. EXPERIMENTAL RESEARCH

The experimental testing equipment is composed of: eddy currents engine dyno, measuring and monitoring instrumentations. In figure 1, the schematic structure of the test bed is presented.
The engine mounted on the test bed is a turbocharged direct injected D 2156 MTN diesel engine, manufactured by Roman SA Brasov. The characteristics of the engine are presented in table 2.

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The engine has been adapted to be hydrogen fuelled. The fuel supply method used is diesel-gas, which consist of the gaseous hydrogen injection in the intake manifold of the engine through a valve mounted at the inlet to the manifold. The injection flow was adjusted by means of a valve. The homogeneous air-hydrogen mixture is subsequently ignited by the flames that appear in the diesel fuel jets prior injected into the combustion chamber by the classic engine injection system.

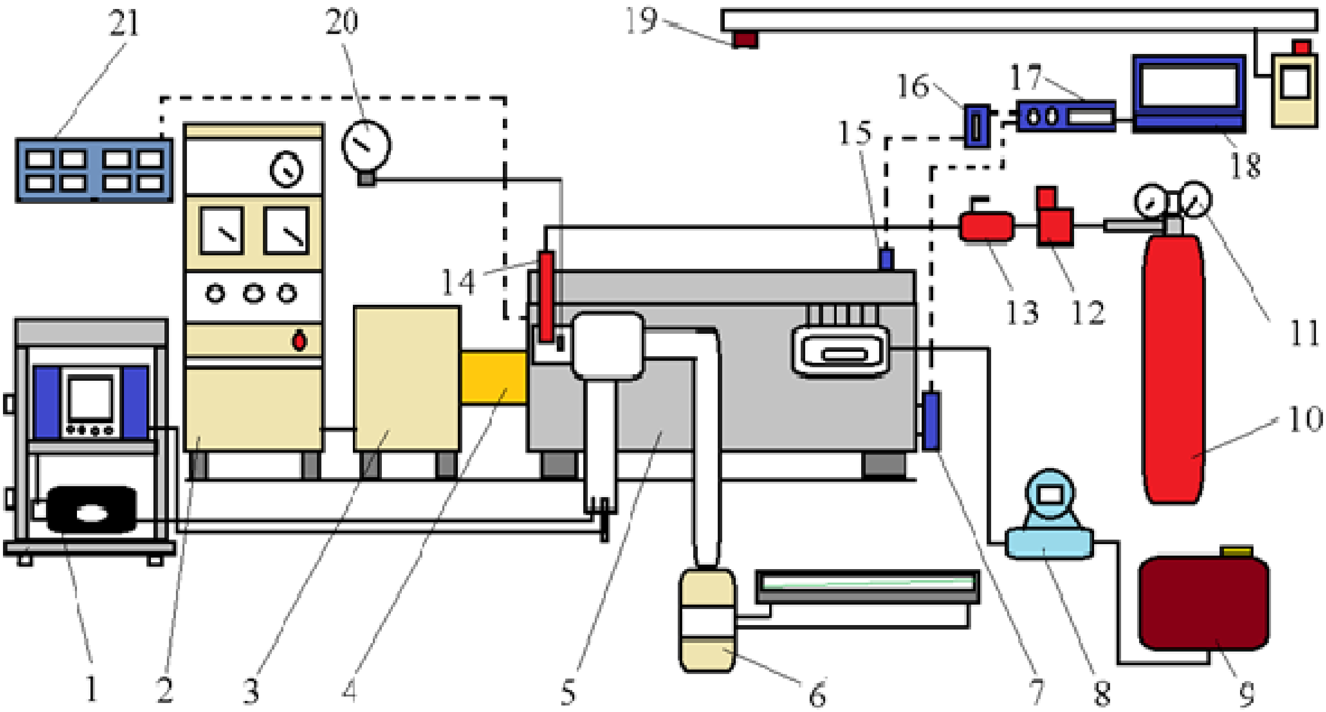

Figure 1. The test stand diagram

Ratings: 1- AVL DiCom 4000 gas analyzer and opacimeter, 2- electric dyno control panel, 3- Hoffman turbocharged electric dyno, 4-coupling, 5- D2156 MTN8 diesel engine, 6-Meriam air flow meter, 7- AVL365C angular position transducer, 8- mass flow meter Krohne Optimass 3050 C for diesel fuel, 9- diesel fuel tank, 10- hydrogen bottle, 11-pressure reducer, 12- Alicat Scientific MCR flowmeter for hydrogen, 13- flame extinguisher, 14- hydrogen injector, 15- piezoelectric pressure transducer Kistler, 16- load amplifier AVL 3067A, 17- data acquisition system AVL Indicom, 18- computer with acquisition plate AVL 91C, 19- hydrogen sensor for the booth enclosure equipped with a warning system in the case of the detection of hydrogen leaks, 20- pressure gauge, overload pressure, 21- Shimaden indicators for intake air temperature, exhaust gases, oil and coolant.

Table 2.
Characteristics of the D 2156 MTN8 engine

Characteristic	Notation	U/M	Value
The power	P_n	kW	188
Maximum power speed	n_n	rpm	2100
Maximum torque	M_{max}	Nm	890
Maximum torque speed	n_M	rpm	1450
Number of cylinders	i	-	6
Compression ratio	ε	-	17.5
Supercharge pressure	p_s	MPa	0.18
Stroke / bore ratio	S/D	mm	150 /121
Injection pressure	p_i	MPa	17.5

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2.1 The working procedure

In the first place the standard reference case was investigated, fuelling the engine just with diesel fuel. After the diesel fuel was partially substituted with hydrogen, aiming to maintain the standard engine power, so the diesel fuel quantity was decreased and hydrogen quantity was increased, the energetic substitute ratio of diesel fuel with hydrogen being situated between [0.85-3.4].
To fuel the engine with hydrogen the diesel-gas method was chosen, this method consisting of gaseous state hydrogen injection into the intake manifold of the engine. The hydrogen flow was adjusted and correlated with the working regimen of the engine by means of a valve.
For all the experiments the engine operating regimen was 1450 rpm and 70% engine load.

3. RESULTS

The experimental investigations led to the following results.

3.1 The maximum in cylinder pressure and the maximum rate of pressure rise

By processing the experimental pressure diagrams it can be observed that both the pressure and the rate of pressure rise increased with increasing substitute ratio of the diesel fuel with hydrogen due to the increase of preformed mixtures burning ratio. In the intake stroke the engine aspirates a homogeneous mixture of hydrogen-air and this homogeneous mixture is ignited by the flames occurred in the prior injected diesel fuel sprays.
Because of this process the combustion intensifies, the preformed mixtures burns with a higher rate and the in cylinder pressure increases.
Also the maximum rate of pressure rise increases.
Figure 2 presents the maximum in cylinder pressure relative to the diesel fuel fuelling case for all the investigated energetic substitute ratios of diesel fuel with hydrogen.
In the figure 3 the maximum rate of pressure rise is presented, also relative to the standard case of fuelling with diesel fuel.

3.2 The energetic specific consumption

The specific energetic consumption decreased with the increasing substitute rate of the diesel with hydrogen due to the improvement of the combustion process, being lower compared to the case when the engine was diesel fuel powered only.
The figure 4 presents the energetic specific consumption relative to the diesel fuel only case.

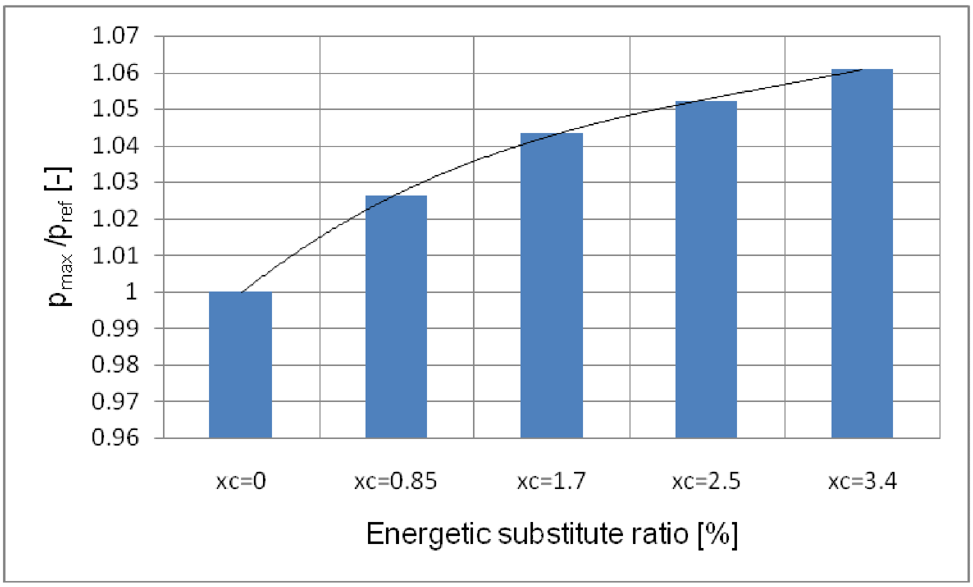

Figure 2. The maximum in cylinder pressure relative to the diesel fuel fuelling case

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3.3 The nitrogen oxides emission level

The nitrogen oxide emissions concentration in the exhaust gases of the diesel engine fuelled with hydrogen and diesel fuel decreased for relatively low rates of substitution of diesel with hydrogen due to the fact that the burning rate of hydrogen is higher than that of diesel and although the temperature of the gases increases, the formation of nitrogen oxides is delayed due to the shorter burning time and reaching the maximum gas temperature much shorter period. This influence has been established by Georgios Pechlivanoglou who established a duration of approximately 2 ms of the high gas temperature [11]. As the degree of substitution of diesel with hydrogen increases, the influence of temperature on the nitrogen oxides formation becomes normal and their concentration start to increase.
The figure 5 presents the nitrogen oxides emission relative to the diesel fuel fuelling case.

3.4 The carbon dioxide emission level

Because of the combustion process improvement and due to the reduction of carbon content of the mixture the results led to a slight decrease in the level of CO_2 emission.
The carbon dioxide emission relative to the diesel fuel fuelling case is presented in the figure 6.

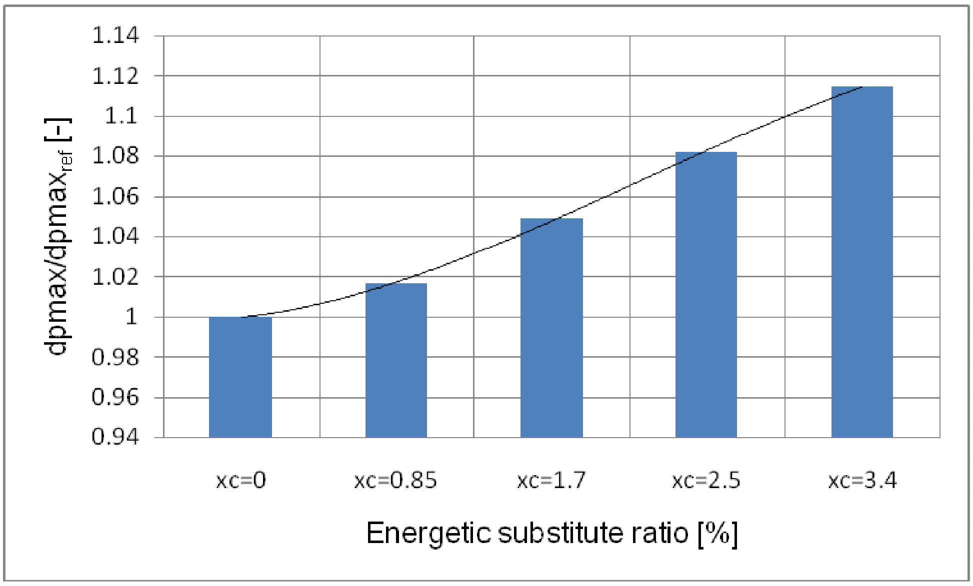

Figure 3. The maximum rate of pressure rise relative to the diesel fuel fuelling case

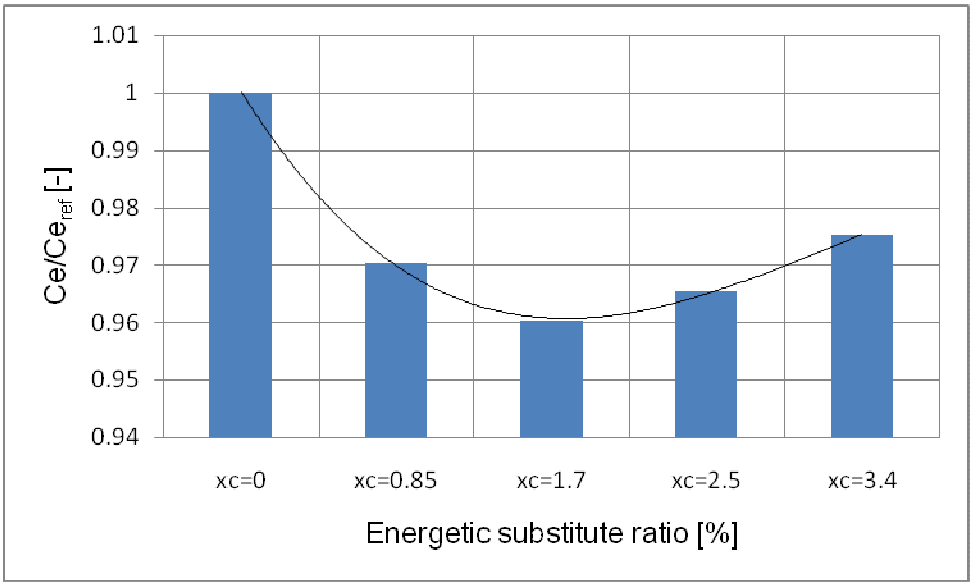

Figure 4. The energetic specific consumption relative to the diesel fuel fuelling case

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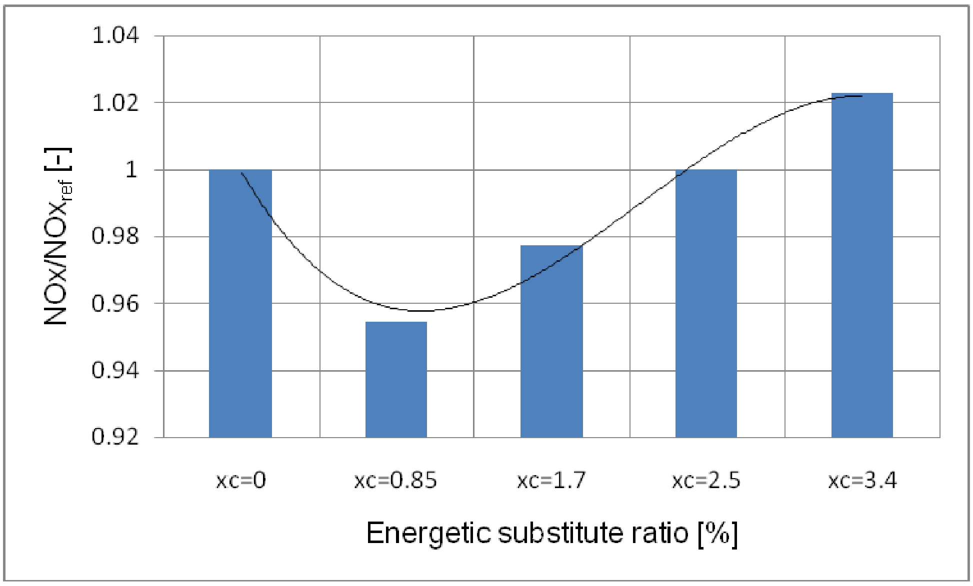

Figure 5. The nitrogen oxides emission relative to the diesel fuel fuelling case

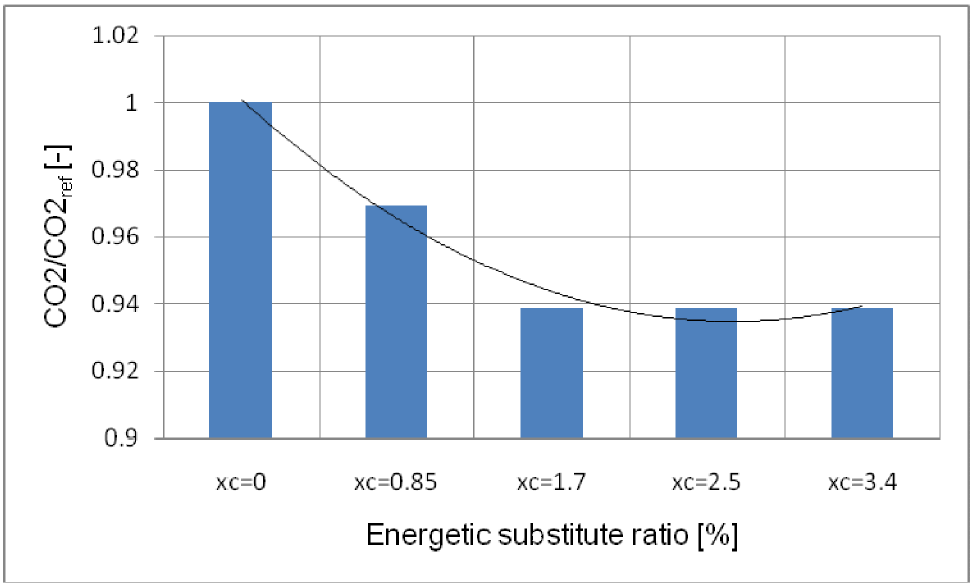

Figure 6. The carbon dioxide emission relative to the diesel fuel fuelling case

3.5 The unburned hydrocarbons emission level

For all the degrees of substitution of diesel fuel with hydrogen it is possible to observe the reduction of the unburned hydrocarbons emission level due to the improvement of the combustion by increasing the burning rate of preformed mixtures combustion.
The figure 7 presents the unburned hydrocarbons emission level relative to the diesel fuel fuelling case.

3.6 The smoke emission level

The smoke emission level decreased for all the investigated cases when the diesel fuel was partially substituted with hydrogen because the number of carbon atoms of the fuel is lower and because the burning rate of diffusive mixtures decreases.
The figure 8 presents the smoke emission level relative to the diesel fuel fuelling case.

3.7 The percentage differences

In the table 3 the percentage differences between hydrogen fuelling cases and diesel fuel fuelling case are presented.

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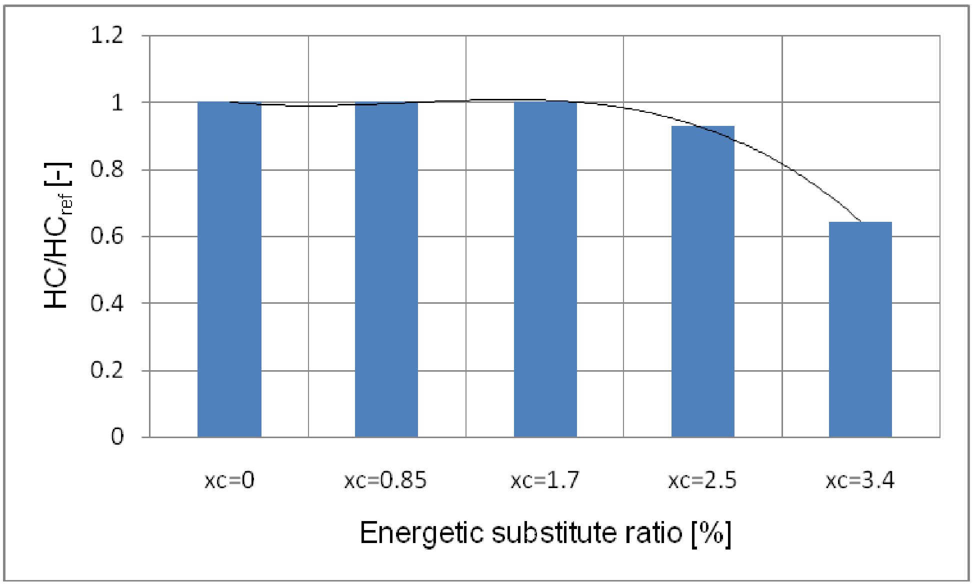

Figure 7. The unburned hydrocarbons emission relative to the diesel fuel fuelling case

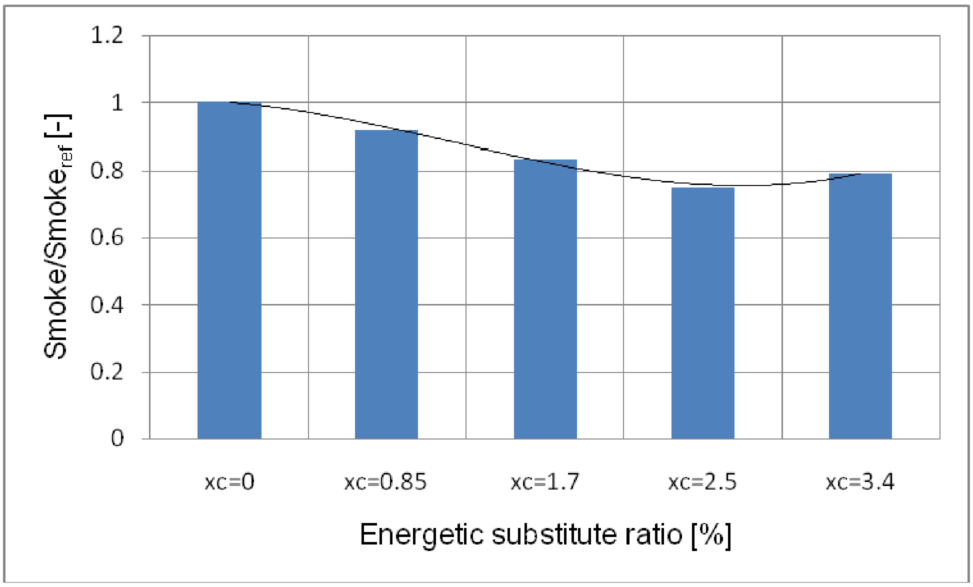

Figure 8. The smoke emission relative to the diesel fuel fuelling case

Table 3.
The percentage differences between hydrogen fuelling cases and diesel fuel fuelling case

xc [%]	pmax [%]	dpmax [%]	Ce [%]	NOx [%]	CO2 [%]	HC [%]	Smoke [%]
xc=0.85	2.61	1.64	-2.97	-4.55	-3.08	0.00	-8.33
xc=1.7	4.35	4.92	-3.96	-2.27	-6.15	0.00	-16.67
xc=2.5	5.22	8.20	-3.47	0.00	-6.15	-7.14	-25.00
xc=3.4	6.09	11.48	-2.48	2.27	-6.15	-35.71	-20.83

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4. CONCLUSION

1. The in cylinder maximum pressure and the maximum rate of pressure rise increased for all the investigated cases, having a maximum of 6.09% for pressure and 11.48% for the maximum rate of pressure rise.
2. The specific energetic consumption was decreased for all the investigated cases of fuelling the engine with diesel fuel and hydrogen, having a minimum of 3.96% for the substitute ratio x_c=1.7.
3. The nitrogen oxides emission level was decreased for substitute ratios between [0.85, 2.5) and increased for the substitute ratio 3.4.
4. The carbon dioxide emission level was decreased for all the investigated cases of fuelling with diesel fuel and hydrogen, recording a minimum of 6.15%.
5. The unburned hydrocarbons emission level was decreased, recording its minimum of 35.71% for the x_c=3.4 case.
6. The smoke emission level was decreased for all the cases of fuelling with diesel fuel and hydrogen, recording its minimum level of 25% for x_c=2.5.

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A REVIEW ON THE CONTAMINATION OF USED ENGINE OIL

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Abstract: *Engine oil plays an essential role in ensuring the optimal operation of the engine and, implicitly, of the entire car. Contamination with different substances is a process that alters the oil's parameters, rendering it unusable. Also, used oil has the potential to further degrade engine components, which has a negative impact from a strictly mechanical, as well as economic and environmental point of view. This paper presents the process of engine oil contamination, including the ways in which it occurs, the types of substances that cause it and the effects it can have on the engine and the environment. Also, statistical data are analysed that compare the properties of fresh engine oil with those of used oil and highlight the differences between them.*

Key-Words: *engine oil, used engine oil, internal combustion engine, contamination, environment*

1. INTRODUCTION

The most important role of engine oil is to ensure the lubrication of engine components. This happens when a protective oil film is formed between the components, thin enough to allow movement, but viscous enough to reduce contact between the moving components of the engine, thus preventing friction [16]. There are also other purposes fulfilled by the engine oil, such as heat transfer, protection of components against corrosive damage, sealing of possible cracks or cleaning of residual deposits.
As expected, during the process of performing its functions, the engine oil is contaminated. In addition to the mechanical impurities that accumulate gradually, the oil degrades in terms of chemical structure during combustion processes in the engine. This process is known as oil breakdown.
The consequence is that the properties of the lubricant are altered to the point where it becomes not only useless for its initial purposes, but even a danger to the safety of the engine and the vehicle.
Engine oil contamination can be caused by multiple factors and manifests itself in different ways. This article aims to review the main ways of contamination, as well as to exemplify the types of contaminants that lead to the formation of used engine oil. Also, statistical data are presented, both in the form of charts and tables, which highlight the changes in the properties of the engine oil following the breakdown process. Each of the properties is analysed individually, and the differences between the values are explained. All the information presented demonstrates the need for careful monitoring of lubricant quality, changing the used oil when necessary.

2. LITERATURE REVIEW

The contamination process essentially represents the degradation of the lubricant to the point at which it can no longer adequately perform its intended functions within an engine [19].
The degradation of the oil includes both physical-chemical and thermal processes. As a result of the oxidation and polymerization of oil hydrocarbons, the formation of organic acids, gums, asphaltenes, carbons and carbohydrates takes place, which causes the viscosity to increase and intensifies the corrosion processes and the formation of deposits in the mechanisms.

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The exhaust gases from the engine combustion chamber, which contain sulfur and nitrogen oxides, water, carbon particles and products of partial oxidation of the fuel, also pass into the oil bath, leading to its contamination. Sulfur and nitrogen oxides form with water the acids H_2SO_4, H_nNO_x, which cause corrosion of the parts. Partial oxidation products of the fuel participate in the formation of deposits, the carbon particles causing the wear of the parts [15].
Engine oil contamination comes in the form of four main mechanisms. These are presented in table 1.

Table 1.
Mechanisms of engine oil contamination [19]

Mechanisms of contamination	Contaminants
Built-in contamination	Abrasive materials, polishing compounds, casting materials, fibers
External ingression	Solid particles from the intake air, exhaust gases, fuel, water, coolant
Internal generation	Wear debris, acids, additive precipitates, sludge
Contamination caused by maintenance	Solid/liquid particles introduced accidentally during oil change or lubrication system maintenance

The process of oil degradation is followed by generation of acids and metallic particles which produce engine wear. In turn, the metallic particles cause more wear, generating more contaminants, process known as the chain-reaction-of-wear [2]. There are five types of engine wear, illustrated in figure 1.

Figure 1. Types of wear processes in the internal combustion engine

One of the criteria for classifying contaminants is the state of matter. Thus, the following three phases can be found [3]:

- Solid contaminants: metallic particles, soot, rubber particles, paint, varnish particles, tinder, fabrics, fibers;
- Liquid contaminants: water/moisture, coolant, fuel, acids;
- Gaseous contaminants: air, exhaust gases.

Another way to classify contaminants is by source, as follows [14]:

- Intake air: dust, sand, other particles;
- Combustion blow-by: soot, fuel, water/moisture, acids, exhaust gases;
- Engine wear: metallic particles, metal oxides;
- Coolant leakage: glycol.

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3. COMPARATIVE ANALYSIS OF ENGINE OIL PROPERTIES

As the contaminants in the engine oil change its structure, they consequently affect its lubricating properties and worsen its characteristics. In the following, the main parameters of engine oils will be presented, in a comparative perspective, for both fresh and used oils.
The measurements presented were taken from multiple sources, and when making the charts, the averages of the values were considered. The used engine oils for which the data were selected are multigrade oils that came from different car services, following periodic lubricant changes.
The fresh engine oil taken into consideration was Evolution Full-Tech FE 5W-30 [20].

3.1. Viscosity

Viscosity is the property of the oil to oppose the flow (relative motion of the constituent particles).
The viscosity level of the oil significantly influences the lubrication capacity of the moving parts, depending on the temperature and speed, the friction coefficient as well as the loss of power due to friction [21].
There are two types of viscosity: dynamic (or absolute) viscosity and kinematic viscosity.
Dynamic viscosity, denoted by η, is defined as the resistance of a fluid to deformation or flow: a fluid flowing through a given orifice in a longer time than another has a higher dynamic viscosity.
The dynamic viscosity usually varies slightly with pressure, but more with temperature.
That is why it is necessary to mention the temperature for which the viscosity is given [16].
The kinematic viscosity (KV), denoted by v, represents the ratio between the dynamic viscosity η and the density of the oil (lubricant) ρ (1).

$$\nu = \frac{\eta}{\rho} \tag{1}$$

Viscosity index (VI) is strictly an empirical number which indicates the effect of variation in temperature on viscosity.
A high viscosity index will always indicates a small variation in viscosity of oil with temperature, which means better protection of an engine that operates under vast temperature variations.
A high value of viscosity index indicates the absence of aromatic and volatile compounds, also means good stability in its thermal properties and low temperature flow behaviors [15].
The table 2 shows the differences between the viscosity properties of fresh engine oils and those of used oils. The sets of values corresponding to the 5 experiments come from 5 different sources.
.

Table 2.
Comparison between the kinematic viscosity and viscosity index of fresh and used engine oil

	Fresh oil (Evolution Full-Tech FE 5W-30)			Used oil		
	KV at 40°C [cSt]	KV at 100°C [cSt]	VI [-]	KV at 40°C [cSt]	KV at 100°C [cSt]	VI [-]
Experiment 1 [18]				106,37	12,66	113
Experiment 2 [6]				100,20	14,31	129,60
Experiment 3 [12]	72,8	12,2	165	115,2	17,36	160
Experiment 4 [17]				135,52	12,87	85,38
Experiment 5 [10]				136,6	13,5	89,11
Average	72,8	12,2	165	118,78	14,14	115,42

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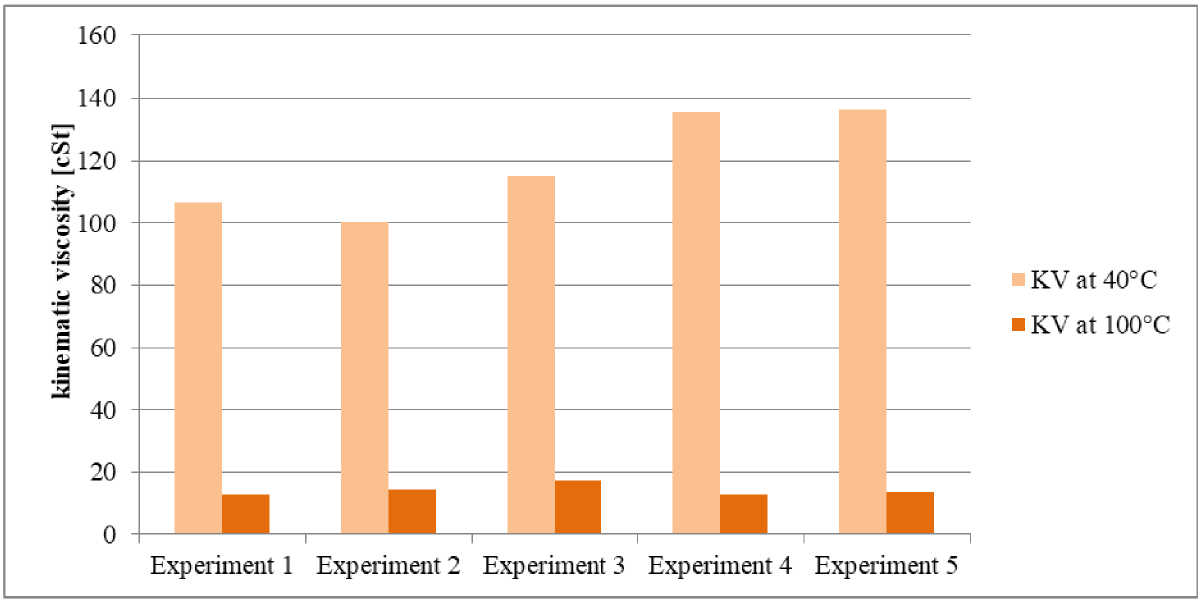

Figure 2. Kinematic viscosity for used engine oil according to 5 different sources

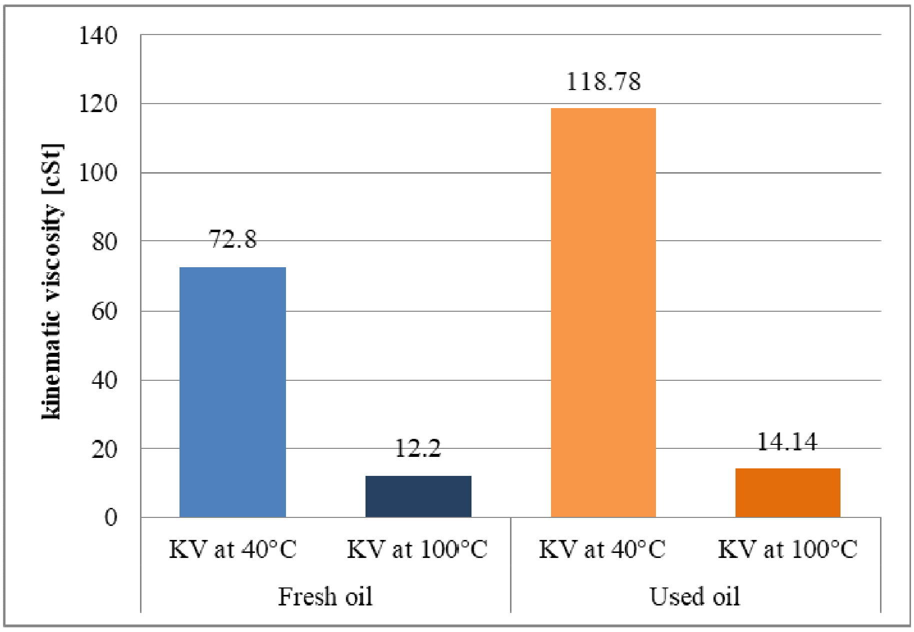

Figure 3. The difference between kinematic viscosity for fresh and used engine oil

Figure 3 displays the differences between the viscosity of fresh and used engine oils.
The kinematic viscosity of used engine oil, represented in this figure, is the result of the average values of the kinematic viscosities extracted from the 5 experiments presented in table 2 and figure 2.
It can be observed that the used engine oil is significantly more viscous than the fresh oil.
This can be explained through the oxidation process which takes place during the engine use and whose by-products are corrosive metal oxides, deposits, and varnishes which lead to an increase in the viscosity. The viscosity index (VI) shown in figure 5 refers to the degree of change in temperature-dependent viscosity: the higher VI of fresh engine oil means a lower viscosity change with the temperature.
Used oils have a lower VI, which makes them more sensitive to temperature changes.
The viscosity index of used engine oil, represented in this figure, is the result of the average values of the viscosity indexes extracted from the 5 experiments presented in table 2 and figure 4.

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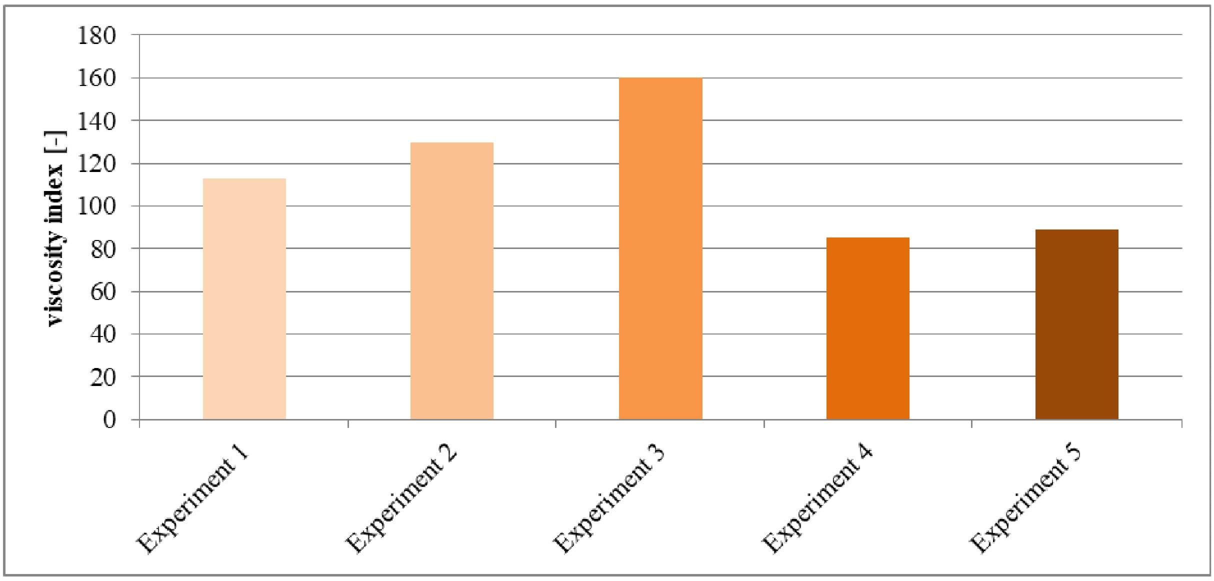

Figure 4. Viscosity index for used engine oils according to 5 different sources

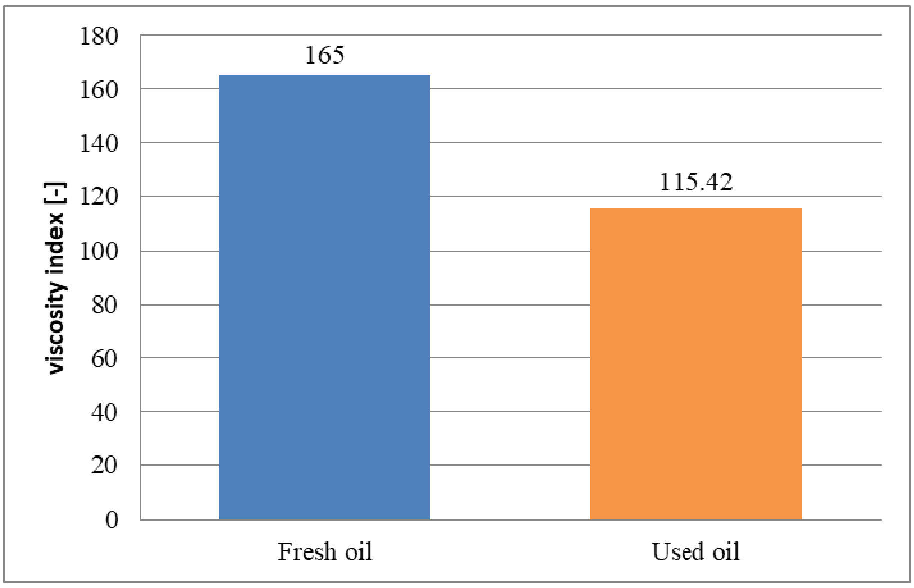

Figure 5. The difference between viscosity index for fresh and used engine oil

3.2. Density

Density of engine oils represents the mass (weight in vacuum) of liquid per unit volume at 15°C [11].
Table 3 presents data on the density of fresh engine oil and various used engine oils.
The sets of values corresponding to the 5 experiments come from 5 different sources.
The density of used engine oil could be higher or lower than that of its virgin base oil depending on the type of contamination.
As figure 7 shows, the density of used engine oil is higher than the fresh oil's, meaning that the used oil was contaminated with soot and heavy metal particles, which added to its weight.
If the used oil had been contaminated due to fuel dilution and/or water originating from fuel combustion in the engine and accidental contamination by rain, its density would have been lower than that of its fresh oil.
The density of used engine oil, represented in figure 7, is the result of the average values of the densities extracted from the 5 experiments presented in table 3 and figure 6.

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Table 3.
Comparison between the density of fresh and used engine oil

	Density [kg/m^3]	
	Fresh oil (Evolution Full-Tech FE 5W-30)	Used oil
Experiment 1 [18]	855	925,3
Experiment 2 [6]		887,12
Experiment 3 [1]		960
Experiment 4 [17]		892
Experiment 5 [10]		926,1
Average	855	918,1

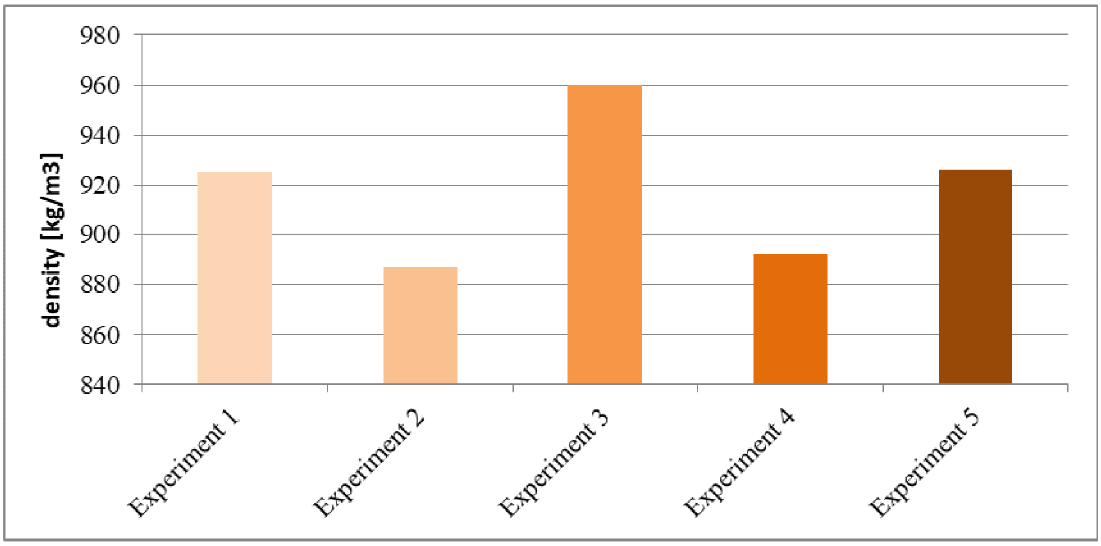

Figure 6. Density for used engine oil according to 5 different sources

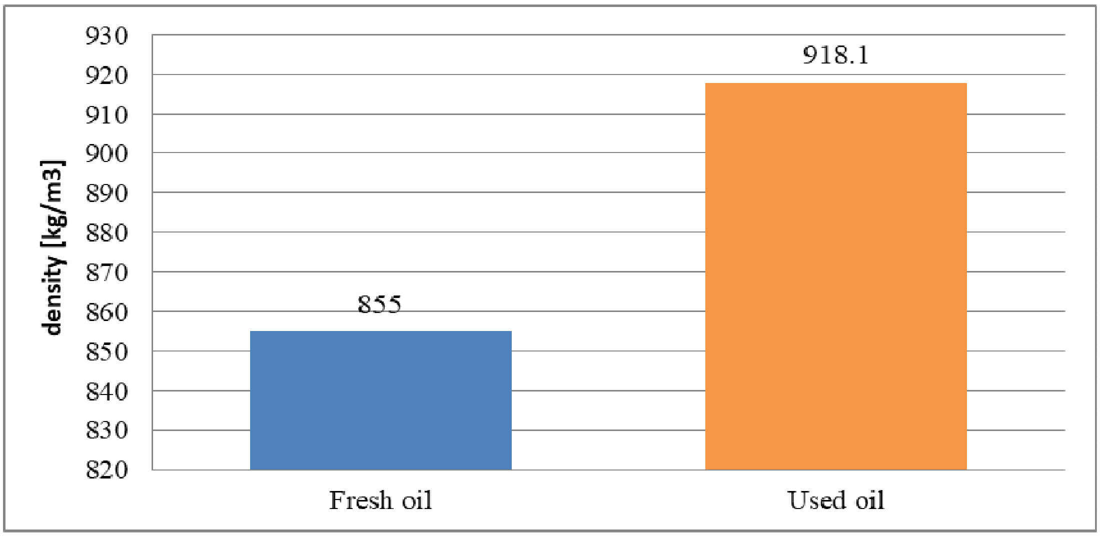

Figure 7. The difference between density for fresh and used engine oil

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3.3. Flash point

Flash point measures the tendency of a sample to form a flammable mixture with air under controlled laboratory conditions. Flash point should not be confused with auto ignition temperature, which measures spontaneous combustion with no external source of ignition [11].
Flash point temperatures for both fresh and used engine oils are shown in Table 4.
Figure 9 highlights the fact that used engine oil has a significantly lower flash point than the fresh oil, due to contamination with various chemicals, such as light-end hydrocarbons from fuel.
Low flash point poses a safety risk to the automobile and to people, as the processes inside the IC engine can generate heat that exceeds the flash point of the contaminated oil, leading to the risk of an explosion. The flash point of used engine oil, represented in figure 9, is the result of the average values of the flash points extracted from the 5 experiments presented in table 4 and figure 8.

Table 4.
Comparison between the flash point of fresh and used engine oil

	Flash point [°C]	
	Fresh oil (Evolution Full-Tech FE 5W-30)	Used oil
Experiment 1 [18]	240	210
Experiment 2 [6]		224,5
Experiment 3 [1]		178
Experiment 4 [17]		204
Experiment 5 [10]		158
Average	240	194,9

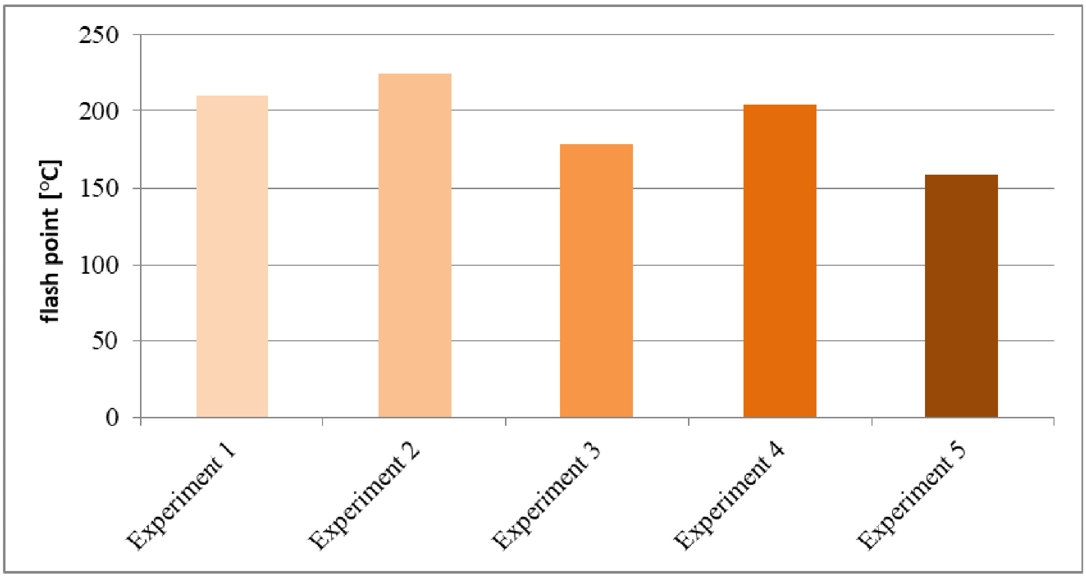

Figure 8. Flash point for used engine oil according to 5 different sources

3.4. Pour point

Pour point is the lowest temperature at which the oil will flow. Low pour point indicates good lubricating oil [5]. Table 5 highlights the differences between the pour point of fresh and used engine oil.

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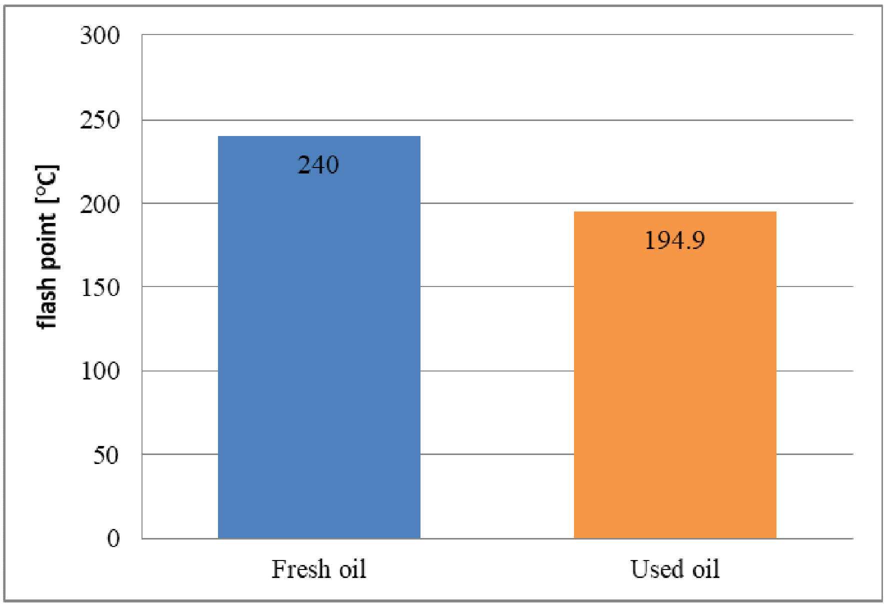

Figure 9. The difference between flash point for fresh and used engine oil

Table 5.
Comparison between the pour point of fresh and used engine oil

	Pour point [°C]	
	Fresh oil (Evolution Full-Tech FE 5W-30)	Used oil
Experiment 1 [6]	-54	-27,5
Experiment 2 [10]		-5
Experiment 3 [4]		-5
Experiment 4 [8]		-15
Experiment 5 [7]		-21
Average	-54	-14,7

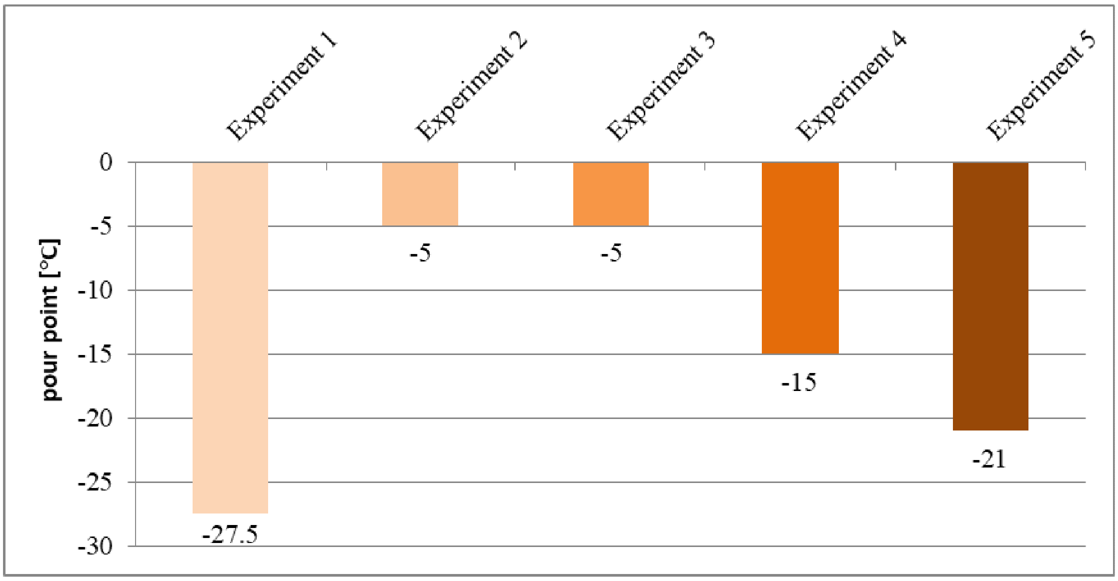

Figure 10. Pour point for used engine oil according to 5 different sources

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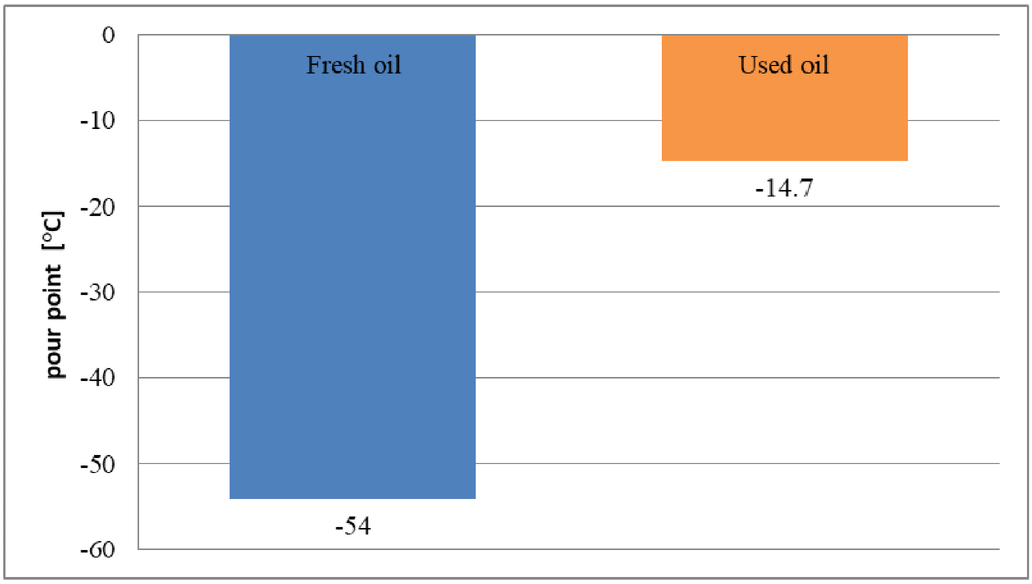

Figure 11. The difference between pour point for fresh and used engine oil

As seen from Figure 11, pour point for used engine oil is notably higher than that of fresh oil.
This occurs due to the depletion of the pour point depressants in the engine oil during its use and also because of the contamination of the used lubricant.
The pour point of used engine oil, represented in figure 11, is the result of the average values of the pour points extracted from the 5 experiments presented in table 5 and figure 10.

3.5. Total Base Number (TBN)

Internal combustion engine oils are formulated with a highly alkaline base additives package to neutralize the acidic products composition. The TBN is a measure of this package and it may be used as an indication for the engine oil's replacement time. This is because TBN depletes with time in service [10]. Total base number is measured in mg KOH/g (sample).Table 6 displays the TBN for fresh and used engine oil. Fresh engine oils are normally formulated with a higher TBN to protect against the formation of acids caused by incomplete fuel combustion.
During its life cycle, the lubricant loses its alkaline package, as shown in Figure 13, this allowing the formation of harmful acids which generate corrosion.
TBN of used engine oil, represented in this figure, is the result of the average values of the TBN's extracted from the 5 experiments presented in table 6 and figure 12.

Table 6.
Comparison between the total base number of fresh and used engine oil

	Total Base Number [mgKOH/g]	
	Fresh oil (Evolution Full-Tech FE 5W-30)	Used oil
Experiment 1 [18]	7,4	4,66
Experiment 2 [6]		2,73
Experiment 3 [1]		1,1
Experiment 4 [17]		4,41
Experiment 5 [10]		0,11
Average	7,4	2,6

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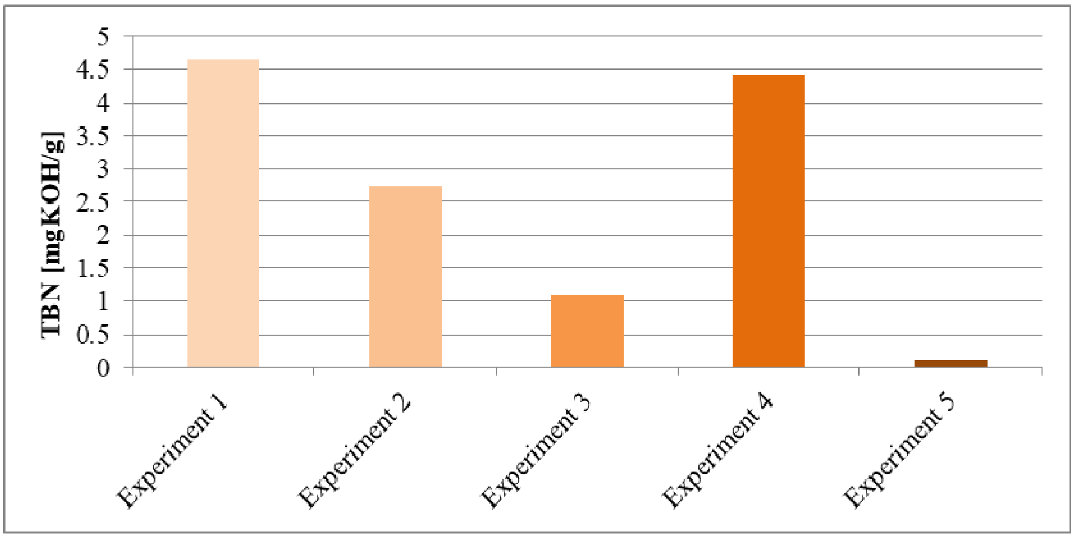

Figure 12. Total base number (TBN) for used engine oil according to 5 different sources

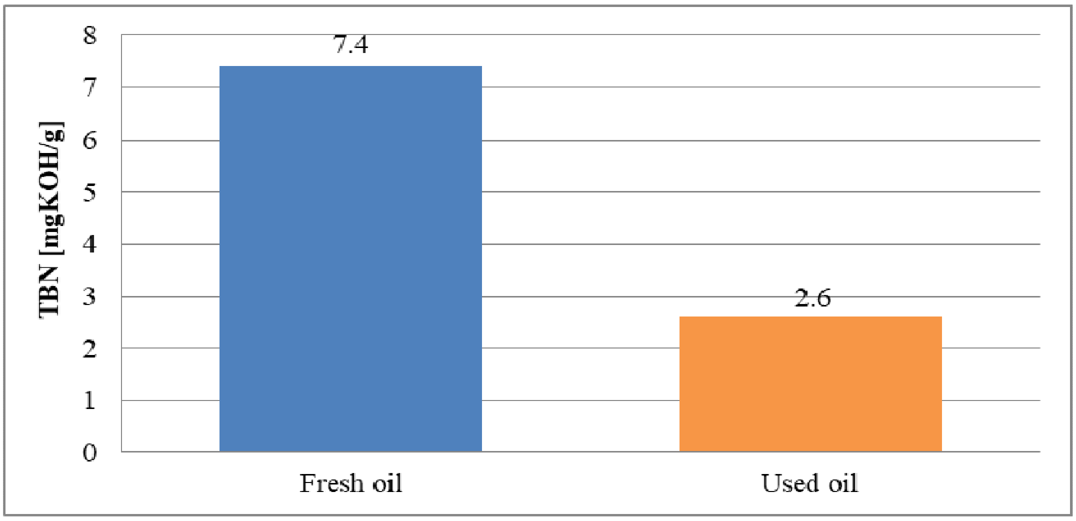

Figure 13. The difference between total base number for fresh and used engine oil

3.6. Metallic particles in used engine oils

The wear of engine components results in metallic particles, such as iron, copper, chromium, zinc, lead and tin. These particles contribute to the process of corrosion inside the engine, resulting in more abrasive particles and metal oxides.

Table 7 shows the metallic elements that can be found in most engine used oils.

Table 7.
Statistical results of metal content of different used engine oil samples

Metal content [ppm]	Experiment 1 [4]	Experiment 2 [9]	Experiment 3 [8]	Experiment 4 [7]	Experiment 5 [13]	Average
Cu	4,6	13	7,53	9,4	7,2	8,35
Mg	81	150	263,18	43,5	37,1	114,96
Cr	1,5	2	15,97	3,2	2,7	5,07
Sn	1,6	1	3,43	9,7	8,3	4,81
Pb	14,6	946	167,40	403	398	385,8
Fe	72	76	35,05	58,6	56,3	59,59
Zn	1280	701	842,37	247	222	658,47

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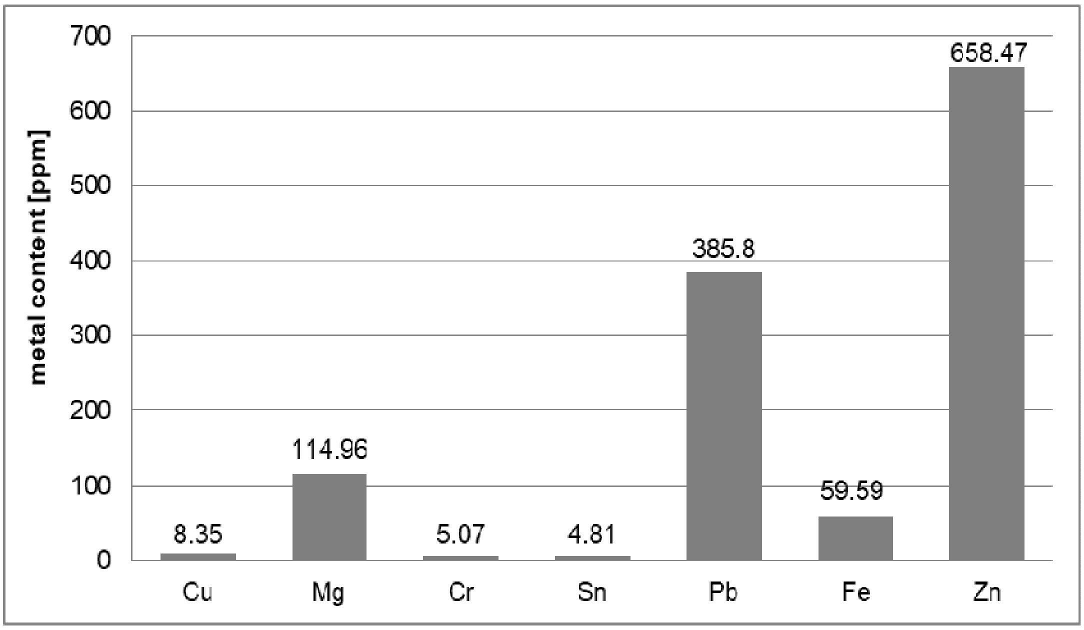

Figure 14. Metallic particles found in used engine oil

Some of the metals found in the used engine oil, such as zinc and magnesium, had been added to improve its properties, as additive components. Copper (Cu) comes from the wear of bearings, valve guides and engine oil coolers. Chromium (Cr) is an indicator of excessive wear of chromed parts such as piston rings and liners. The presence of tin (Sn) particles shows the wear of pistons, certain shaft types, bearings or bushings and valve guides. Lead (Pb) is associated with bearing wear, fuel source (leaded gasoline), and contamination due to the use of galvanized containers [10]. Cadmium (Cd) is introduced in the engine oil as a contaminant during use. Manganese (Mn) appears as a product of the wear of cylinder liners, valves, and shafts. Iron (Fe) is the most common metal that comes from the process of engine component wear and it comes from various places in the engine such as liners, camshafts and crankshaft, pistons, gears, rings, and oil pump. The metallic particles keep degrading the engine oil and the engine components, accelerating corrosion and wear.

4. CONCLUSION

Contamination of engine oil is a process that inevitably leads to its degradation and the need to replace it. Also, the contamination determines the appearance of the wear of the engine components, which in turn generates particles that maintain the wear process, thus creating the so-called chain reaction of wear. Wear manifests itself in various forms, such as: abrasion, adhesion, corrosion, erosion and fatigue. The major contaminants that cause them are the metal particles and acids that are formed during the combustion process.

The used engine oil changes its original properties, becoming increasingly inefficient and dangerous for engine components as it accumulates contaminants. The differences between the properties of fresh and used engine oil are easily noticed. Viscosity increases in case of contamination with metallic particles or soot and decreases for fuel contamination. Viscosity index is lower for used oil, which shows that the viscosity is significantly affected by changes in temperature. The used oil's density is higher due to the presence of heavy metals and aromatic compounds. The flash point is alarmingly low, which can lead to the risk of ignition of the oil, while the pour point is higher than that of the fresh oil, which makes it impossible for the oil to continue to flow at low temperatures. The TBN value decreases, because the neutralization additives deplete in time.

Changes in the properties of the lubricant no longer allow it to function properly inside the engine and they emphasize the need to correctly manage the entire life cycle of the engine oil. Efficient monitoring of the lubricant and knowledge of the types of contaminants detected can provide indicators of the condition of the entire engine, which prevents excessive wear in the future and reduces the negative economic and environmental impact.

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SIMULATION AND COMPARATIVE ANALYSIS OF POLLUTANT EMISSIONS BEFORE AND AFTER PID CONTROL OF ENGINE FUNCTIONING

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Abstract: *Present paper aims to optimize performances obtained in case of a spark-ignition engine by reducing both fuel consumption and pollutant emissions. Therefore, the study has three parts begining with a theoretical optimization of engine functioning for an Audi A6 motor vehicle, by using a program developed in Matlab20a. Follow-up, optimized data have been used to simulate pollutant emissions with the use of a different programming software. There have been taken into account all functional, geometrical and of performance parameters in order to conduct a real simulation. In the final analysis, simulated data from experimental tests and after applying PID controller have been saved separately and used to plot results in form of graphs, also in Matlab20a software.*

Key-Words: *pollutant emissions, fuel consumption, PID optimization, software simulation.*

NOMENCLATURE

PID – Proportional Integrative Derivative

1. INTRODUCTION

Nowadays, environmental pollution has become a serious topic, which is constantly monitored by specialists. According to statistics, in 2015 there have been approximately 73 millions motor vehicles in daily use on public roads. It is estimated a number of 2 billion vehicles by 2035, which will determine an increased atmospheric and environmental pollution [1][6].

Current concern of automotive engineers is to reduce fuel consumption with impact on preserving oil supplies and also to decrease the amount of pollutant emissions which are responsible for global warming. Reduced fuel consumption implies more fuel efficient engines. Also, the smaller the quantity of burned fuel, the lower the amount of exhaust gas resulted from engine functioning [5].

Within this article, it is intended to determine exhaust gas quantity and it's constituents after applying a PID controller for optimal results. Initial data used for subsequent optimization process have been obtained during tests conducted on an Audi A6 3.0 TFSI Quattro motor vehicle.

The testing procedure consisted in a relatively aggressive driving (or dynamic driving) of the vehicle, on a crowded highway. Specific parameters were acquired and collected with the use of a dedicated diagnostic tester for VAG, Ross-Tech VCDS group [4].

The Audi A6 vehicle is equipped with a 2995 cc V6 engine, maximum engine power is 245 kW, and maximum torque according to the manufacturer is 440 Nm.

Also, the producer indicates a fuel consumption of 9.8 l/100 km for urban driving, 6 l/100 km for extra-urban and 7.4 l/100 km for combined driving. Regarding vehicle mass and dimensions, the parameters are the following: 2360 kg mass, 4932 mm total length, 1874 mm width and 1455 mm height.

2. OPTIMIZATION THROUGH PID CONTROLLER

The analysed motor vehicle comes equipped with a factory three-way catalytic converter, which transforms the pollutant emissions in safe constituents for the environment.

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Present paper was not focused on changing catalytic converter parameters, but on reaching lower fuel consumptions and decreased amount of toxic gases by applying PID controller (proportional-integral-derivative) on speed variation obtained experimentally.
This control algorithm is specific to automated system theory and combines the advantages and disadvantages of the three basic coefficients used to obtain an optimal result.
Some of the advantages worth mentioning are: rapid response, zero state error and high order overload.
The output size, used to actuate PID controller, noted „c", is defined by the following mathematical expression [2]:

$$c = k_p\left(e + \frac{1}{T_i}\int_0^t e dt + T_d\frac{de}{dt}\right) + c_0 \tag{1}$$

where kp – proportional factor and it is equal to $k_p = \frac{100}{BP}$, BP represents proportionality band width, T_i – integral time constant, T_d – derivative time constant, c_o – control in absence of deviation, e – relative error.
In a comprehensive understanding, fuel economy means to reduce fuel consumption. Nowadays, it is aimed to obtain a higher fuel saving, which has a negative effect on engine dynamics, meaning that it is not possible to obtain an increase of all specific parameters. For further understanding, fuel saving can be indicated by an average fuel consumption expressed in liters per 100 kilometers (l/100 km) and engine dynamics can be evaluated by average speed, average acceleration etc. Due to the complexity of analysis of the two phenomena, present paper is focus only on fuel saving aspects.
Therefore, when applying a PID controller on vehicle speed variation, it was obtained a decrease in average speed. The results are presented in figure 1. As it can be observed from the graph, the average speed obtained experimentally was 105.68 km/h, and after applying the PID controller, the average speed decreased to 98.66 km/h. Hence, a comparative analysis of the two values indicate a decrease of average speed by 6.64%.
Yet again, on the graph there are also presented all three variables of transfer function for PID controller: $k_p = 1.64$, $T_i = 19.12$ and $T_d = 0.40$. The values of these constants have been determined empirically, by taking into account dynamic characteristics of the analysed vehicle.

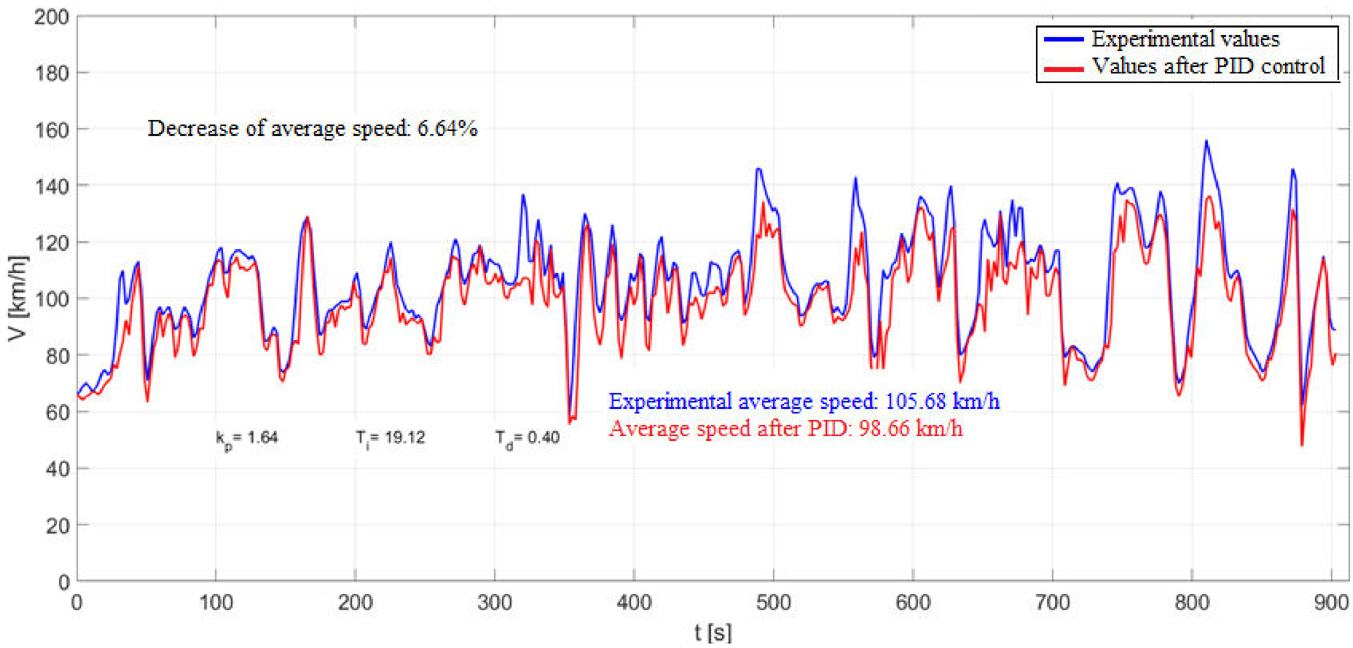

Figure 1. Vehicle speed before and after applying a PID controller

3. SOFTWARE SIMULATION

Based on automobile characteristics and speed values (initial and after PID controller) there have been performed two parallel simulations in a dedicated and advanced software program.

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It was developed a model able to simulate the vehicle while driving in certain conditions, similar to those existing at the time of experimental tests.
The model used for simulation is depicted in figure 2.
It must be mentioned that some parameters were not adjusted according to reality, namely wind speed, slope variation of the road and accurate indication of when the gear shifting occurred due to the automated gearbox.
At the same time, the simulation is very strictly controlled because it takes into account multiple physical phenomena that are characteristic to the driving tests performed on a highway.
For example, there were taken into account parameters such as: all resistive forces, contact forces between the tire and the rolling track, friction forces characteristic to mechanical connection of the four-wheel drive, thermodynamic processes which occur within the spark-ignition motor vehicle etc. [3].
From the model presented in figure 2, it can be observed that the software uses different colors depending on the constituents.
Therefore, red is used in case of electronic components and circuits, turquoise is used to simulate different predefined mechanical assemblies and subassemblies specific to automotive engineering (e.g. engine, automatic gearbox, motor vehicle etc.) and green is used to indicate individual mechanical parts (e.g. transducers).

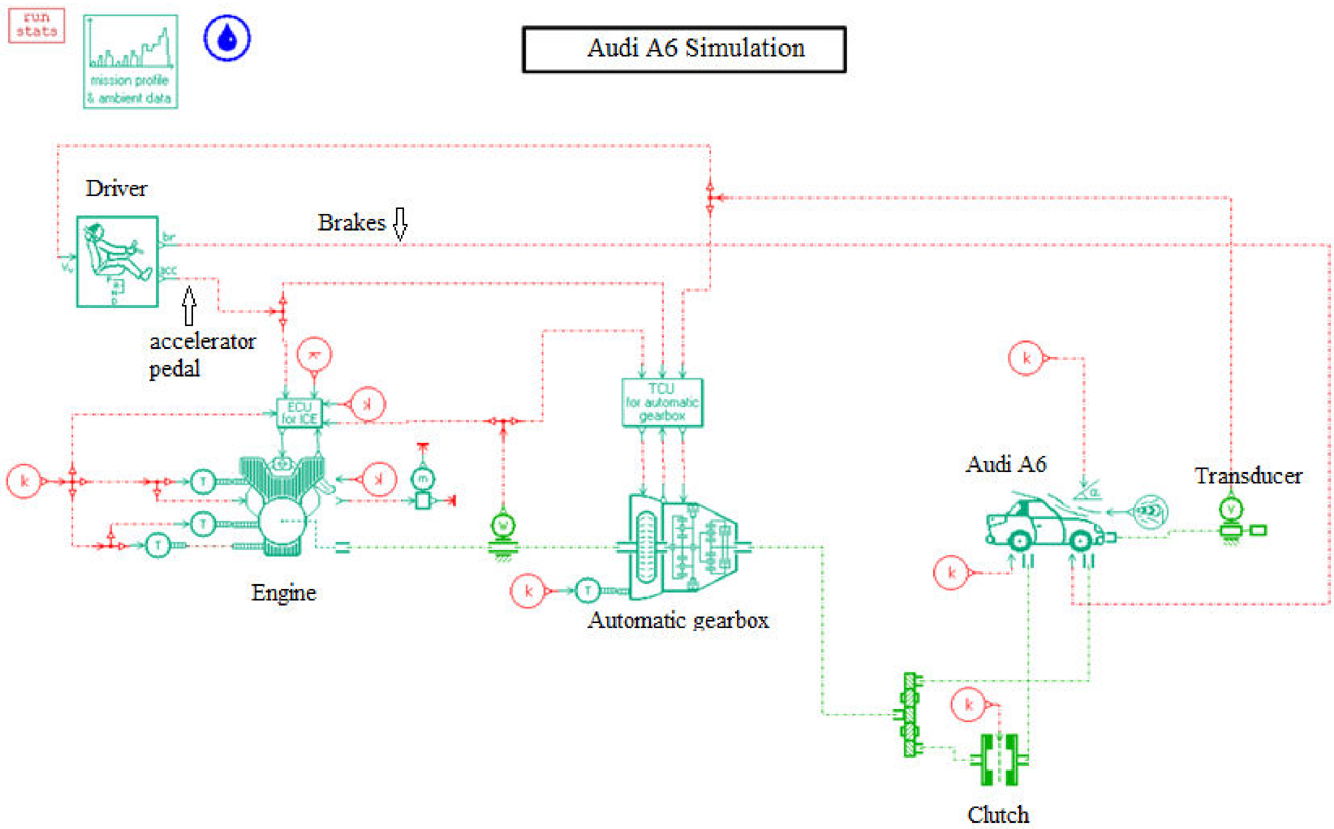

Figure 2. Simulation model

4. SIMULATION RESULTS

Simulation results regarding exhaust gases are presented in the following figures.
There can be depicted graphs of different pollutant emissions, before and after applying a PID controller.
In figures 3a and 3b there are presented instantaneous emissions of carbon monoxide, resulted from simulation, before and after the optimization process.
The entire simulation lasted 905 seconds.
As it can be observed from the graphs, in case of optimized engine, the quantity of carbon monoxide measured at the exhaust pipe is with approximately 11% lower that without applying a PID controller (207.5 mg/s before PID control and 185.0 mg/s after the optimization process).

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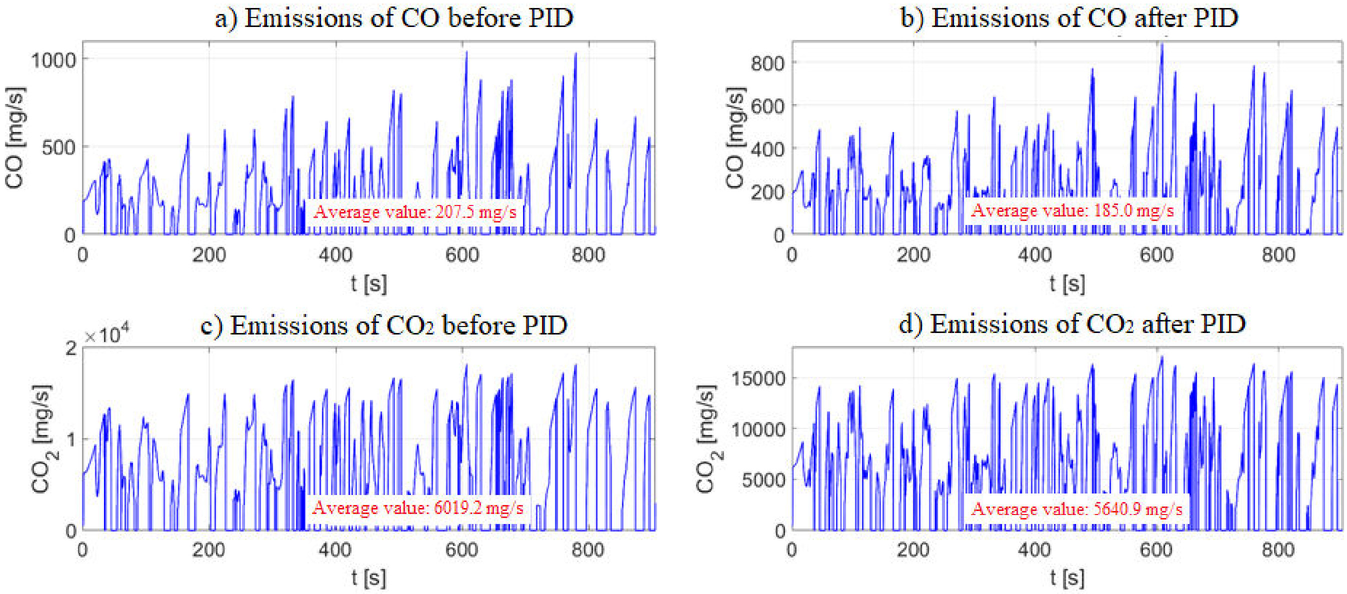

Figure 3. Comparative emissions of CO and CO2 resulted from simulation, Audi A6

Yet again, in figures 3c and 3d, there are presented carbon dioxide quantities resulted from simulation with the Audi A6 automobile, running on the highway, before and after applying a PID controller. According to the manufacturer, for EURO 6 engines, the NEDC (New European Driving Cycle) test indicates 172 g/km of carbon dioxide generated while driving on highway, which is similar to the value resulted from simulation, namely 217.88 g/km [7].

As it can be observed from the bottom left graph, the initial simulation of the motor vehicle indicated an average value of 6.019 g/s carbon dioxide, while the bottom right graph shows that the average value of CO2 emissions is 5.640 g/s. Hence, due to the optimization process of engine functioning, it was obtained a decrease of 6.7 % in case of CO2 emissions.

In figure 4 there are presented emissions of hydrocarbures and nitrogen oxides, during the two parallel simulation conditions.

In case of the upper graphs, it can be observed that the use of a PID controller determined a decrease by 2.8% of hydrocarbures resulted from engine functioning (50.6 mg/s during initial simulation as opposed to 49.2 mg/s, after applying a PID controller).

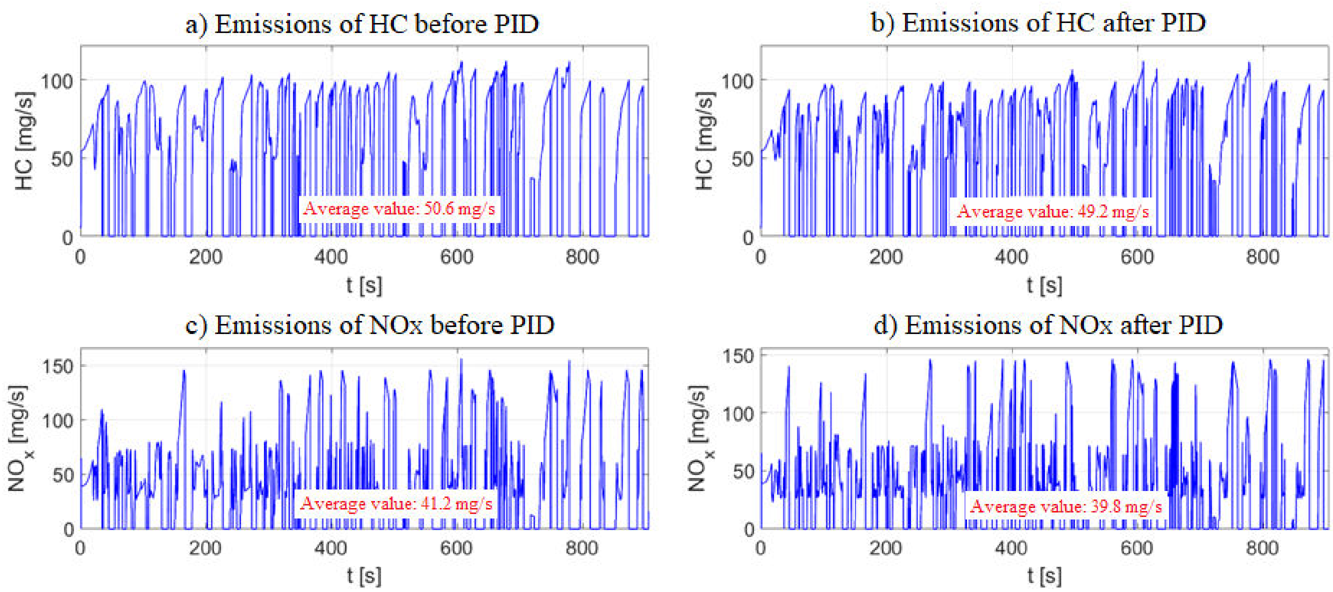

Figure 4. Comparative emissions of hydrocarbures and nitrogen oxides resulted from simulation, Audi A6

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From the lower graphs of figure 4, a comparative analysis can be made regarding emissions of nitrogen oxides resulted during simulation.
As it can be observed, the optimization process applied on engine resulted in a decrease of 3.4% regarding emissions of NOx (the average value of NOx emissions before applying PID controller was 41.2 mg/s and after the optimization process it was recorded an average value of 39.8 mg/s). Simulation time lasted 905 seconds.
In addition to the analysis focused on reducing pollutant emissions by applying a PID controller, follow-up there are also presented several results regarding the effects on engine fuel efficiency, mainly average hourly fuel mass consumption. In figure 5 there are presented comparative results of hourly fuel consumption, before and after applying proportional-integral-derivative control.
By analysing the two graphs, it can be observed a decrease of average fuel consumption, from 6.9 kg/h to 6.4 kg/h. The difference of 0.5 kg/h between the two situations, can also be expressed in average volumetric fuel consumption, obtaining a value of 0.37 litre/h.

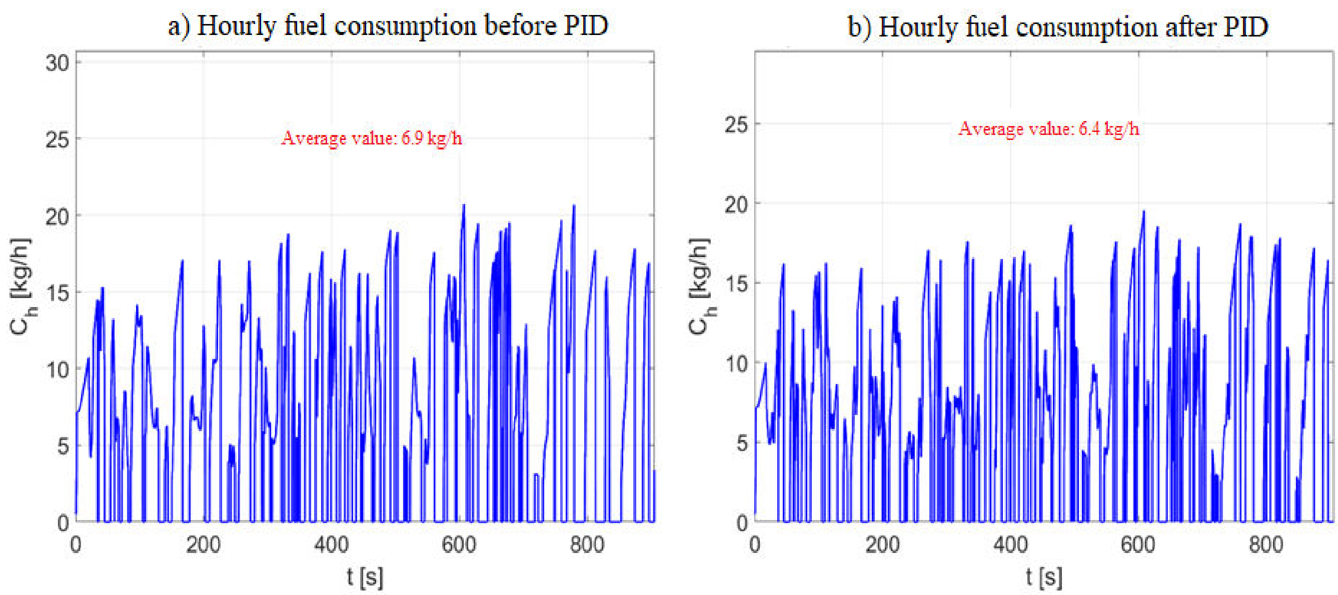

Figure 5. Hourly fuel consumption, before and after PID control, Audi A6

5. CONCLUSION

The paper presented a comparative analysis regarding pollutant emissions and engine efficiency, based on experimental results obtained while performing tests with an EURO 6 automobile.
With the use of parameters acquired during tests, there were performed comparative simulations of engine functioning, before and after applying a PID controller.
Thereby, simulation error can be excluded.
On the other hand, it was also observed a drawback while using simulation, namely that the model show zero fuel consumption and exhaust gases during braking periods, which is not correct.
Regarding the amount of pollutant emissions and engine efficiency, all figures argued that the use of a proportional-integral-derivative controller to actuate the accelerator pedal, has the advantage of improving fuel economy (in this case, by approximately 1.32%, from 2.32 litres to 2.29 litres) and reducing the amount of exhaust gases.
Still, it has to be mentioned that a decrease of fuel consumption determines also a decrease of vehicle speed, due to the fact that fuel saving and engine dynamics are divergent one from the other.
As a result, it was observed a decrease of average speed by 6.64% after the optimization process.
Also, on average, pollutant emissions recorded after the optimization process were by approximately 2.5% lower than before applying PID controller.

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ASPECTS REGARDING EXPERIMENTAL ANALYSIS OF PHYSICAL PROPERTIES OF A DIESEL ENGINE FUELS

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Abstract: *In this work is presented the basic objective of the research with the aim to study physical mixture of bio-fuel and diesel fuel – bio-fuel. It examines experimental physical properties of the various blends of bio-fuel and diesel (density, viscosity, flash point, cloud point, thermal analysis) being then a comparative analysis of different standards for bio-fuel.*

Keywords: *Diesel fuel, compression ignition engine, density, viscosity, flash point, cloud point, energy performance, engine testing cell*

1. INTRODUCTION

Considering the fact that energy requirements are on the rise and that fossil fuel supplies are exhausted, anthropogenic emissions of greenhouse gases (ges), being the main cause of climate change and the ecological system talk about the need to research new ways of producing energy from sources and alternatives to replace these classic fuels [1].
The issue of alternative energy sources is not a novelty, because their use was widely applied in the Republic. of Moldova due to the requirements of European Union fact that confirms the ONU Convention for Climate Change (1992) and the Kyoto Protocol (1997), ratified by the Republic of Moldova in 2003, but also the need to reduce sources of environmental pollution, in general, of residues resulting from the burn of fuel, derived from fossil hydrocarbons (petrol, natural gas, diesel, etc.). For the Republic of Moldova the most accessible sources of alternative energy to fossil fuels are plants and partly animal fats [2][3][4].
Pure vegetable oil - is the oil produced from oilseeds by pressing, extraction, crude or refined, but not chemically modified, in case if its use is compatible with a type of engine and with the corresponding emissions requirements. Due to lower exhaust emissions, vegetable oils used as fuel are gaining more and more popularity. From an economic point of view, it has been found that the optimal variant is the use in Internal Combustion Engine (ICE) of monoesters obtained from vegetable oils, in this case from rapeseed oil. Rapeseed oil can reduce carbon dioxide emissions by 70% compared to petroleum-based fuel, thus reducing greenhouse gases, which contribute to global warming.
Biofuel is composed of alkyl esters obtained by transesterification of vegetable oils or animal fats. This biofuel is biodegradable, it is not toxic and generates fewer noxious poisons from its burning: such as NO_2, SO_2 than petrol products when it is burnt. In the Republic of Moldova, as in other European countries, the use of biofuels as an alternative to diesel fuel will be achieved in stages from the following considerations: the low volume of rapeseed oil production in the republic (only 3 thousand tons of oil was produced in 2007 from rapeseed by the Moldavian-German company „Bio-Raps-Compania"); lack of biofuel production facilities; dependence on biofuel exporting countries.
Therefore, the first stage of the use of biofuel according to the requirements of art. 6 of the Renewable Energy Law [4] in the year 2010 the volume of biodiesel and diesel fuel will account for 5% of the volume of diesel sold, and in 2020 this biodiesel-diesel mixture will be -20%.
The research's aim was to study the physical characteristics of the mixture of biofuels and diesel.

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2. MATERIAL AND METHOD

The tests were carried out in the Internal Combustion Engines Testing Laboratories and the Physical and Chemical Properties and Exploration of Petroleum Products Research, the Faculty of Agrarian Engineering and Auto Transport, at the Department of Transportation Engineering and Tractors, several researches have been carried out on:

- the possibilities of using vegetable oils (rapeseed, sunflower, soybean), metyl-esters, mixtures and waste oils as well as diesel fuel;
- the influence of these fuels on:
- engine performance (engine torque, engine power, specific fuel consumption);
- pollutant emissions of the engine;
- engine durability;
- the influence of some factors on the properties of biofuels;
- biodiesel addition.

In order to evaluate the possibility of using vegetable oils and their derivatives as diesel substitutes,, were taken into consideration the following main characteristics: viscosity, density, calorific value, cold behavior, stability during storage. The fuel viscosity influences the engine power and spraying it into the combustion chamber. The calorific power allows to provide the maximum power that can be developed by an engine for a given injection pump flow rate. Comparative analysis on chemical elements shows the advantage of using biofuel from rapeseed oil to classic fuel. Biofuels are slightly poorer than diesel in terms of carbon content (-8,98 %) and hydrogen content (0,79 %). It is noted the fact that, the oxygen is present in the biofuel structure (approx.10%) – which favors the combustion process in the engine. It also notes the total lack of sulfur - which leads to the reduction of chemical pollution (does not contribute to SO_2 emissions). Comparing the physical characteristics of fuel from vegetable oil to classical fuel (diesel), the qualities of this new fuel are once again highlighted.

3. RESULTS AND DISCUSSIONS

The physical properties are experimentally analyzed of various biofuel and diesel blends (density, viscosity, flash point, disruptive point, thermal analysis) being made then a comparative analysis with different biofuel standards. The fuel mixture was prepared in gravimetric proportion from a single reference diesel and biofuel batch in the following ratio: diesel / biofuel 80/20 (B20); 50/50 (B50); 25/75 (B75), pure biofuel 0/100 (B100). Table 1 includes the quality characteristics of the studied fuels.

Table 1
Quality characteristics of the studied fuels

Task	Composition	Kinematic viscosity at 20°C [cSt]	Absolute density [g/cm³]	Point of inflammation [°C]	Point of disorder [°C]	Power calorific lower [MJ/kg]
№ 1	Diesel fuel	4,92 ± 0,24	0,834 ± 0,04	65 ± 3,8	-15 ± 0,73	43,89
№ 2	Diesel fuel 80% Biofuel 20%	6,71 ± 0,34	0,846 ± 0,04	76 ± 4,2	-12 ± 0,61	43,24*
№ 3	Diesel fuel 50% Biofuel 50%	9,12 ± 0,47	0,862 ± 0,04	85 ± 5,0	-10 ± 0,47	42,28*
№ 4	Diesel fuel 25% Biofuel 75%	11,60 ± 0,57	0,880 ± 0,05	>100 ± 6,0	-8 ± 0,44	41,48*
№ 5	Pure biofuel	13,01 ± 0,64 5,20 ± 0,26**	0,895 ± 0,05	>120 ± 7,0	-2 ± 0,01	40,69*
№ 6	Rapeseed oil	75,58 ± 3,78	0,915 ± 0,05	> 120 ± 7,5	-2 ± 0,02	40,69

Note:
** Values are presented after calculation.*
*** Kinematic viscosity at 40°C, cSt according SM STB 1657:2009 (EN 14214:2003)*

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For the evaluation of the possibility of using the diesel fuel - biofuel as an alternative fuel the following physical and chemical properties must be considered: kinematic viscosity at 20°C, density, point of inflammation, crystallization point, distillation range, lower calorific value, storage stability.
Absolute density, kinematic viscosity and vaporization temperature become important characteristics for achieving the combustion process of the fuel mixture. The absolute density or specific weight for biofuel is 7.3% higher than for diesel. The kinematic viscosity influences the engine power and fuel spraying into the combustion chamber. The experimental data presented demonstrates that, with the increase of biofuel added to diesel fuel, the viscosity of the mixture increases compared to diesel: for the mixture B20 with 36,4%; the mixture B50 of 1,85 times and the B75 of 2,35 times [5].
Fuel mixture B20 has the kinematic viscosity of 6,71 mm2/s very close to the limiting summer viscosity range – 3 … 6 mm^2/s (after STAS 305-82) which allows to use this blend of fuel for Diesel engine's operation without constructive changes of the engine. This fuel blend B20 was used in engine D-241 tests and to the in-service tests of tractors MTZ-80 equipped with these engines. Figure 1 shows some D-241 engine components after 100 hours of operation with alternative fuels.

Figure1. D-241 engine components after 100 hours kinematic of operation with alternative fuels

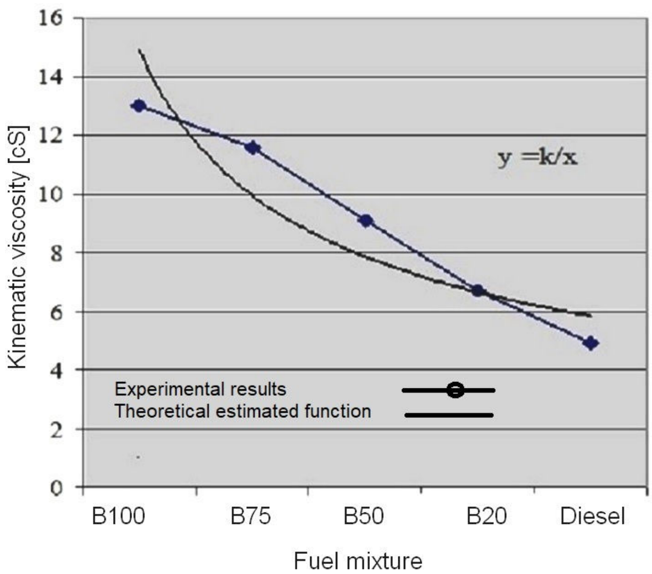

Figure 2. The variation of the viscosity of the studied fuels

The B20 fuel mixture will ensure a light start of the diesel engine, even in the cold weather of the year, will provide a good quality of self-ignition and combustion of the fuel blend.
The change in the kinematic viscosity of the biofuel blend in dependence on the biofuel weight in this mixture is shown in Figure 2.
The ignition and the B20 fuel combustion process will essentially depend on actual air mixing and combustion initiation temperature, and this blend of diesel fuel - biofuel (B20) may be recommended to be used especially during the warm year.
The existence of a dual fuel system: diesel and biofuel, which becomes necessary in cold periods, when due to the high viscosity of the biofuel, the fuel injection is inadequate, creating problems, especially when starting the engine. Another factor is the type of biofuel feedstock used on the engine.
Inflammation temperatures for the studied samples change significantly (within the limits of 75-120°C) which is an important fuel safety indicator.
The biofuel-gas mixture is a less dangerous fuel compared to diesel fuel, namely: lower ignition and explosion hazards during transport or during storage.
Calorific heat is an important fuel feature that determines the maximum engine power at a correct injection pump setting.
For vegetable oils, the average calorific value is about 40,688 MJ/kg, compared with 43,890 MJ/kg for diesel fuel [6]. For the B20 fuel blend, calorific value (after calculation) will be 42,640 MJ/kg with only 1.48% lower than diesel fuel, with 7.3% less for rapeseed oil.
The non-essential reduction in the calorific value of the B20 fuel will not contribute significantly to lowering the engine's energy performance (power, torque, fuel consumption).

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4. CONCLUSION

The study on the use of biofuel allows the following conclusions:

- The B20 fuel mixture has a calorific value (after calculation) of 42,640 MJ/kg with only 1.48% less than diesel, which will not contribute significantly to the performance decrease energy of the engine;
- The fuel blend B20 (diesel + 20% biofuel) has been shown to be the most optimal blend in terms of the diesel engine's energy performance compared to its diesel fuel efficiency;
- Specific fuel consumption is changing insignificantly, determined not so much by hourly consumption, how to reduce engine power when running on blends of fuels (diesel fuel - biofuel);
- Biofuel and biofuel diesel blends ensure a reduction in CO, CO_2 and C_nH_m emissions in exhaust gases up to engine load of 75% effective power;
- Attempts at the stand demonstrate the fact, that the engine fueled with diesel fuel and 20% biofuel can work impeccably up to the limit of wear, which is more than satisfactory;
- Taking into account the general tendency in Europe as well as the natural climatic conditions of the geographical position of the Republic of Moldova, as well as the socio-economic requirements of the Republic, vegetable oils and vegetable esters have the most promising economic development prospects in the direction of biofuel production ;
- The use of biofuel in the Internal Combustion Engine (ICE) contributes to the reduction of pollutant emissions in the exhaust gases, which is an important thing for our century.

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The Romanian Journal of Automotive Engineering has as its main objective the publication and dissemination of original research in all fields of „Automotive Technology, Science and Engineering”. It fosters thus the exchange of ideas among researchers in different parts of the world and also among researchers who emphasize different aspects regarding the basis and applications of the field.

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The Scientific Journal of SIAR
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SIAR tracks the progress of the automotive engineering in Romania by: the development of automotive engineering, the development of technologies, and road transport services; supporting the work of the haulers, supporting the technical inspection and of the garage; encouraging young people to have a career in the automotive engineering and road haulage; stimulation and coordination of activities that promote an environment that is suitable for continuous education and improving of knowledge of the engineers; active exchange of ideas and experience, in particular for students, master students, PhD students, and young engineers, and dissemination of knowledge in the field of automotive engineering; cooperation with other technical and scientific organizations, employers' and socio-professional associations through organization of joint actions, of mutual interest.
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Frequency: Quarterly Electronic publication on: www.ro-jae.ro
Total number of issues: 30 Type: Open Access
The above constitutes series nr. 1 of SIAR scientific magazine.

2. Ingineria automobilului (in English: ***Automotive Engineering***)
ISSN 1842 – 4074
Period of publication: as of 2006 Format: print and online, Romanian
Frequency: Quarterly Electronic publication on: www.ingineria-automobilului.ro
Total number of issues: 57 Type: Open Access
(including the December 2020 issue)
The above constitutes series nr. 2 of SIAR scientific magazine (Romanian version).

3. Ingineria automobilului (in English: ***Automotive Engineering***)
ISSN 2284 – 5690
Period of publication: 2011 – 2014 Format: online, English
Frequency: Quarterly Electronic publication on: www.ingineria-automobilului.ro
Total number of issues: 16 Type: Open Access
(including the December 2014 issue)
The above constitutes series nr. 3 of SIAR scientific magazine (English version).

4. *Romanian Journal of Automotive Engineering*
ISSN 2457 – 5275
Period of publication: from 2015 Format: online, English
Frequency: Quarterly Electronic publication on: www.ro-jae.ro
Total number of issues: 24 (December 2020) Type: Open Access
The above constitutes series nr. 4 of SIAR scientific magazine (English version).

Summary

Total of series:	*4*
Total years of publication:	*26 (11: 1990 – 2000; 15: 2006 – 2020)*
Publication frequency:	*Quarterly*
Total issues published:	*87 (Romanian), out of which, the last 40 were also published in English*