PLOVDIV UNIVERSITY
"PAISII HILENDARSKI"

FACULTY OF PHYSICS AND TCHNOLOGY

DEPARTMENT OF ELECTRONICS, COMMUNICATIONS AND INFORMATION TECHNOLOGIES

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APPLICATION OF COMPUTER TECHNOLOGIES TO IMPROVE ENVIRONMENTAL INDICATORS IN ROAD TRANSPORT

ABSTRACT

of a dissertation for the acquisition of an educational and scientific degree "DOCTOR"

Field of higher education:
5.Tehcnical sciences

Professional field:
5.3. "Communication and Computer Engineering"

Doctoral program:
"Automation of areas of the intangible sphere (medicine, education, science, administrative activity, etc.)"

Scientific supervisor:
Prof. Slavi Yasenov Lyubomirov, PhD

Plovdiv, 2025

The dissertation has a volume of 155 pages , including 81 figures, 12 tables formed in the introduction, 4 chapters, general conclusions, scientific and applied contributions, a list of used terms and abbreviations, a list of the author's publications. The list of cited literature includes 131 titles.

The designations of the formulas, figures and tables in the abstract match those in the dissertation work.

The dissertation work was discussed and directed for defense at a meeting of the extended departmental council of the department "ELECTRONICS, COMMUNICATIONS AND INFORMATION TECHNOLOGIES" at the UNIVERSITY OF PLOVDIV "PAISII HILENDARSKI" on 09.01.2025, Protocol No. 70.

The defense of the dissertation will take place on 18.03.2025. from 13:00 in the hall 4th floor, 21 Kostaki Peev St. at a meeting of the scientific jury.

The materials for the defense of the doctoral student are available to those interested in the office of the Faculty of Physics and Technology at the PAISII HILENDARSKI UNIVERSITY OF PLOVDIV, room 214.

Scientific jury: Prof. Dr. Nevena Stoyanova Mileva
Prof. Dr. Dimitar Mihailov Tokmakov
Prof. Dr. Todor Stoyanov Jamiykov
Assoc. Prof. Dr. Borislav Hristov Milenkov
Assoc. Prof. Dr. Nikolay Atanasov Shopov

Author: Mag. Eng. Hristo Anastasov Kanevski
Title:**APPLICATION OF COMPUTER TECHNOLOGIES TO IMPROVE ENVIRONMENTAL INDICATORS IN ROAD TRANSPORT**

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GENERAL CHARACTERISTICS OF THE DISSERTATION

Relevance of the problem

The topic of the current dissertation examines a problem that has been worked on extremely actively in recent years on a global scale, it is related to the development of new computer technologies to improve environmental performance in road transport.

The environmental performance of vehicles on the road is the focus of attention of manufacturers, regulators and consumers. Reliability, speed, handling and fuel consumption are the focus of car manufacturing, diagnostics and operation.

The identification of pollutants and the mechanisms that created them led to the progressive development of increasingly stringent regulations to address source problems.

Conducting laboratory tests of spark-ignition engines with simulated faults is of utmost importance. Combustion and emission aftertreatment technologies differ significantly between diesel engines and spark ignition engines.

In the process of solving the scientific problem, the dissertation directly corresponds with the research of a number of bulgarian and foreign scientists who have made a significant contribution to the identification of pollutants and the mechanisms that created them, including conducting laboratory tests of an engine with simulated malfunctions.

The thesis concept proposes the implementation of a programmable electronic control system to replace the original vehicle system for a research purpose to study pollutant emissions.

Studies have been made of the harmful emissions emitted by a gasoline engine depending on the air/fuel ratio and ignition angle controlled by a microprocessor unit. Practical measurements were carried out at different engine speeds. Data on fuel-air ratio and emission levels are presented and analyzed using statistical methods.

Based on the research conducted, optimization of the fuel-air mixture ratio of gasoline internal combustion engines is recommended.

Recommendations are proposed for the implementation of dynamic operating modes and fuel maps for the engines in order to reduce harmful emissions in different driving modes.

The research carried out is relevant both now and in the foreseeable future in the direction of improving the environmental characteristics of vehicles.

Purpose of the dissertation:

The purpose of the dissertationis to investigate the possibilities of applying computer technologies to improve environmental performance in road transport. On this basis, to justify approaches for carrying out research in the car with the aim of improving the environmental characteristics in terms of CO, HC, CO_2.

Tasks to achieve the goal:

1. To carry out a study and analysis of the specifics of the composition of the exhaust gases for the assessment of harmful emissions affecting the environmental indicators in internal combustion engines, systematization of the sources to improve the environmental indicators.
2. To implement and test an experimental set-up and methodology for researching various malfunctions of internal combustion engines and their impact on harmful emissions.
3. Selection of an approach for conducting the research on the factors influencing the emissions of harmful gas components of a car with an internal combustion engine.
4. To implement experimental research by applying computer technologies to improve the factors affecting environmental indicators.
5. To carry out research in a car to improve the environmental performance in terms of CO, HC, CO_2 and analyze the results.

Research methods and tools used:

The research methods used are from the scientific fields: electronic systems in the car, fuel systems and systems, control systems of internal combustion engines, computer diagnostics of the car and statistical methods and analyses.

Implementation and practical applicability

The data on the influence of the correction of the ignition angle on the amount and composition of the exhaust gases have been implemented, studied and analyzed. Research and analysis of data on the influence of the fuel-air mixture ratio on the composition of the exhaust gases has been carried out.

Posts on the subject

The main results have been published in: 2 issues in the International Conference of Education, Research and Innovation, 2 issues in the collections of reports of SUB - Smolyan, 1 issue in the collection of reports "EDUCATION, SCIENCE, SOCIETY" and 1 issue in the international collection "Ecologia" Balkanica. Five of the publications are co-authored with the supervisor and one is independent.

Volume and structure of the dissertation work

The dissertation has a volume of 155 pages, including 81 figures, 12 tables formed in the introduction, 4 chapters, general conclusions, scientific and applied contributions, a list of used terms and abbreviations, a list of the author's publications. The list of cited literature includes 131 titles, all in latin.

CONTENTS OF THE DISSERTATION

Chapter 1. Analysis of the state of the problem

In chapter one of the dissertation, a literature study on the specific issue is conducted. An analysis of the state of the air pollution problem, which is of critical importance for all of us, both nationally and globally, is presented. The features of the main sources of pollution, namely road transport, which has an impact on air pollution, are specified. The problems from the conducted literature study are analyzed. To achieve the set goal, the tasks of the dissertation are defined. The relevance of the problem of reducing the adverse effects of transport, which is an important goal of EU policy, is emphasized.

From the overview, it was found that CO, CO2 and HC emissions have the most adverse effect. Particular attention is paid to compliance with environmental norms in the production of engines and to the various methods and systems for minimizing the toxicity of exhaust gases.

The amounts of toxic substances in the exhaust gases of gasoline engines are presented in table 1.1.

Table 1.1. Composition and amount of harmful exhaust gases according to the type of engine.

Composition of exhaust gases	Quantitatively content [%]		Kind
	For diesel engines	For gasoline engines	
Nitrogen	76 - 78	74-77	non-toxic
Nitrogen oxides	0.0002 - 0.05	0.0 – 0.8	toxic
Oxygen	2 - 18	0.3 – 8.0	non-toxic
Water	0.5 – 4.0	3.0 – 5.5	non-toxic
Carbon monoxide	0.01 – 0.5	5.0 – 10.0	toxic
Carbon dioxide	1.0 – 10.0	5.0 – 12.0	non-toxic
Hydrocarbons	0.009 – 0.5	0.2 – 3.0	toxic
Soot	0.01 – 1.10 g/m3	0.0 – 0.04 g/m3	toxic

The modern scale of production of internal combustion engines and their use has led to the fact that their impact on environmental protection has become significant. The amount of emissions from internal combustion engines is such that they can significantly change the concentrations of chemicals that make up the air, water, soil, which become dangerous to life. As a result of operation, the emission control systems integrated in cars gradually deteriorate, leading to an increase in the levels of harmful gases emitted by them. Road transport is one of the main sources of air pollutants.

There is a need to simulate the various faults in a car engine and show their effect on vehicle emissions. It is imperative to implement and test an experimental methodology to investigate various engine malfunctions.

In addition, most emissions-related damage is invisible, with the exception of smoke problems, which are rare on modern vehicles, making them difficult for vehicle owners and mechanics without emissions testing equipment to find. In this context, it is of particular importance to focus on this worldwide problem, namely to simulate a number of engine faults and track their impact on harmful emissions.

Chapter 2. Technologies for improving the environmental performance of internal combustion engines

Chapter two of the dissertation focuses on the problems caused by carbon deposits in internal combustion engines, their impact on their power and environmental characteristics, the symptoms that appear as a result of the accumulated deposits. The result of the removal of unwanted deposits on the internal parts of the engine is presented and analyzed.

2.2.1. Impact of nagari on the operation of DHG

Carbon soot is known to cause a drastic decrease in fuel economy and performance. Many cars rely on built-in computer modules and sensors for optimal engine performance. This is a prerequisite to analyze the influence of carbon soot and the consequences and causes influencing the unfavorable condition of modern engines.

2.2.2. Design features of the used research equipment ETU-2200E.

In the course of the research, the ETU-2200e research equipment was used (fig. 2.4). It is a stand for cleaning both gasoline and diesel engines.

The stand is used to clean the engine of carbon deposits by connecting in series to the fuel system. The internal combustion engine runs with the additive solution to clean these deposits for a certain period of time and the corresponding fuel used by the engine (diesel/gasoline).

2.2.3. Results

After the tests done on the selected car for smokiness (soot), an exceptional improvement of its environmental characteristics was observed. After comparing the measured values - before and after the cleaning cycle, we can report a drastic drop in harmful emissions.

Table 2.2 presents the results of the vehicle test before the cleaning cycle.

Table 2.2. Smoke meter results obtained before cleaning.

Vehicle data		
Brand – Opel Reg. No. CM9793AX	Model - ASTRA	
Environment		
Temperature degrees C-8	Pressure kRa-85	Humidity %:84
Measured values		
Engine temperature - 80 degrees C RPM min 850(1/min)		
Norms:		
Engine temperature - 80 degrees C RPM min 500 -1000(1/min) Deviations 0.25	Maximum revolutions 1000 to 5000 (1/min) Smoke standards - 3(m-1)	
Smoke values:	(m-1)	(1/min)
Smoke acceleration #1 k	0.05	850
Smoke acceleration #2 k	0.06	2010
Smoke acceleration #3 k	0.07	2080
Smoke acceleration #4 k	0.07	2130

In table 2.3. the results obtained after the cleaning cycle are expressed.

Vehicle data		
Brand – Opel Reg. No. CM9793AX	Model - ASTRA	
Environment		
Temperature degrees C-6	Pressure kRa-86	Humidity %: 87%
Measured values		
Engine temperature - 80 degrees C RPM min 850(1/min)		
Norms:		

Engine temperature - 80 degrees C RPM min 500 -1000(1/min) Deviations 0.25	Maximum revolutions 1000 to 5000 (1/min) Smoke standards - 3(m-1)	
Smoke values:	(m-1)	(1/min)
Smoke acceleration #1 k	0.03	2150
Smoke acceleration #2 k	0.02	2040
Smoke acceleration #3 k	0.03	2080
Smoke acceleration #4 k	0.03	2120

2.2.4. Conclusions

From the experiments conducted and the results obtained, it can be concluded that cleaning the internal parts of the engine with a stand (ETU-2200E) leads to an improvement in the performance of the engine and its environmental parameters. It can be seen from the analysis of the results that there is a reduction in harmful emissions.

Chapter 3. Simulations of internal combustion engine malfunctions in order to study their impact on harmful emissions

In this thesis chapter, various faults in an automobile engine are simulated and their impact on vehicle emissions is indicated.

3.1. Simulation of engine faults and their impact on harmful emissions.

A total of 10 different malfunctions are presented. The graphical results are analyzed to provide information on the emission performance of motor vehicles. The data is used to assess the effect of parameters such as engine load and ambient temperature on vehicle emissions. Tests were made that were simulated and grouped into the following functional areas: air intake, fuel supply, ignition and exhaust aftertreatment systems.

3.1.4. Experimental results

The tests carried out give reason to establish that, at first glance, insignificant damages can worsen the composition of harmful emissions many times. The concentration of carbon dioxide remains relatively stable, with the biggest impact being the malfunction in the throttle valve mechanism. With her, the values reach 14.872%. The graph of carbon dioxide values is summarized and depicted in Figure 3.2.

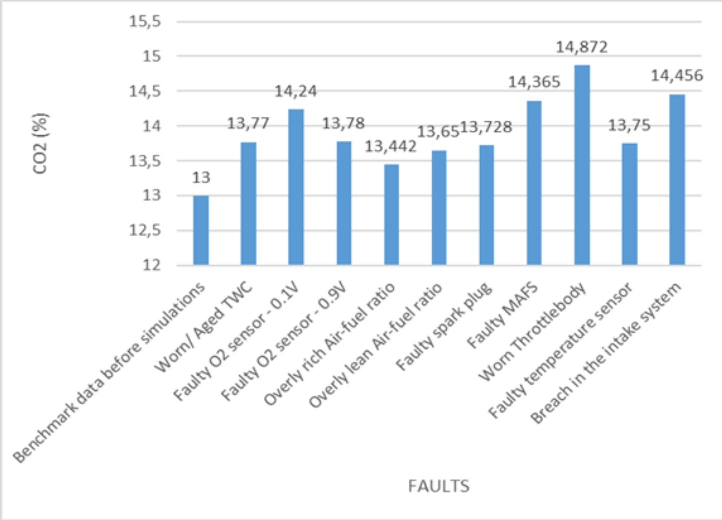

Fig. 3.2.CO2 emission results for the various faults.

The highest concentration of carbon monoxide is reported when the oxygen sensor malfunctions with a constant voltage of 0.9 V., and the values reach 3.06% (fig. 3.3.).

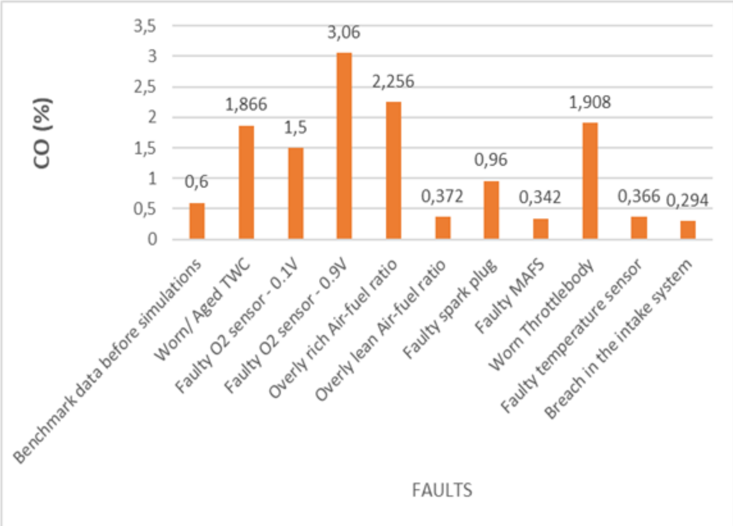

Fig. 3.3.CO emission results for the different faults.

The highest concentration of hydrocarbons is reported when the oxygen sensor malfunctions with a constant voltage of 0.9 V., and the values reach 429.51 ppm (fig. 3.4.).

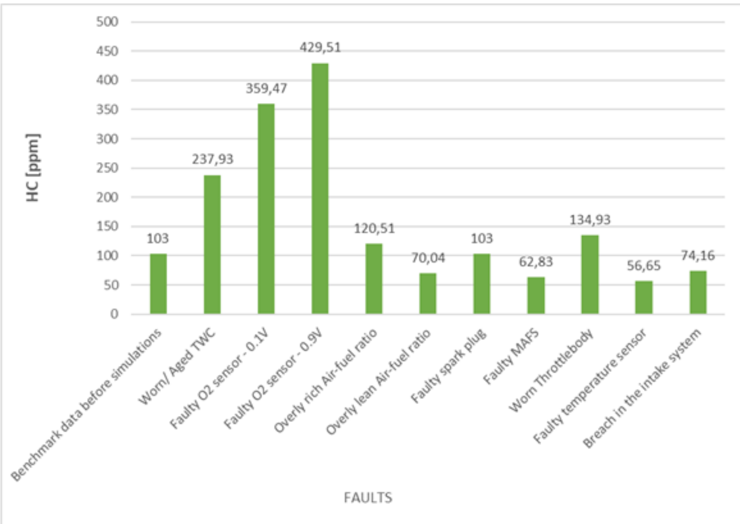

Fig. 3.4.HC emission results for the various malfunctions.

3.2. RESEARCH OF GAS INJECTORS AFFECTING HARMFUL EMISSIONS.

The research presented in this part of the dissertation focuses on the analysis of signals from electronically controlled valves (injectors) that regulate fuel injection into the intake manifold of internal combustion engines. Experiments show that the electronic control of the injectors provides more precise dosing of the fuel, which leads to more efficient combustion and, accordingly, to lower levels of harmful emissions.

3.2.4 Principle of checking with an oscilloscope of a gas injector.

Channel A:

Connect a 10:1 attenuator to the Channel A input of the oscilloscope, then connect the measuring probe to the attenuator. The red lead of the probe is connected to one of the injector terminals, the black lead to ground (chassis).

Channel B:

Connect a 60 amp clamp-on amp to the Channel B input on a ±20A range. The switch should be in the 1mV/10mA position.

The amp clamp is turned on and pressing the ZERO button resets the clamp before connecting to the injector circuit.

The clamp amps should be connected to only one of the two wires to the injector regardless of which one (only the polarity changes depending on the wire selected).

The engine is started and allowed to warm up to operating temperature.

Results

Performing diagnostics using an oscilloscope allows you to monitor the voltage and current passing through the gas injector in real time. Each injector is tested separately. Fig. 3, Fig. 4, Fig. 5 and Fig. 6 show the results of the study.

When the solenoid is actuated, a magnetic field is formed, after it is turned off, this magnetic field is induced back into the solenoid, resulting in a voltage spike. The peak voltage is compared to that of the other injector. A different peak voltage indicates a problem with the electrical circuit. When the voltage drops, the signal should drop smoothly. A non-uniform fall of the signal means a mechanical jamming of the solenoid (Fig. 3.7). A smooth change in signal should be observed for the current signal. An abrupt change indicates a short circuit in the circuit.

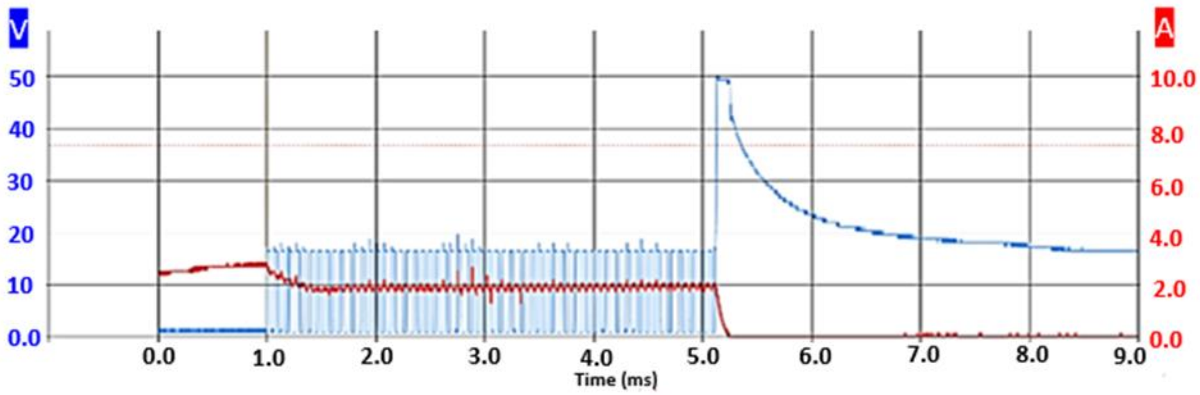

Fig. 3.7. First cylinder LPG injector test results.

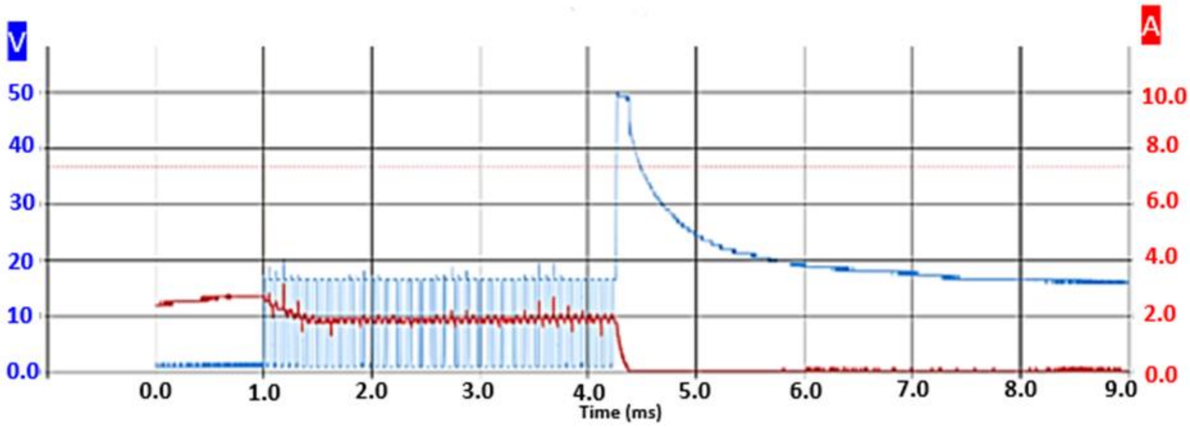

Fig. 3.8. Second cylinder LPG injector test results.

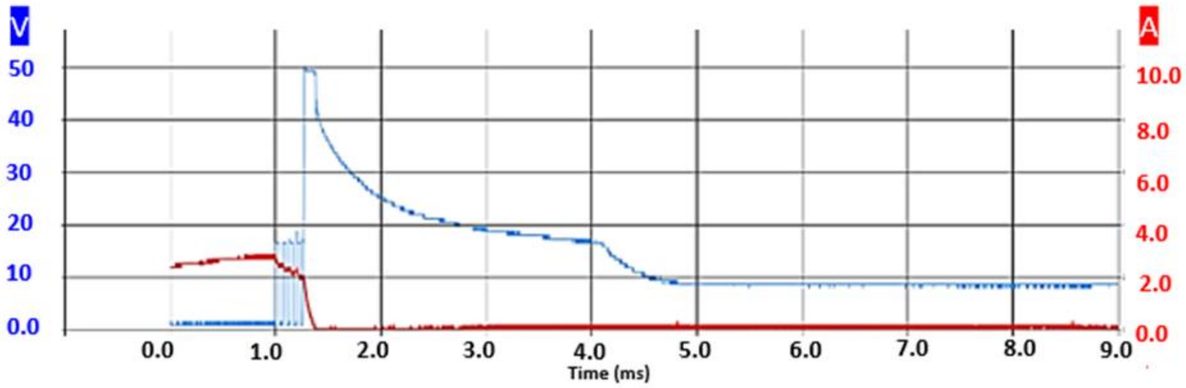

Fig. 3.9. Third cylinder LPG injector test results.

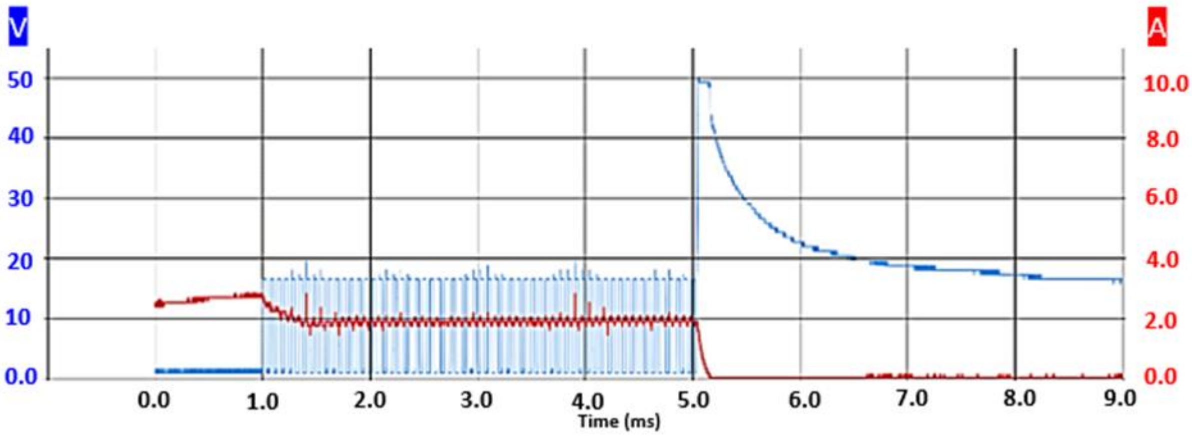

Fig 3.10. Fourth cylinder LPG injector test results.

After the investigation, a malfunction was detected in the operation of injector 3. The other injectors are working properly.

3.4 Conclusions

After the tests, it was found that at first glance minor faults can worsen the composition of harmful emissions many times. From an environmental point of view, this research has provided essential information regarding the influence of various failures on the composition and amount of harmful emissions emitted by internal combustion engines.

CHAPTER 4. EXPERIMENTAL RESEARCH

This chapter of the dissertation presents a study on the influence of fuel air mixture ratio and ignition angle on harmful emissions from a gasoline engine. The research results are analyzed from an ecological point of view. In the presented scientific work, the experiments were carried out with a BMW 318 gasoline engine. It is equipped with a MegaSquirt 3 electronic control unit, TunerStudio MS software and a Kane AUTO plus gas analyzer. The concentrations of carbon monoxide (CO), carbon dioxide (CO_2) and unburned hydrocarbons (HC) were measured. The tests were done at different engine speeds, different air fuel ratios and different ignition angles. The data obtained from the presented studies were used to compile correlation equations that describe the relationship between the fuel-air mixture ratio, the ignition angle and the levels of harmful emissions.

4.1.1 Hardware

The hardware product MegaSquirt 3 (Fig. 4.1) was used to provide the conceptual project of the dissertation work.

4.2. Study of harmful emissions from a gasoline engine depending on the air/fuel ratio.

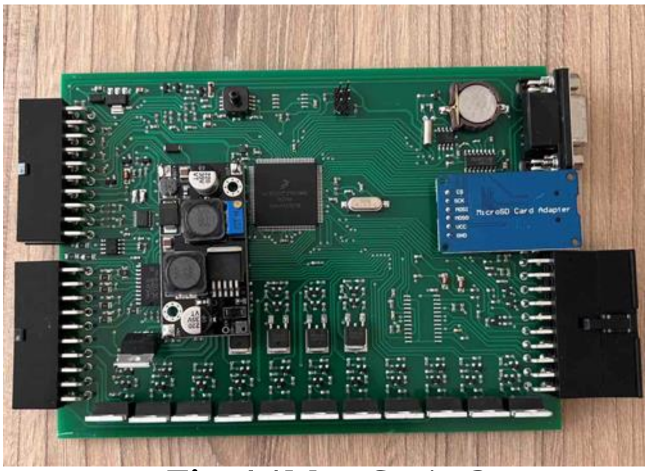

Fig. 4.1 MegaSquirt 3 microprocessor controller.

The research was conducted with a BMW 318 gasoline engine equipped with a MegaSquirt 3 electronic control unit and TunerStudio MS software. The engine is connected to a Kane AUTOplus gas analyzer that measures carbon dioxide (CO_2), carbon monoxide (CO) and hydrocarbon (HC) emissions.

4.2.1. Description of the experimental setup.

The experimental setup used to conduct the study is depicted in Figure 4.3. The engine is mounted on a laboratory bench, allowing monitoring of its main parameters and work processes. The MegaSquirt 3 electronic control unit is configured to control the ignition and other engine parameters, using the Tuner Studio MS software product for configuration.

Fig. 4.3 Experimental setup.

4.3. Software for tuning and monitoring engine parameters

Features of TunerStudio MS: Intuitive user interface that allows fast and efficient tuning of engine parameters. Provides real-time data monitoring including engine RPM, coolant temperature, manifold pressure and other important parameters. Ignition Tuning and Fuel Maps: tools to create and edit ignition and fuel maps that allow optimization of engine performance under various conditions.

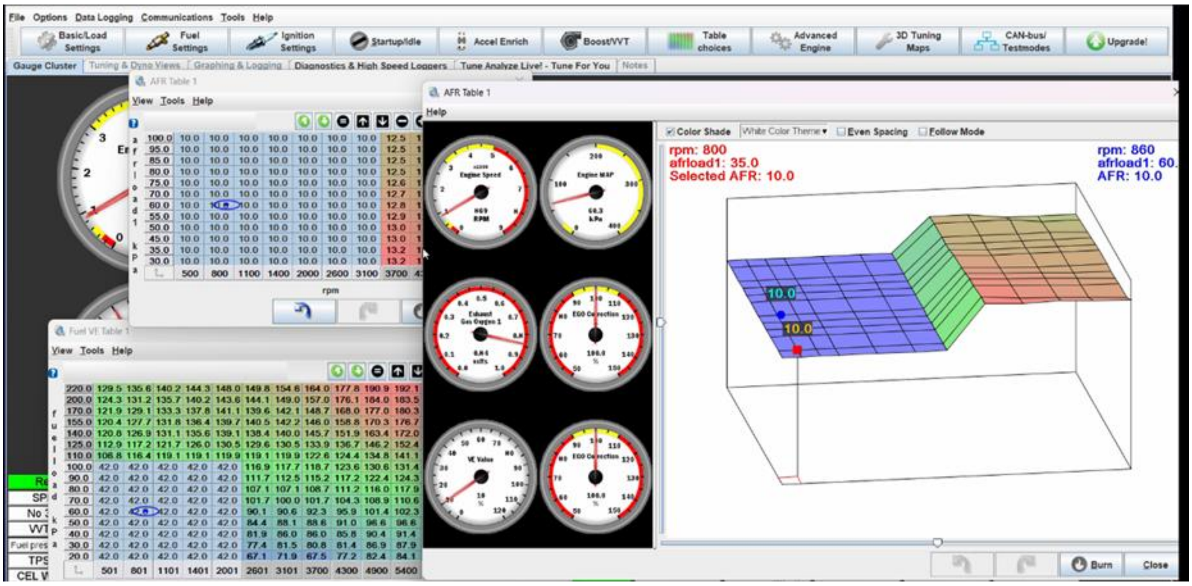

Fig. 4.4. Tuner Studio MS.

4.4.Experimental results

Experimental studies were conducted on the harmful emissions released during the operation of a gasoline engine with internal combustion - carbon dioxide (CO_2), carbon monoxide (CO) and hydrocarbons (HC), at different fuel-air mixture ratios and at different engine speeds.

The results of the conducted studies of the change in CO_2 depending on the fuel-air mixture ratio and engine speed are presented in tabular form - Table 1. Correlation equations were used to process the results, through which the correlation coefficients of the studied emissions are obtained.

Table 4.1.CO2 depending on the values of the fuel air mixture ratio and the engine speed

CO2		Engine RPM (RPM/min)						
		800	1000	1200	1400	1600	1800	2000
Fuel-air ratio	10:1	2.80	3.53	4.25	5.00	5.32	5.40	4.47
	11:1	2.14	3.72	3.99	4.80	5.36	5.41	4.74
	12:1	2.20	3.82	3.48	4.81	5.39	5.42	4.70
	13:1	1.97	3.43	3.40	4.78	5.31	5.43	4.70
	14:1	2.33	3.56	3.33	4.85	5.46	5.51	4.70
	15:1	1.69	3.72	3.43	4.80	5.36	5.56	4.70
	16:1	2.02	3.66	3.11	4.68	5.35	5.57	4.68
	17:1	1.84	3.23	3.32	4.65	5.35	5.53	4.68
	18:1	1.52	3.22	3.22	4.67	5.36	5.58	4.64
	19:1	2.10	3.17	3.20	3.84	5.29	5.60	4.59
	20:1	1.80	3.15	3.48	3.96	5.34	4.66	4.70

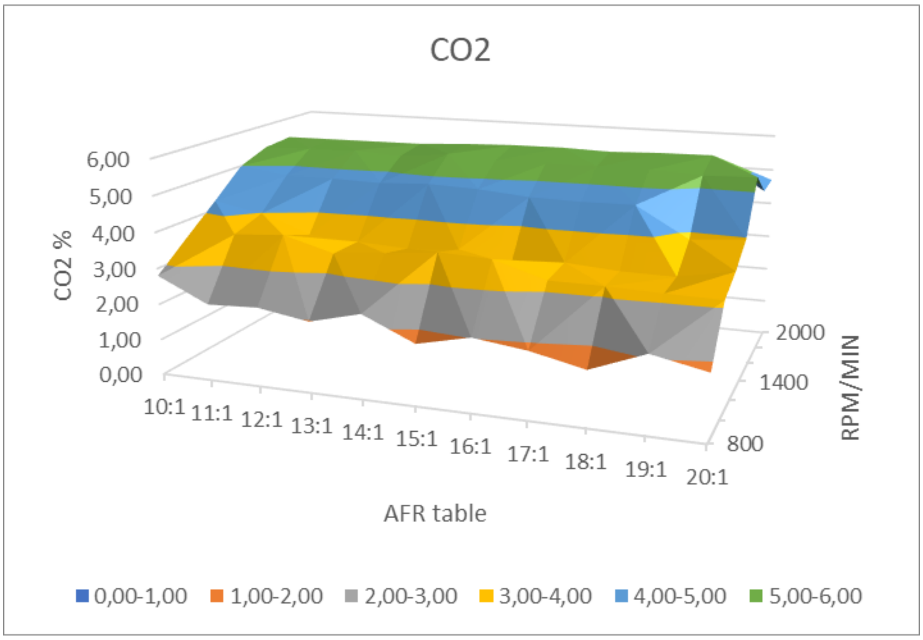

Fig. 4.6. Diagram of CO2 at different fuel air mixture ratio and different engine speeds.

The analysis of the results, visualized in Fig. 4.6, gives grounds to draw the following conclusions:

1. At values of the fuel-air mixture ratio in the range of 17:1 to 20:1 and engine revolutions in the range of 800-1200 rpm, CO2 values are the lowest - 1.5 to 4%;
2. The highest CO2 values are at fuel-air ratio in the range of 10:1 to 14:1 and engine speed in the range of 1400-1800 rpm;
3. The values of the correlation coefficients prove a strong dependence between the ratio of the fuel-air mixture and the measured CO2 values.

In fig. 4.10 is a graph showing the relationship between AFR (Air-Fuel Ratio) and CO2 emissions (%) at 1400 revolutions per minute (RPM). The equation of the line: $y=-0.089x+5.9705$, which shows that for every 1 unit increase in AFR, CO2 emissions drop by about 0.089%. Correlation coefficient (P-value): P = -0.80424 indicates a strong negative correlation between the two variables. The graph shows that at 1400 RPM increasing AFR (richer fuel mixture) also results in a reduction in CO2 emissions as well as at lower revs.

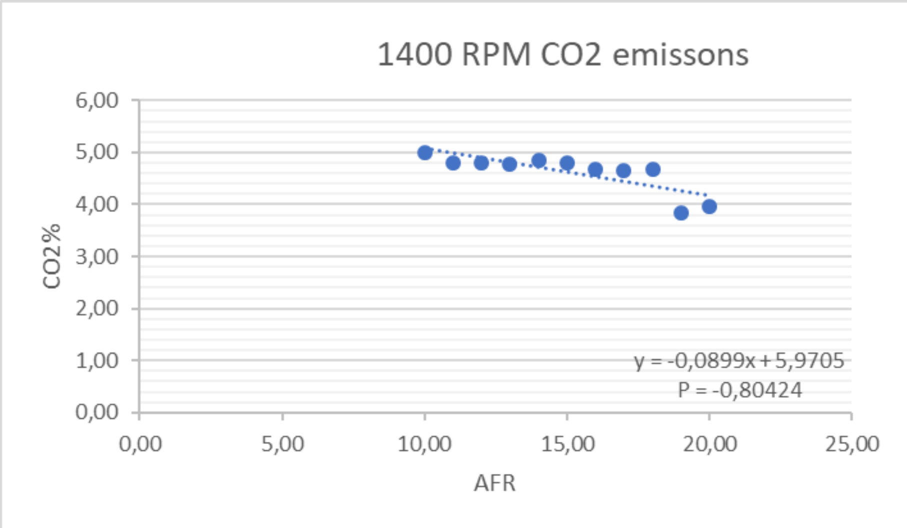

Fig. 4.10. Graph illustrating the correlation between CO2 and different fuel air ratio at 1400 rpm.

In fig. 4.12. is a graph showing the relationship between AFR (Air-Fuel Ratio) and CO2 emissions (%) at 1800 revolutions per minute (RPM). The equation of the line: y=-0.02x+5.7245, which shows that for every 1 unit increase in AFR, CO2 emissions increase by about 0.002%. Correlation coefficient (P-value): P = 0.938781 indicates a strong positive correlation between the two variables. The graph shows that at 1800 RPM the AFR change has a strong effect on CO2 emissions.

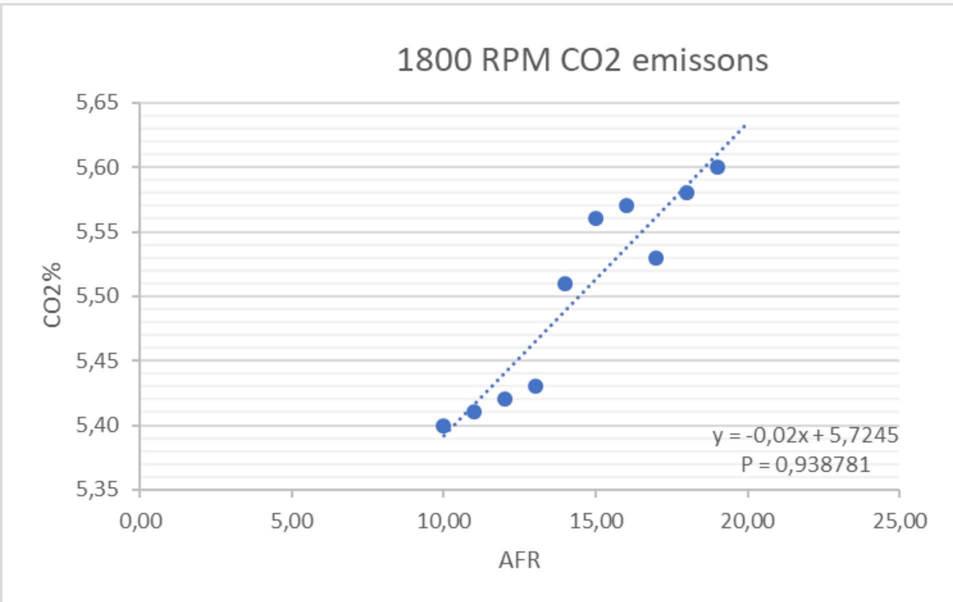

Fig. 4.12. Graph illustrating the correlation between CO2 and different fuel/air ratios at 1800 rpm.

The results of the conducted research on the change of unburned hydrocarbons (HC) depending on the values of the ratio of fuel air mixture and engine revolutions are presented in tabular form (see table 2). For processing the results, correlation equations were used, through which the correlation coefficients of the studied emissions are obtained.

Table 4.2.HC depending on the values of the ratio of fuel air mixture and engine speed.

HC		Engine RPM (RPM/min)						
		800	1000	1200	1400	1600	1800	2000
Fuel air mixture ratio	10:1	4098.00	3449.00	3875.00	4321.00	4416.00	4966.00	4061.00
	11:1	4506.00	3661.00	3950.00	4461.00	4813.00	5041.00	4824.00
	12:1	4409.00	3718.00	3501.00	4431.00	5011.00	5113.00	4809.00
	13:1	4598.00	3815.00	3663.00	4402.00	4942.00	5122.00	4796.00
	14:1	4397.00	3812.00	3563.00	4500.00	5163.00	5170.00	4806.00
	15:1	4638.00	3745.00	3500.00	4513.00	5144.00	5218.00	4794.00
	16:1	4715.00	3788.00	3409.00	4371.00	5184.00	5223.00	4785.00
	17:1	4715.00	3856.00	3474.00	4431.00	5184.00	5200.00	4756.00
	18:1	4747.00	3997.00	3458.00	4516.00	5190.00	5257.00	4701.00
	19:1	4728.00	3942.00	3399.00	3653.00	5169.00	5303.00	4641.00
	20:1	4152.00	3909.00	3688.00	3854.00	5218.00	4613.00	4600.00

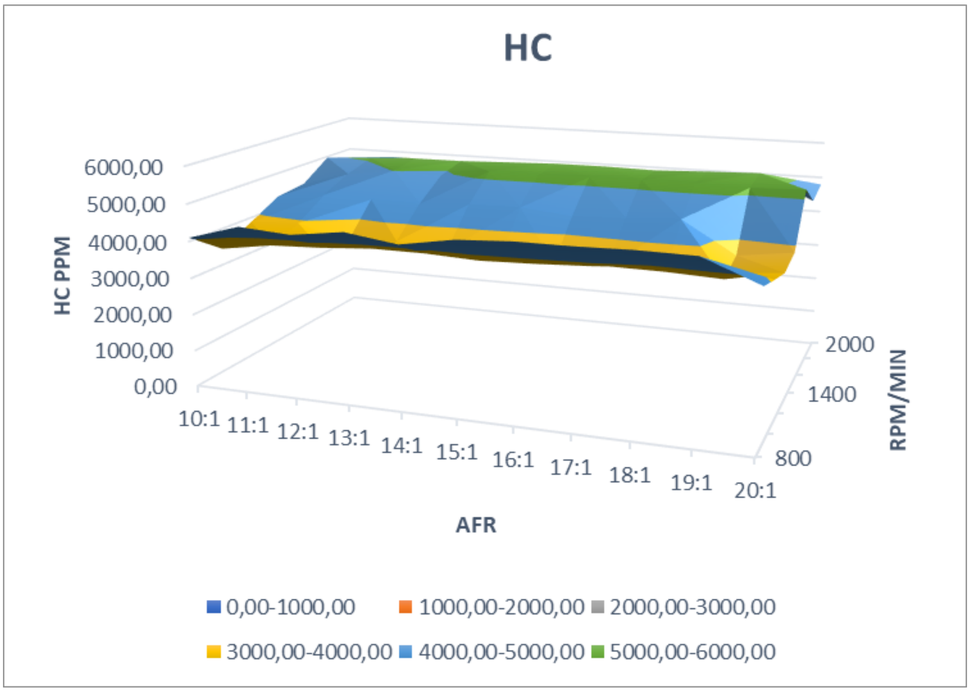

Fig. 4.14.HC diagram at different fuel air mixture ratio and different engine speeds.

The analysis of the results visualized in Fig. 4.14, gives reason to draw the following conclusions:

4. At values of the ratio of the fuel-air mixture in the range of 14:1 to 18:1 and engine revolutions in the range of 1000-1200 rpm, the values of HC are the lowest - 3000 to 4000 rpm;

5. The highest values are the HC ratio of the fuel-air mixture in the range of 17:1 to 19:1 and engine revolutions in the range of 1600-1800 rpm;

6. The values of the correlation coefficients prove a clearly expressed dependence between the fuel-air mixture ratio and the measured HC values at 1600 rpm and a weak dependence at 800 and 1000 rpm.

7. Also evident from the results is the fact that with a richer mixture, the HC levels drop at higher revs, which is also based on the greater velocity of the exhaust gases.

Fig. 4.15. shows a graph showing the relationship between AFR (Air-Fuel Ratio) and HC emissions (ppm) at 800 revolutions per minute (RPM). The equation of the line: y=24.764x+4147, which shows that with each increase in AFR by 1 unit, HC emissions increase by 24.764 ppm. Correlation coefficient (P-value): P = 0.841768 shows a strong positive correlation between the two variables. The graph shows that at 800 RPM, with increasing AFR, HC emissions increase.

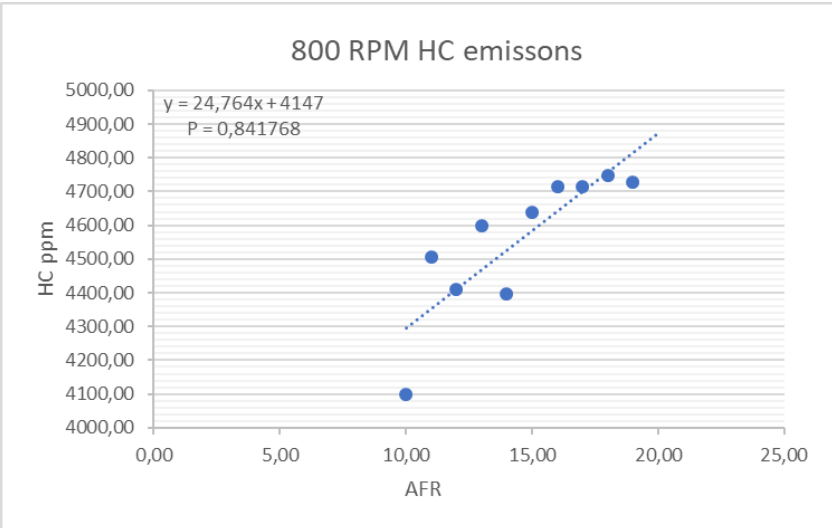

Fig. 4.15. Graph illustrating correlation between HC and different fuel air ratio at 800 rpm.

In fig. 4.20 is a graph showing the relationship between AFR (Air-Fuel Ratio) and HC emissions (ppm) at 1800 revolutions per minute (RPM). The equation of the line: y=-0.6909x+5121.8, which shows that for every 1 unit increase in AFR, HC emissions increase by 0.6909 ppm. Correlation coefficient (P-value): P = 0.955521 indicates a very strong positive correlation between the two variables. The graph shows that at 1800 RPM, as AFR increases, HC emissions significantly increase.

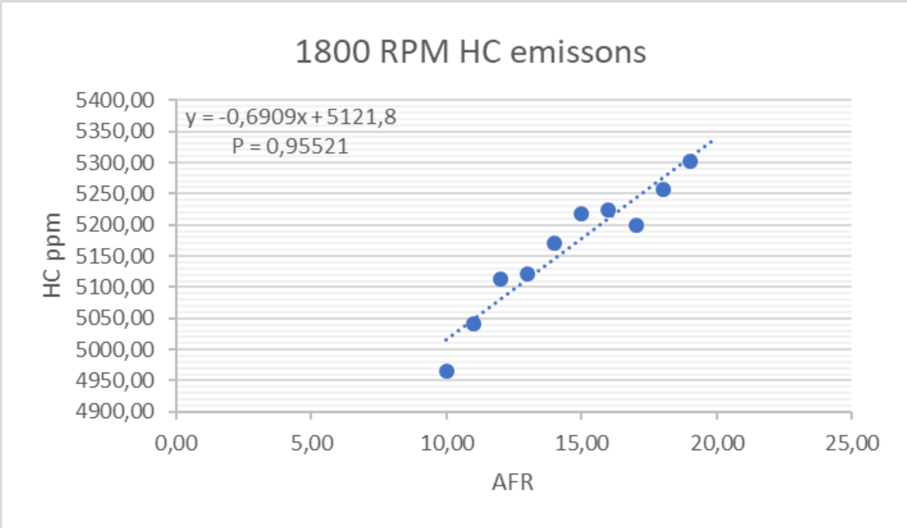

Fig. 4.20. Graph illustrating the correlation between HC and different fuel air ratio at 1800 rpm

Table 4.3.CO depending on the values of the fuel air mixture ratio and the engine speed

CO		Engine RPM (RPM/min)						
		800	1000	1200	1400	1600	1800	2000
Fuel-air ratio	10:1	0.07	0.09	0.03	0.08	0.07	0.61	0.14
	11:1	0.07	0.09	0.01	0.07	0.21	0.56	0.12
	12:1	0.03	0.08	0.08	0.06	0.22	0.55	0.10
	13:1	0.03	0.09	0.09	0.05	0.43	0.48	0.10
	14:1	0.02	0.09	0.09	0.06	0.52	0.46	0.10
	15:1	0.01	0.08	0.09	0.50	0.50	0.41	0.11
	16:1	0.02	0.08	0.06	0.06	0.61	0.42	0.11
	17:1	0.01	0.08	0.05	0.03	0.56	0.33	0.09
	18:1	0.01	0.08	0.05	0.03	0.56	0.34	0.09
	19:1	0.00	0.07	0.04	0.13	0.55	0.32	0.11
	20:1	0.07	0.06	0.03	0.08	0.51	0.32	0.09

The results of the conducted research on the change of carbon oxides (CO) depending on the values of the ignition angle and engine revolutions are presented in tabular form (see table 4.3). For processing the results, correlation equations were used, through which the correlation coefficients of the studied emissions are obtained.

The analysis of the results visualized in Fig. 4.22, gives reason to draw the following conclusions:

8. At air-fuel ratio values in the range of 16:1 to 20:1 and engine speeds in the range of 800-1400 rpm, CO values are the lowest at 0.01 to 0.1% ;
9. The CO values are highest at the fuel-air mixture ratio in the range of 10:1 to 11:1 and engine revolutions in the range of 1600-1800 rpm;
10. The values of the correlation coefficients prove a clear relationship between the ignition angle and the measured CO values.
11. It can be seen from the results and the diagram that the strong release of CO at 1800 engine rpm and the fuel-air mixture ratio in the range of 10:1 to 14:1 and the

subsequent reduction of CO with increasing engine speed and fuel-air enrichment mixture.

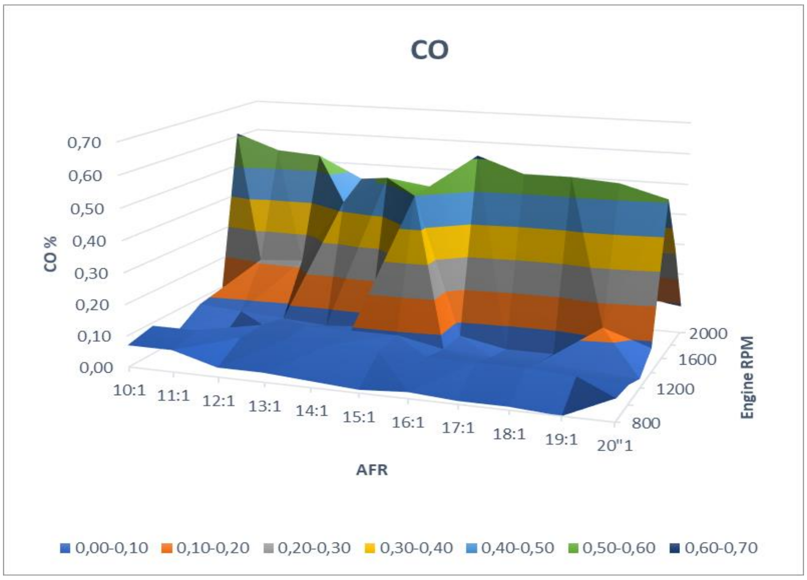

Fig. 4.22.CO diagram at different fuel air mixture ratio and different engine speeds

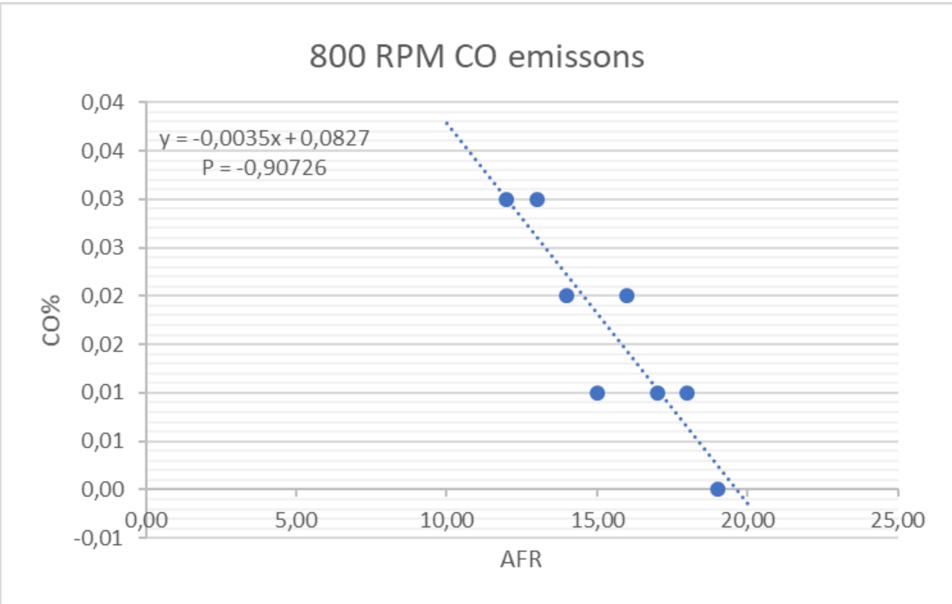

Fig. 4.23. Graph illustrating the correlation between CO and different fuel air ratio at 800 rpm

In fig. 4.23. is a graph showing the relationship between AFR (Air-Fuel Ratio) and CO % emissions at 800 revolutions per minute (RPM). The equation of the line: y=-0.0035x+0.0827, which shows that for every 1 unit increase in AFR, CO emissions decrease by about 0.0035%. Correlation coefficient (P-value): P = -0.90726 indicates a moderate negative correlation between the two variables. The graph shows that at 800 RPM, as AFR increases, CO emissions decrease.

In fig. 4.28 is a graph showing the relationship between AFR (Air-Fuel Ratio) and CO % emissions at 1800 revolutions per minute (RPM). The equation of the line: y=-0.0307x+0.8973, which shows that for every 1 unit increase in AFR, CO emissions decrease by about 0.0307%. Correlation coefficient (P-value): P = -0.9741, indicating a strong negative correlation between the two variables. The graph shows that at 1800 RPM, as AFR increases, CO emissions decrease significantly.

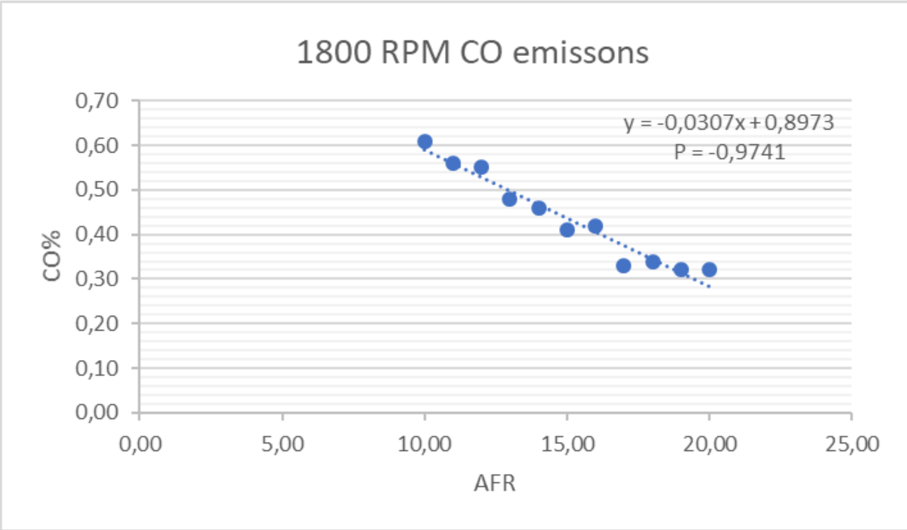

Fig. 4.28. Graph illustrating the correlation between CO and different fuel air ratio at 1800 rpm.

4.5.1.1. Procedure for changing the ignition angle.

Determination of the initial ignition angle according to the manufacturer's specifications. Change the ignition angle in steps of 5 degrees in the range from 0 to +40 degrees.

4.6.Experimental results

Experimental studies were conducted on the harmful emissions released during the operation of a gasoline engine with internal combustion - carbon dioxide (CO2), carbon monoxide (CO) and hydrocarbons (HC), at different ignition angles and different engine speeds.

The results of the conducted research on the change in CO2 depending on the values of the ignition angle and engine revolutions are presented in tabular form (see table 4.4.). For processing the results, correlation equations were used, through which the correlation coefficients of the studied emissions are obtained.

Table 4.4.CO2 depending on the ignition angle values and engine speed

CO2		Engine RPM (RPM/min)						
		800	1000	1200	1400	1600	1800	2000
Ignition angle [degrees]	0	2.8	3.7	5.4	5.7	8.8	6.67	6
	5	2.71	3.79	4.6	5.06	8.69	3.86	4.59
	10	2.02	3.8	4.1	4.06	8.26	6.5	4.65
	15	2,016	3,069	4.17	4.46	6.34	4.25	4.47
	20	1.8	3.05	3.42	3.9	4,305	4.56	4.43
	25	1.6	3.13	3.11	3.84	5.01	4.6	4.23
	30	1.63	2.51	3.59	3.93	4.1	4.52	4.18
	35	1.55	2.5	3.75	4.81	3.16	4.44	4.15
	40	1.6	2.35	3,075	4.73	3.25	4.42	4.09

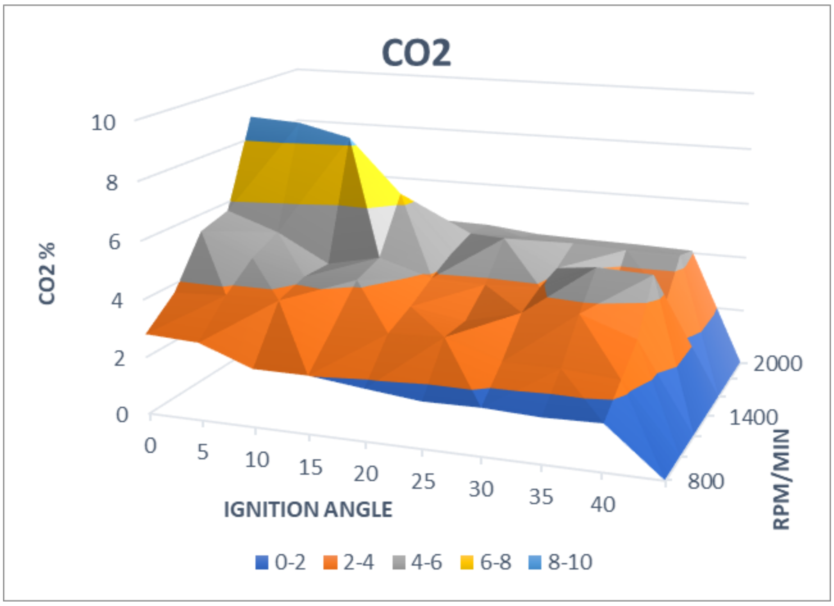

Fig. 4.30. Chart of CO2 at different ignition angles and different engine speeds.

The analysis of the results visualized in Fig. 4.30, gives reason to draw the following conclusions:

12. At ignition angle values of 15-40 degrees and engine revolutions in the range of 800-2000 rpm, CO2 values are the lowest - 1.8 to 4.5%;

13. The highest CO2 values are at an ignition angle of 0-10 degrees and engine revolutions in the range of 1400-2000 rpm;

14. The values of the correlation coefficients prove a strong dependence between the ignition angle and the measured CO2 values.

In fig. 4.31 is a graph showing the relationship between ignition angle and CO2 % emissions at 800 revolutions per minute (RPM). The equation of the line: y=-0.0319x+2.6096, which shows that for every 1 unit increase in ignition angle, CO2 emissions decrease by about 0.0319%. Correlation coefficient (P-value): P = -0.90259 indicates a strong negative correlation between the two variables. The graph shows that at 800 RPM, as the ignition angle increases, CO2 emissions decrease significantly.

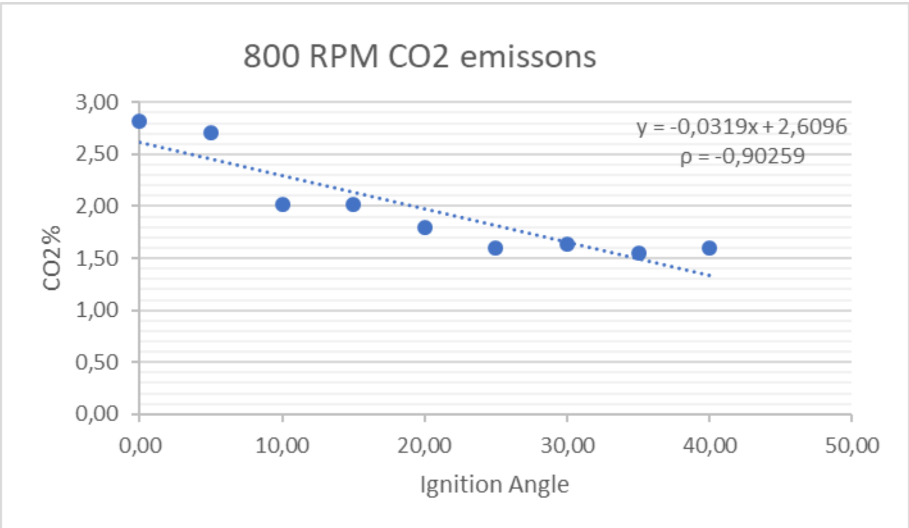

Fig. 4.31. Graph illustrating the correlation between CO2 and different ignition angles at 800 rpm.

In fig. 4.32. is a graph showing the relationship between ignition angle and CO_2 % emissions at 1000 revolutions per minute (RPM). The equation of the line: y=-0.0408x+3.9342, which shows that for every 1 unit increase in ignition angle, CO_2 emissions decrease by about 0.0408%. Correlation coefficient (P-value): P = -0.94592 indicates a strong negative correlation between the two variables. The graph shows that at 1000 RPM, as the ignition angle increases, CO_2 emissions decrease significantly.

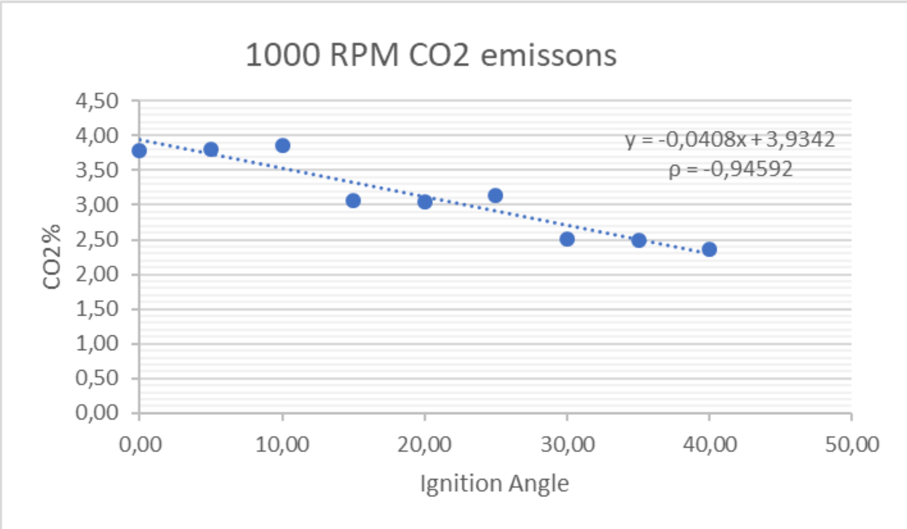

Fig. 4.32. Graph illustrating the correlation between CO_2 and different ignition angles at 1000 rpm.

The results of the conducted research on the change of unburned hydrocarbons (HC) depending on the values of the ignition angle and engine revolutions are presented in tabular form (see table 4.5.). For processing the results, correlation equations were used, through which the correlation coefficients of the studied emissions are obtained. The tabular results are illustrated graphically in Fig. 4.38.

Table 4.5. Results of studies conducted on the modification of unburned hydrocarbons (HC)

HC		Engine RPM (RPM/min)						
		800	1000	1200	1400	1600	1800	2000
Ignition angles[degrees]	0	4180,00	3701,00	4258,00	4314,00	2615,00	2965,00	3449,00
	5	4426,00	4482,00	4249,00	4487,00	2588,00	5403,00	5571,00
	10	4333,00	4448,00	3803,00	3857,00	2463,00	2425,00	5678,00
	15	4296,00	3832,00	3831,00	4072,00	2393,00	4908,00	5784,00
	20	4275,00	3793,00	3711,00	3864,00	4014,00	5019,00	5930,00
	25	4300,00	3609,00	3350,00	3872,00	2885,00	5075,00	5995,00
	30	4278,00	3876,00	3686,00	3915,00	4000,00	5083,00	8954,00
	35	4086,00	3796,00	3784,00	2592,00	3646,00	5105,00	5951,00
	40	4255,00	3970,00	3825,00	2754,00	3775,00	5144,00	6254,00

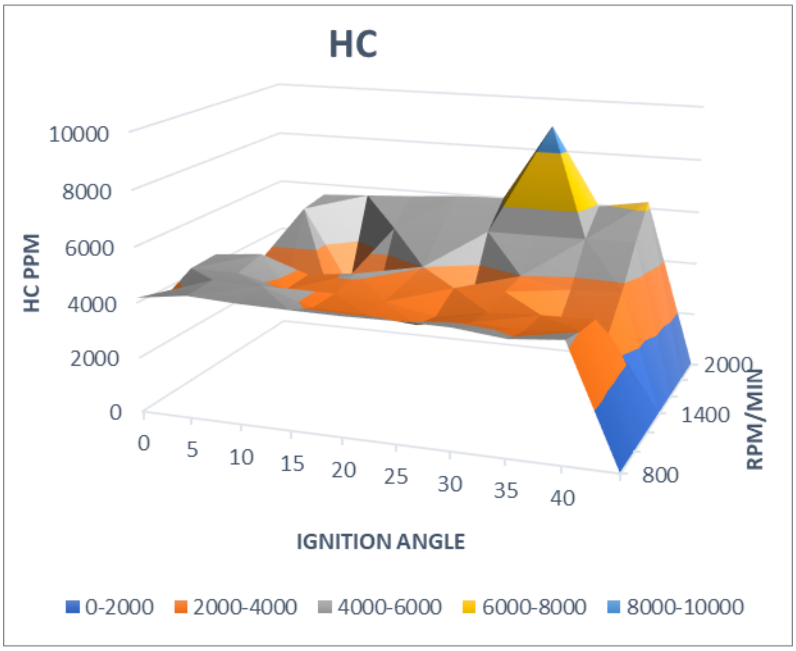

Fig. 4.38.HC diagram at different ignition angles and different engine speeds

The analysis of the results visualized in Fig. 4.38, gives reason to draw the following conclusions:

15. At ignition angle values of 0-20 degrees and engine revolutions in the range of 800-1400rpm values of HC are the lowest - 2000 to 4500 rpm;
16. The highest values of HC are at an ignition angle of 20-40 degrees and engine speed in the range of 1600-2000rpm;
17. The values of the correlation coefficients prove a clear dependence between the ignition angle and the measured values of HC at 1600 rpm. and weak dependence at 800 and 1000rpm.

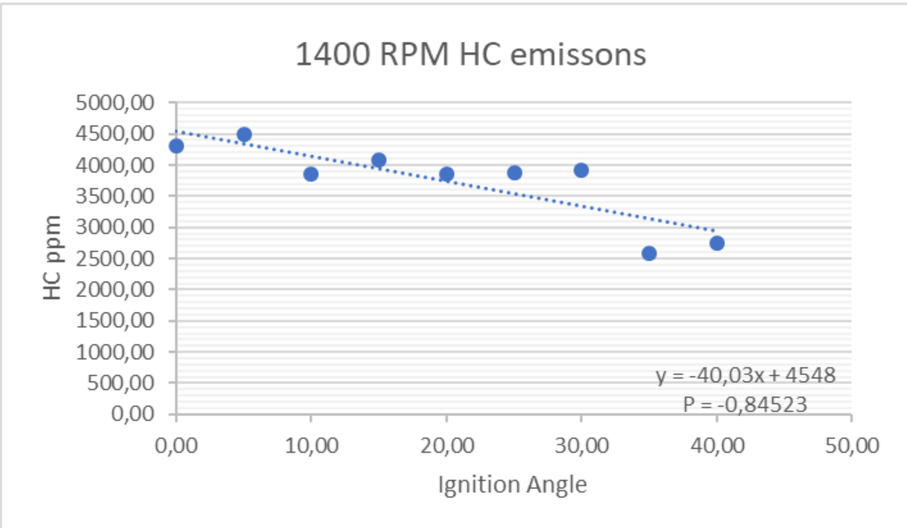

Fig. 4.41. Graph illustrating the correlation between HC and different ignition angles at 1400 rpm.

In fig. 4.41. is a graph showing the relationship between ignition angle and HC emissions (ppm) at 1400 revolutions per minute (RPM). The equation of the line: y=-40.03x+4548, which shows that for every 5 degree increase in ignition angle, HC emissions decrease by about 40.03 ppm. Correlation coefficient (P-value): P = -0.84523 indicates a strong negative correlation between the two variables. The graph shows that at 1400 RPM, as the ignition angle increases, the HC emissions decrease significantly.

In fig. 4.44. is a graph showing the relationship between ignition angle and HC emissions (ppm) at 2000 revolutions per minute (RPM). The equation of the line: y=63.743x+4676.9, which shows that for every 5 degree increase in ignition angle, HC emissions decrease by about 63.743ppm. Correlation coefficient (P-value): P = 0.709254 indicates a moderate positive correlation between the two variables. The graph shows that at 2000 RPM, as the ignition angle increases, the HC emissions increase.

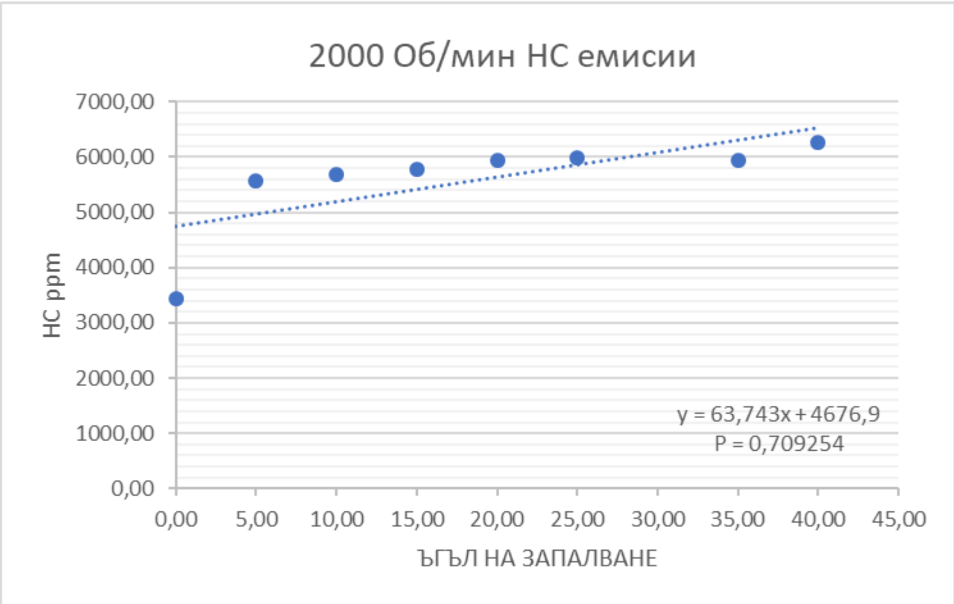

Fig. 4.44. Graph illustrating the correlation between HP and different ignition angles at 2000 rpm.

The analysis of the results visualized in Fig. 4.45, gives reason to draw the following conclusions:

18. At ignition angle values of 15-25 degrees and engine revolutions in the range of 800-1400 rpm, CO values are the lowest - 0.07 to 1%;
19. The highest CO values are at an ignition angle of 0-15 degrees and engine speeds in the range of 1600-2000 rpm;
20. The values of the correlation coefficients prove a clear relationship between the ignition angle and the measured CO values.

Table 4.6. Results of research conducted on carbon monoxide (CO) modification

CO		Engine RPM (RPM/min)						
		800	1000	1200	1400	1600	1800	2000
Ignition angle [degrees]	0	0.10	0.36	0.04	0.14	0.43	2.56	3.15
	5	0.11	0.36	0.08	0.15	0.12	2.39	1.66
	10	0.08	0.28	0.08	0.10	0.10	0.11	1.68
	15	0.07	0.10	0.09	0.10	0.14	0.13	2.01
	20	0.07	0.11	0.08	0.08	0.04	0.15	2.08
	25	0.08	0.08	0.07	0.07	0.11	0.12	2.41
	30	0.07	0.09	0.09	0.06	0.02	0.14	2.36
	35	0.08	0.08	0.08	0.13	0.08	0.16	2.35
	40	0.08	0.08	0.08	0.14	0.07	0.20	2.64

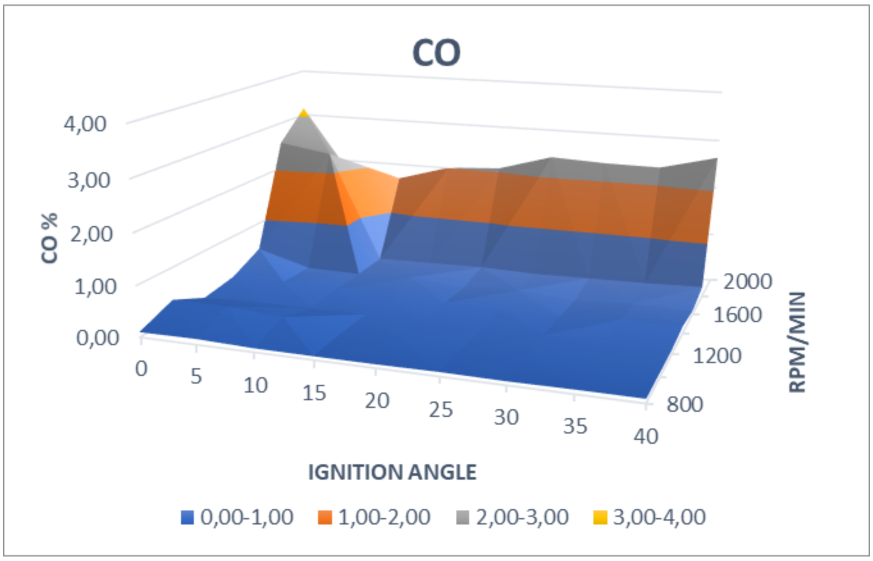

Fig. 4.45. Diagram of CO at different ignition angles and different engine speeds

In fig. 4.47. is a graph showing the relationship between ignition angle and CO % emissions at 1000 revolutions per minute (RPM). The equation of the line: y=-0.0079x+0.3284, which shows that for every 5 degree increase in ignition angle, CO emissions decrease by about 0.0079%. Correlation coefficient (P-value): P = -0.86701 indicates a moderate negative correlation between the two variables. The graph shows that at 1000 RPM, as the ignition angle increases, CO emissions decrease significantly.

In fig. 4.48. is a graph showing the relationship between ignition angle and CO % emissions at 1200 revolutions per minute (RPM). The equation of the line: y=0.0005x+0.066, which shows that for every 5 degree increase in ignition angle, CO emissions decrease by about 0.0005%. Correlation coefficient (P-value): P = 0.486864 indicates a moderate positive correlation between the two variables. The graph shows that at 1200 RPM, as the ignition angle increases, CO emissions increase.

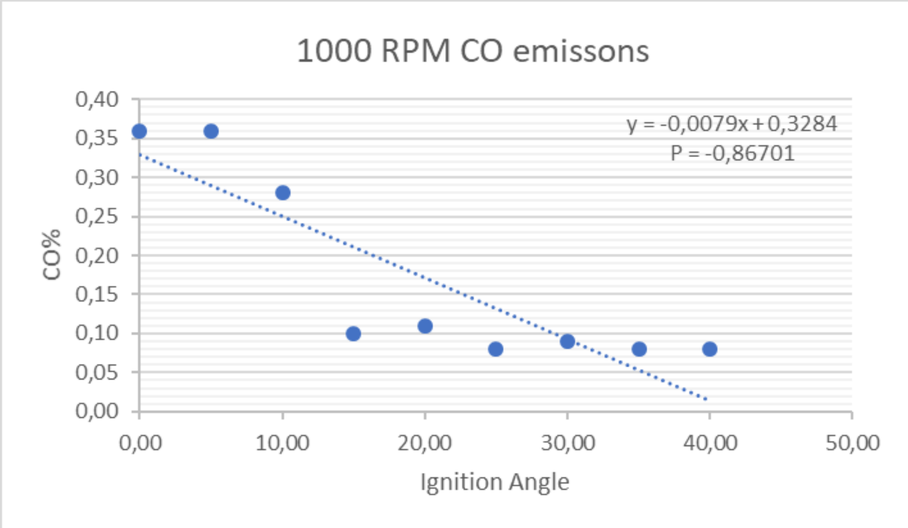

Fig. 4.47. Graph illustrating the correlation between CO and different ignition angles at 1000 rpm

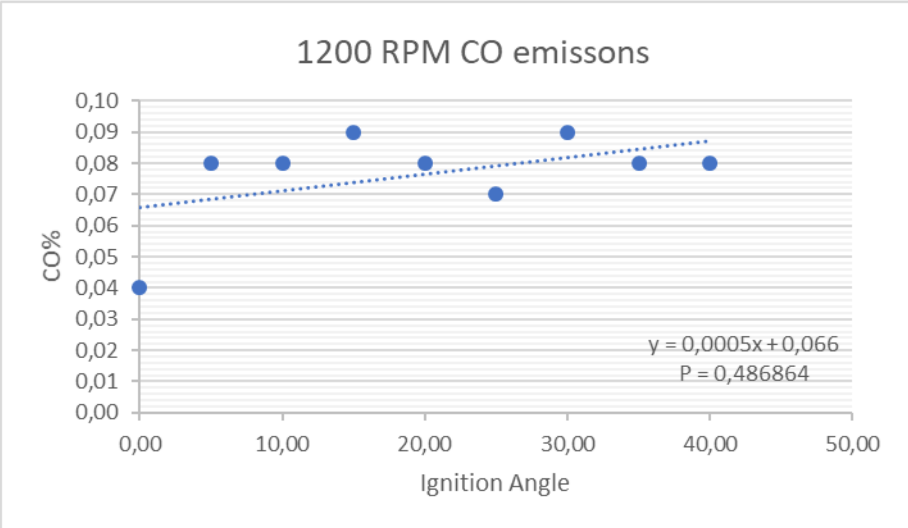

Fig. 4.48. Graph illustrating the correlation between CO and different ignition angles at 1200 rpm

Conclusions

In the fourth chapter of the dissertation, a study is presented on the influence of the fuel-air mixture ratio and the ignition angle on harmful emissions from a gasoline engine.

The research was conducted with a BMW 318 gasoline engine equipped with a MegaSquirt 3 electronic control unit and TunerStudio MS software. The engine is connected to a Kane AUTOplus gas analyzer that measures carbon dioxide (CO2), carbon monoxide (CO) and hydrocarbon (HC) emissions. The experimental setup used to conduct the study is depicted in Figure 4.3. The engine is mounted on a laboratory bench, allowing monitoring of its main parameters and work processes. The MegaSquirt 3 electronic control unit is configured to control the ignition and other engine parameters, using the Tuner Studio MS software product for configuration.

The concentrations of carbon monoxide (CO), carbon dioxide (CO2) and unburned hydrocarbons (HC) were measured. The tests were done at different engine speeds, different air fuel ratios and different ignition angles.

The features of the software and the intuitive user interface allow quick and efficient adjustment of the engine parameters. The ability to monitor real-time data including engine speed, coolant temperature, manifold pressure and other important parameters, ignition tuning and fuel maps is provided. Tools are available to create and edit ignition and fuel maps that allow optimization of engine performance under various conditions.

The precision of the measurements is guaranteed by repeated repetition and arithmetic mean of the obtained values.

The following conclusion can be drawn from the conducted research and data analysis: the optimal ratio of the fuel-air mixture is in the range from 15:1 to 17:1, in which the harmful emissions of CO2, CO and HC have minimal environmental consequences.

Regarding engine speed, it can be concluded that the most favorable values for harmful components are between 1000 and 1400 rpm.

Recommendations are proposed for the implementation of dynamic operating modes and fuel maps for the engines in order to reduce harmful emissions in different driving modes.

Based on the research done, optimization of the fuel-air mixture ratio of gasoline engines with internal combustion is recommended.

From the conducted research and data analysis, the following conclusion can be drawn; the optimal ignition angles, at which harmful CO2, CO and HC emissions have minimal environmental consequences, are from 15 to 25 degrees. Regarding the engine speed, it can be concluded that the most favorable values of the harmful components are between 800 and 1600 rpm.

CONCLUSION

In chapter one of the dissertation, a literature study on the specific issue is conducted. An analysis of the state of the air pollution problem, which is of critical importance for all of us, both nationally and globally, is presented. The features of the main sources of pollution, namely road transport, which has an impact on air pollution, are specified. The problems from the conducted literature study are analyzed. To achieve the set goal, the tasks of the dissertation are defined. The relevance of the problem of reducing the adverse effects of transport, which is an important goal of EU policy, is emphasized.

Chapter two of the dissertation focuses on the problems caused by carbon deposits in internal combustion engines, their impact on their power and environmental characteristics, the symptoms that appear as a result of the accumulated deposits. The result of the removal of unwanted deposits on the internal parts of the engine is presented and analyzed.

The focus is on methods and systems for reducing the toxicity of exhaust gases. A schematic diagram of an electronic fuel injection system with two oxygen sensors is presented. Schemes of EGR, SCR systems, etc. are considered.

It is concluded that the main emphasis in this context is the electronic systems for improving the harmful emissions of cars. For the most common and effective electronic systems, information is provided about their design features and the principle of operation. Attention is paid to the application of technology to improve the environmental performance of internal combustion engines, the impact of soot on the operation of LPG. In the course of scientific research, eight signs have been formulated that need to be taken into account regarding carbon black.

In the course of the research, the ETU-2200e research equipment was used, which is a bench for cleaning gasoline and diesel engines.

Procedures of necessary actions are presented to carry out the process of removing unwanted overlays, having a strong impact on the environmental indicators of the car.

At the end of the second chapter of the dissertation, the composition of car exhaust gases and the percentage content of each of the components in diesel and gasoline engines are described. Information is given on the saturation of harmful components at different engine loads.

As a conclusion, it can be summarized that systems for improving the environmental characteristics of cars with an electronic control unit have a major role in reducing harmful emissions from cars. The electronic systems for improving the environmental characteristics of internal combustion engines are studied and described in detail, as well as their principle of operation.

From the experiments conducted and the results obtained, it was concluded that cleaning the internal parts of the engine with a stand (ETU-2200E) leads to an improvement in the performance of the engine and its environmental parameters. From the analysis of the results, it is evident that there is a reduction in harmful emissions measured with a bench (OPA-100).

In the third chapter, various faults in a car engine are simulated and their effect on vehicle emissions is indicated. An experimental methodology for the study of various engine malfunctions has been implemented and tested. It is justified that determining the degree of influence of the different simulated faults is achieved by comparing the reference data with the measured data from the different simulations.

A total of 10 different faults are given. Their results are analyzed and presented graphically, on the basis of which information is provided on the efficiency of emissions of motor vehicles. The resulting research data is used to assess the effect of parameters such as engine load and ambient temperature on vehicle emissions. In this context, tests were made that were simulated and grouped into the following functional areas: air intake, fuel supply, ignition and exhaust gas aftertreatment systems.

In the course of the study, it was found that the deterioration of the emission control systems in a spark ignition engine is primarily a gradual wear process that occurs as the vehicles accumulate mileage. In order to identify the impact of damage aggravation, a Volkswagen Golf passenger car with a gasoline engine was used, on which the engine hardware system failures were simulated during the experiments.

The next important focus is the laboratory testing of a spark ignition engine through simulated faults.

The conducted tests give reason to establish that at first glance insignificant damage can worsen the composition of harmful emissions several times. The concentration of carbon dioxide remains relatively stable, with the biggest impact being the malfunction in the throttle valve mechanism. With her, the values reach 14.872%.

It was found that the highest concentration of carbon monoxide was reported when the oxygen sensor malfunctioned with a constant voltage of 0.9 V, with values reaching 3.06%.

The results showed that the highest concentration of hydrocarbons was recorded when the oxygen sensor malfunctioned with a constant voltage of 0.9V, with values reaching 429.51 ppm.

Another important study, which is presented in the third chapter, is on gas nozzles affecting harmful emissions. It focuses on the analysis of signals from electronically controlled valves (nozzles) that regulate fuel injection into the intake manifold of internal combustion engines. The analysis of the experiments shows that the electronic control of the nozzles provides more precise dosing of the fuel, which leads to more efficient combustion and, accordingly, to lower levels of harmful emissions.

Particular attention is paid to the analysis of nozzles with electronically controlled valves that inject liquefied petroleum gas. The equipment used to carry out the research is a car oscilloscope "CarScope PLUS 4CH Msa/s Automotive DSO".

The results of the gas nozzle test on the first, second, third and fourth cylinders are graphically presented.

A comparative analysis of the waveforms of two structurally different air volume sensors was performed. During the experiment, data was taken from a mechanical air quantity sensor model BOSCH 1 734 655.9

The following experiment was done using a filament air volume sensor model ZDTOPA 93BB-12B579-BA where a thermistor measures the temperature of the incoming air.

Chapter four focuses on experimental research.

The influence of the fuel-air mixture ratio and the ignition angle on harmful emissions from a gasoline engine has been practically investigated.

The experiments were carried out with a BMW 318 gasoline engine equipped with a MegaSquirt 3 electronic control unit, TunerStudio MS software and a Kane AUTOplus gas analyzer. The concentrations of carbon monoxide (CO), carbon dioxide (CO2) and unburned hydrocarbons (HC) were measured at different engine speeds, different fuel-air ratios and different ignition angles. The obtained data were used to compile correlation equations that describe the relationship between the fuel-air mixture ratio, the ignition angle and the levels of harmful emissions.

A MegaSquirt 3 electronic control unit was used to provide the conceptual design of the dissertation work and the practical experiments.

Engine parameter tuning and monitoring software is used, which allows fast and efficient engine parameter tuning, providing real-time data monitoring.

A procedure for changing the fuel-air mixture ratio is presented in detail. Emission measurements are conducted at various engine speeds: 800, 1000, 1200, 1400, 1600, 1800, and 2000 rpm. For each combination of air-fuel ratio and rpm, the Kane AUTOplus gas analyzer records CO, CO2 and HC concentrations.

The precision of the measurements is guaranteed by their multiple repetition and the arithmetic mean of the obtained values. The scope of the study includes the influence of external factors such as ambient temperature and fuel quality, which may affect the results.

The data obtained are analyzed using statistical methods to determine the correlation between the fuel air mixture ratio and the levels of harmful emissions. Correlation equations are derived that describe the relationship between the fuel-air mixture ratio and emissions at different engine speeds.

The results of the conducted research on the change in CO_2 depending on the fuel-air mixture ratio and the engine speed are presented in tabular form.

The analysis of the results are visualized graphically, specific conclusions are drawn after each study.

From the study, the relationship between AFR (Air-Fuel Ratio) and CO emissions % at different revolutions per minute (RPM) is given graphically. The line equations and correlation coefficients with their analysis are given.

Studies of harmful emissions from a gasoline engine depending on the ignition angle are presented.

A procedure for changing the ignition angle is presented in detail. Emission measurements are carried out at different engine speeds: 800, 1000, 1200, 1400, 1600, 1800, and 2000 rpm. The data are analyzed using statistical methods to determine the correlation between the ignition angle and the levels of harmful emissions. Correlation equations are derived that describe the relationship between the ignition angle and emissions at different engine speeds.

CO diagrams are presented at different ignition angles and different engine speeds.

The obtained simulation results are analyzed and presented tabularly and graphically. They confirm the mathematical relationships discussed in chapter four.

DISSERTATION CONTRIBUTIONS

Scientific and applied contributions:

1. Methods, techniques and the specifics of the composition of the exhaust gases have been researched, systematized and analyzed for the assessment of harmful emissions affecting the environment from an ecological point of view.
2. An experimental set-up and methods for studying various malfunctions of an internal combustion engine and their impact on harmful emissions have been implemented and tested.
3. Factors affecting harmful emissions from internal combustion engines using spark ignition and an electronic control unit are investigated. A comparative analysis of the obtained results was carried out.
4. Research and analysis of data on the influence of the fuel-air mixture ratio on the composition of the exhaust gases has been carried out. From the obtained results, it follows that in the range of the ratio from 15:1 to 17:1, the harmful emissions of CO_2, CO and HC have minimal environmental consequences.
5. The data on the influence of the correction of the ignition angle on the amount and composition of the exhaust gases have been implemented, studied and analyzed. It is experimentally proven that the minimum ecological consequences of harmful CO_2, CO and HC emissions are in the range of 15 to 25 degrees.

Applied Contributions:

1. Studies of simulated malfunctions of a spark-ignition automobile engine, through laboratory tests and their impact on harmful emissions, have been conducted and presented.
2. Studies of electronically controlled gas nozzles affecting emission levels have been performed and presented.
3. The variation of unburned hydrocarbons (HC), carbon oxides (CO) and carbon dioxide (CO2) was investigated as a function of electronically programmable corrections of ignition angle and engine speed.
4. A study of harmful emissions from a gasoline engine, depending on the air/fuel ratio, controlled by a microprocessor unit, has been conducted. Practical measurements have been carried out at different engine speeds. Data on the fuel/air mixture ratio and harmful emissions levels have been presented and analyzed using statistical methods..
5. Experimental studies have been carried out on the harmful emissions emitted during the operation of a gasoline engine with internal combustion - carbon dioxide (CO2), carbon monoxide (CO) and hydrocarbons (HC), at different fuel-air mixture ratios, different values of the ignition angle and different engine speeds.

LIST OF PUBLICATIONS RELATED TO THE DISSERTATION PAPER

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2. **Hr. Kanevski, Sl. Lyubomirov, R. Minchev. An overview of the problems and solutions related to environmental pollution caused by automobiles. — In: Third National Scientific Conference "Man and the Universe" November 25-26, 2021, SUB-Smolyan. ISSN 1314-9400 (online, pp. 465 – 471.**
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