The Factorial Experiment used in the Analysis of the Quality of Noxes Emitted by Automobiles

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Abstract: *Although we are in a continuous development thanks to technology, we are too little aware of the impact technology has on the environment. Thanks to technology, new constituents appear that have a harmful effect on air pollution. One of the main sources of environmental pollution is transport. To analyse the quality of exhaust fumes from cars equipped with spark ignition engines, in this case study a factorial experiment was carried out with six influencing factors on an objective function. The factorial experiment allows us to create three-dimensional graphs, graphs that allow a fine interpretation of the input data and pertinent conclusions that are obtained on the researched object. As a result of the experimental research, the inclusion of gas emissions in the normal parameters according to the norms of the Euro classes was followed. The collected data were processed with the help of active type factorial experimentation research, they were entered into the statistical software, resulting in graphs with the necessary information that can be used in the optimization of the objective functions. From the collected data, it results that regardless of the parameters of the influencing factors, the values of the objective functions are within the parameters according to the Euro norms.*

Keywords: *automobiles, factorial experiment, noxes, statistics*

1 INTRODUCTION

The spark ignition engine is considered the most polluting due to its spread in several fields of activity (Awad et al., 2018). For a correct analysis of internal combustion engines with spark ignition on the environment is the study of the emission of particles that represent the totality of the matter collected on a Teflon filter when the burnt gases pass (Lhuillier et al., 2020). The measurements carried out on vehicles of different brands and years of manufacture revealed how important the technical condition and the emissions emitted by them are (Sun et al., 2020). To reduce the risk of extinguishing the flame at the wall, different individual or combined measures can be taken:

- the concentration of HC (hydrocarbons) decreased by impoverishing the mixture, up to almost the limit of extinguishing the flame in the gas mass;
- increasing the pressure, especially the temperature of the gases burning near the wall by reducing the thickness of the boundary layer;
- ensuring oxygen and a high temperature for the components in the boundary layer by intensifying the oxidation reactions;
- reduction of the surface area of the combustion chamber and cylinder capacity;
- reducing the distance between the first segment and the piston head and reducing the bore/unit cylinder ratio, reducing the piston-cylinder clearance.

2 NOXES AND POLLUTION

Experimental research is increasingly used nowadays, in many fields of activity, but especially in development research. The initial plans initially used by Fisher in 1926 to solve some agricultural problems are widely used in a very large number of industrial and research sectors (Titu et al., 2011), (Titu et al., 2007).

This experimental method is used to find an optimal solution.

The big car manufacturing companies present us with the latest technologies for obtaining high-performance engines and the methods of eliminating the noxes emitted by them (Merulla et al., 2019). The norms regarding the legislation in the field of pollution with the means of transport are established worldwide by the big car manufacturers in collaboration with the environmental protection institutions.

The spark ignition engine is considered the most polluting due to its spread in several fields of activity (Nguyen et al., 2021). For a correct analysis of internal combustion engines with spark ignition on the environment is the study of the emission of particles that represent the totality of the matter collected on a Teflon filter when passing the burnt gases (Dey et al., 2019). The measurements carried out on vehicles of different brands and years of manufacture revealed how important the technical condition and the emissions emitted by them are (Zhu et al., 2020).

Transports are one of the main sources of environmental pollution, the impact of transports on the environment and the health of the population is a very complex problem, considering the fact that the long-term effect of different types of pollution has not yet been evaluated. Pollution destroys the environment due to its contamination with residual matter, industrial waste, exhaust gases, etc. The natural balance of atmospheric gases has been maintained for millions of years, the environment is now threatened by human activity (Aakko-Saksa et al., 2020). These dangers would be global warming, air pollution, the greenhouse effect, thinning of the ozone layer and acid rain.

In the last 200 years, global industrialization has greatly disturbed the ratio of gases necessary for atmospheric balance (Zhang et al., 2020). Due to the burning of coal and methane gas, they led to the

formation of very large amounts of carbon dioxide and other gases, especially after the appearance of the automobile. Another source of pollution is due to the development of agriculture, which determined the accumulation of large amounts of methane and nitrogen oxides in the atmosphere.

Air pollution by automobiles is achieved through the emissions of lead, aldehydes, carbon dioxide, and smoke that contribute to the formation and accentuation of the greenhouse effect. The smoke produced by automobiles is a mixture of complex pollutants that, together with other compounds, attack the tissues in the lungs, causing chronic bronchitis and stroke.

In spark-ignition engines that mainly use gasoline as fuel, the following are used:

1) catalytic systems, this catalyst transforms the combination of the main polluting compounds into a new, less polluting combination;
2) the Gas system is based on the hygrometry of the supply air; it consists in spraying a well-determined amount of water in the intake air;
3) the solution for intermittent interruption of engine operation whenever this possibility exists (Start stop system);
4) by recycling combustion gases, reductions in nitrogen oxide emissions are obtained.

All types of transport contribute to environmental pollution, due to the composition of its systems and the propagation from one component to another (Schwarz et al., 2019). Although technological and fuel advances have been made, transport pollution has remained at high levels.

The dispersion of pollutants depends on their area and geographical factors, location. A flat relief and permanent air currents facilitate a large dispersion of polluting substances, on the other hand, depressions and valleys favour the accumulation and persistence of pollutants.

On the other components of the environment, the changes are induced directly, due to the changes in the climate system: the intensification of desertification (in areas affected by droughts), the acceleration of torrential erosion (in regions affected by large amounts of precipitation), changes in the water regime of the soil.

3 THE EFFECTS OF POLLUTANT EMISSIONS ON THE HUMAN BODY

The roads traveled by automobiles became part of the natural landscapes, important areas of gardens and green spaces were transformed into parking lots and garages. Catalysts (for gasoline engines) and particle filters (for diesel engines) play the basic role in reducing noxes emissions. Practically during the RAR control or the ITP check regarding noxes, the gas analyser test shows the engine emissions after combustion and the efficiency of the catalyst. The noise level and tightness depends on the rest of the components (pipes, drums, connections). The level of noxes and the efficiency of the catalysts is measured by the ECU through the lambda probes and depending on the valuesreceived from these sensors, the mixture is adjusted for the most complete combustion. For particulate filters, the ECU actually manages their operation by controlling the exhaust and injection temperatures.

In developed countries, environmental pollution has reached frightening limits. In connection with the fact that toxic substances migrate through the air from one country to another and even from one continent to another, there is irreversible pollution of water, air and soil, which is not only local in nature.

From year to year, the expenses invested in combating the consequences of the ecological impact increase. The main role in atmospheric pollution is played by emissions from road traffic, power plants and businesses. In the majority of developed countries, the contribution to the total content of atmospheric pollutants is about 60% in the sphere of car transport about 60%, in industry 17%, in the energy industry 14%, in waste incineration 9%. In big cities, cars are the main source of pollution with carbon monoxide, hydrocarbons, nitrogen oxides, aldehydes, soot, and several allergenic substances.

Effects on the environment:

- the formation of tropospheric ozone, which is very toxic for organisms;
- damage to the flora, especially the species of conifers and fruit trees.

Effects on population health:

- respiratory and cardiac diseases due to CO;
- respiratory tract irritations due to NOx (Nitrogen oxides);
- eye irritations and carcinogenic effects caused by hydrocarbons;
- anaemia, diseases of the nervous system due to lead compounds;
- nervous depressions due to benzene compounds.

4 PRESENTATIONS OF THE STUDY AND EXPERIMENTAL DATA

To analyse the quality of exhaust fumes from cars equipped with spark ignition engines, in this case study a factorial experiment was carried out with six influencing factors on an objective function.

The influencing factors of HCppm are the following: CO, CO_2, speed, temperature, O_2, CO_{corr}.

As a result of the experimental analysis, it was found that in this experiment the disturbing factors did not intervene during the recordings, which in this case consisted of power outages and equipment failure.

The factorial experiment allows us to create three-dimensional graphs, graphs that allow a fine interpretation of the input data and pertinent conclusions that are obtained on the researched object.

The interpretation of the data was done for the objective function correlated with two influencing factors, so the graphs obtained allow both the observation of the relationship between the HCppm objective function and the influencing factors (CO, CO_2, O_2, speed, temperature and CO_{corr}). The objective

function on which the six factors will influence is HCppm (hydrocarbon parts per million by volume).

Following the obtained experimental data, the most important graphs will be presented using the Statistica Stat Soft program. This program involves the introduction of certain indicators and the creation of the graphs presented below. I made graphs for each objective function:

- Histograms
- Regular 2D Scatterplots
- 3D Surface Plots Quadratic

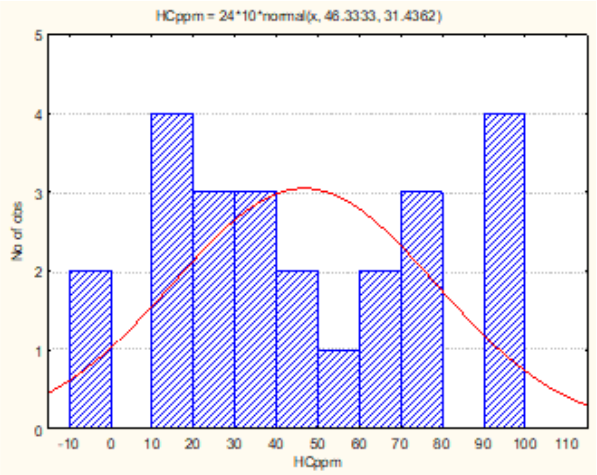

Fig. 1. Hydrocarbons per million volumes

Figure 1 shows the amount of HCppm in the exhaust gases. As can be seen, 4 of the 24 measurements have values between 10-20 ppm, and another 4 have values between 90-100 ppm, 2 have the minimum values between -10-0 ppm, and the others taking values between 20-80 ppm.

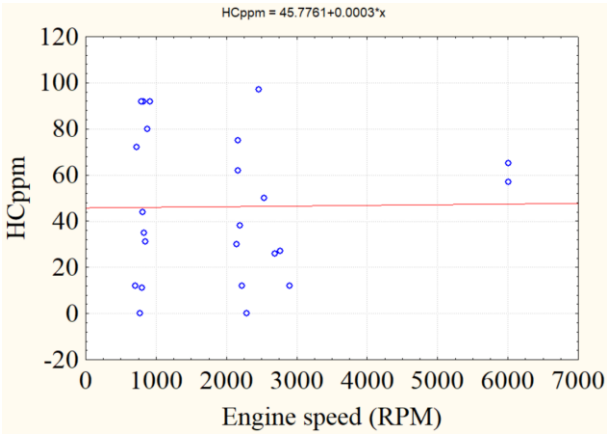

Fig. 2. HCppm depending on speed

Figure 2 shows HCppm as a function of engine speed. As can be seen, HCppm has a value between 0-100 when the engine is idling. At an engine speed between 2000-3000 rpm, the HCppm values do not change, and at a speed of 6000 rpm, the HCppm value is between 50-70.

Figure 3 shows HCppm as a function of engine temperature. As can be seen, HCppm has a value between 0-20 at an engine temperature between 45-50^{0}C. HCppm takes different values between 0-100 depending on the engine temperature between 55-90^{0}C.

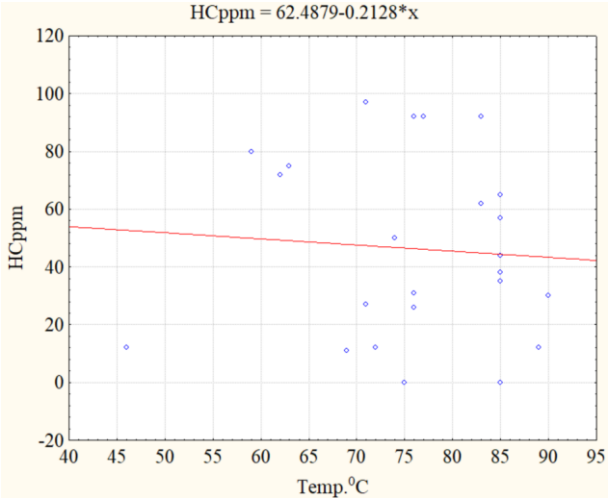

Fig. 3. HCppm depending on temperature

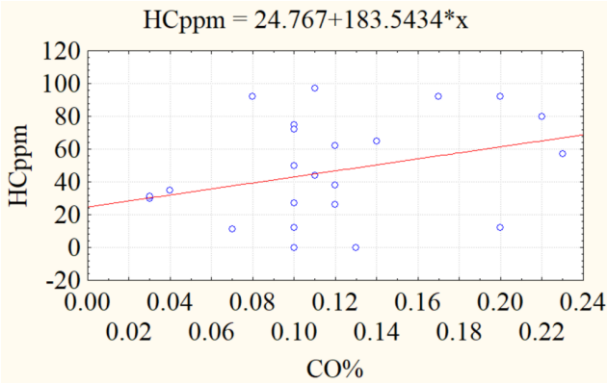

Fig. 4. HCppm as a function of carbon monoxide

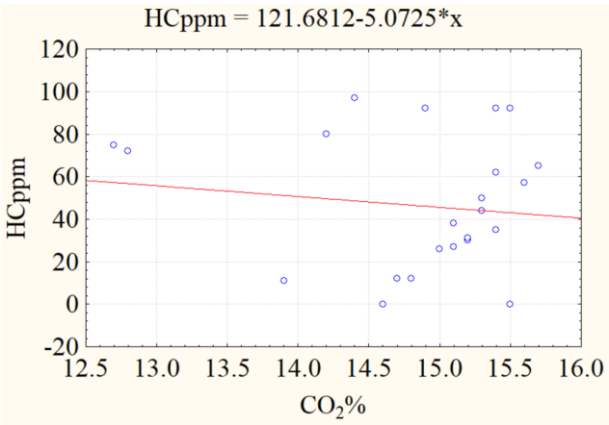

Fig. 5. HCppm as a function of carbon dioxide

Figure 4 shows HCppm as a function of carbon monoxide. As can be seen, HCppm takes values between 0-one hundred depending on the amount of carbon monoxide between 0.02-0.24%. Most HCppm values are between 0.08-0.14% of carbon monoxide.

Figure 5 shows HCppm as a function of carbon dioxide. As can be seen, HCppm takes values between 60-80 at a carbon dioxide amount between 12.5-13%. At carbon dioxide values between 13.5-16%, HCppm values are between 0-100.

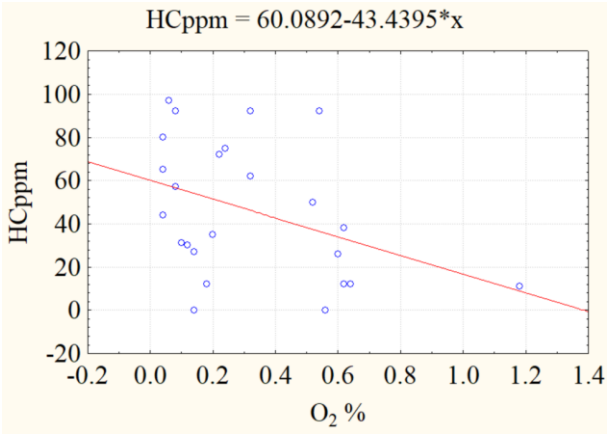

Fig. 6. HCppm depending on oxygen

Figure 6 shows HCppm as a function of oxygen. As can be seen, HCppm takes values between 0-20 at an amount of oxygen between 1-1.2% At oxygen values between 0-0.7%, the values of HCppm are between 0-one hundred.

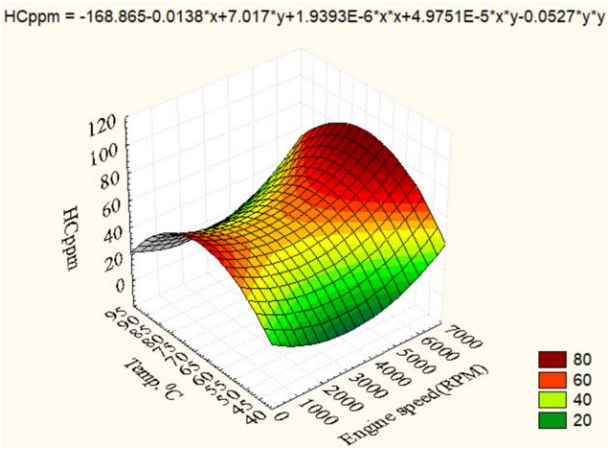

Fig. 7. HCppm depending on speed and temperature

In figure 7 the objective function HCppm is influenced by speed and temperature. An increase of HCppm to 80-ppm can be observed with the increase of engine speed and a temperature of 70-75^{0}C. The lowest value of the HCppm is 20ppm at an engine temperature between 45-50^{0}C and with increasing speed. At the normal engine operating temperature of 900C, the HCppm takes the value of 20 ppm.

In figure 8 the objective function HCppm is influenced by the temperature and the amount of carbon monoxide. An increase of the HCppm to 100 ppm can be observed with the increase of the amount of carbon monoxide to 0.24% and a temperature of 70-75^{0}C. The lowest value of the HCppm is -80ppm at an engine temperature between 45-50^{0}C with the decrease in the amount of carbon monoxide between 0-0.02%.

In figure 9 the objective function HCppm is influenced by the speed and the amount of carbon monoxide. An increase in HCppm to 180 ppm can be observed with the increase in engine speed and the decrease in the amount of carbon monoxide between 0.04-0.06%. The lowest value of HCppm is 40ppm at idle engine speed and when carbon monoxide drops to 0.02%. With the increase of carbon monoxide to 0.24% and at an idle engine speed, the amount of HCppm is found at 120 ppm.

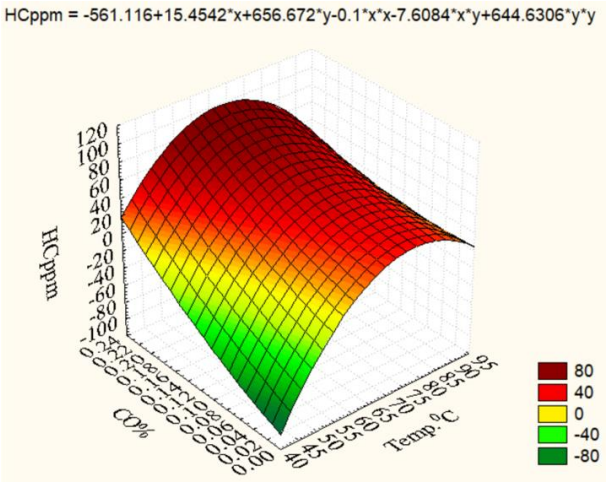

Fig. 8. HCppm depending on temperature and carbon monoxide

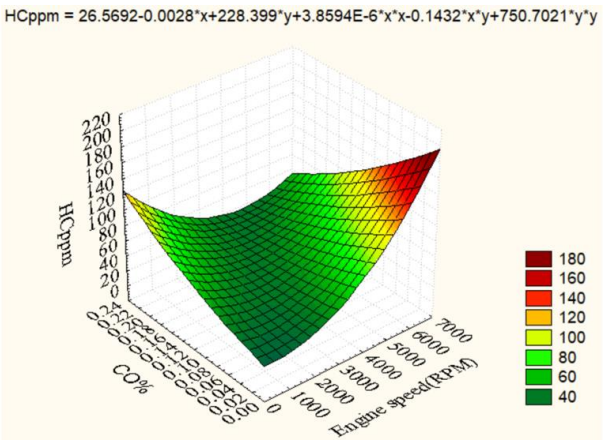

Fig. 9. HCppm depending on speed and carbon monoxide

5 CONCLUSIONS

Considering the presented data, it can be observed that the values of the objective function HCppm change their parameters depending on the values of the influence functions (speed, temperature, CO, CO_2, O_2, CO_{corr}). According to European standards, vehicles equipped with EURO 2, 3, 4 and 5 pollution standards have a maximum value of 100 ppm. According to the graphs in this paper, the values of this HCppm objective function are between -10-100, oscillating due to the influence functions.

The device used to measure the noxes is the gas analyser model VLT 4588. The device is used to analyse the exhaust gases of gasoline engines using the infrared method. The CO/CO_2/HC values in the exhaust gases are monitored. It is also important to measure oxygen content (O_2) and lambda factor values in vehicles equipped with catalytic converters and lambda probes. By burning fuel by automobiles, exhaust gases

are emitted into the atmosphere. Their composition consists of carbon monoxide, carbon dioxide, hydrocarbons, and other organic compounds.

The objective function HCppm as a function of speed does not change the amounts of hydrocarbons, it only changes their grouping, when the engine is idling the hydrocarbons are more grouped, and at speed they are more scattered. According to the graph in which the objective function is HCppm, and as influence functions temperature and carbon monoxide, we noticed that HCppm takes high values when influencing factors have high values.

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