The water vapor influence in gas emissions in a four stroke diesel engine

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Abstract: - In nowadays there are an increased number of cars and vehicles, which run on gasoline or diesel fuel. As a result of this is the production of air pollution. There are several many types of air pollutant. These include smog, acid rain, the greenhouse effect and holes in the ozone layer. Some of these pollutants can be created by human activities, such as cooking, smoking, car emissions, smokestacks and other industrial inputs into the atmosphere and other by atmospheric conditions, such as the wind and rain. This work examines the effect of water vapour in gas emissions in Diesel engine. It includes the background and the calculation of an adequate supply of water vapour in the exhaust pipe, the operating principles of the Diesel engine, nozzles and the basic principles of spraying. It also includes the process of setting up the experimental setup and the execution of our experiments. Finally the diagrams that derived from the experimental measurements of the quantities of air pollutants, with water vapour and without, are presented, and their description, their analysis, general conclusions and our suggestions for further investigation.

Key-Words: - Gas emissions, Diesel engine, Water vapour injection.

I. INTRODUCTION

The atmospheric conditions such as the wind, rain, stability affect the transportation of the air pollutant. Furthermore, depending on the geographical location temperature, wind and weather factors, pollution is dispersed differently. For instance, the wind and rain may effectively dilute pollution to relatively safe concentrations despite a fairly high rate of emissions. In contrast when atmospheric conditions are stable relatively low emissions can cause buildup of pollution to hazardous levels. While the climatic conditions change continuously, it was taken measures worldwide for the reduction of pollutant substances that emanates from the engines of internal consumption. For many years the continuous pollution of atmosphere from damaging particles that are owed in the first place in transports has led to the phenomenon of greenhouse. For this reason, European Union has taken binding decisions on the countries-member regarding to the emissions of gases of greenhouse. The exhausts that are produced by a Diesel machine are NO, CO, HC and smoke as well. NO, CO and uninflammable hydrocarbons HC, are dangerously for the environment while the smoke is dangerous mainly for the human health [1,2]. The first pollutant that it was measured in the automobile industry in the decade of 1970 is CO. It combines with oxygen in the atmosphere and forms dioxide of coal (CO_2). Despite the fact that CO_2 is not toxic, it becomes harmful for the atmosphere when it meets bigger concentrations than regular. When the quantity of dioxide of coal that exists in the atmosphere is bigger than it should be, then plants cannot absorb it and change it to oxygen [3,4]. As a result, the balance of nature is disturbed, leading to the "phenomenon of greenhouse", which is a complicated process by which the earth is becoming progressively warmer. Gases like carbon dioxide, methane, ozone and other gases build up in the atmosphere and absorb that heat that used to reflect out into space. Also the monoxide of coal (CO) causes the death as it is colourless, odourless, tasteless, that binds the hemoglobin of blood and thus prevents the transport of blood in the webs. The monoxides of nitrogen (NO) acting catalytic via a line of photochemical reactions contribute in the production of ozone in the low layers of atmosphere.

$$NO + O_3 \rightarrow NO_2 + O_2$$

$$NO_2 + O \rightarrow NO + O_2$$

Besides the photochemical smog, it causes the acid rain as well. The uninflammable hydrocarbons (HC) contribute to a great degree in the form of ozone, which it constitutes the main source of photochemical smog. Hydrocarbons are emitted to the atmosphere from the incomplete combustion of the fuels and also from the evaporation of the fuels. Some hydrocarbons such as benzene and butadiene are toxic and can cause cancer to humans. Finally smoke is in the general category of air pollutant transfer and thus it is considered dangerous in the lungs and generally in human health, mainly when molecules are less than five micrometers in diameter. Under these circumstances molecules are not filtered from the respiratory system [5,6,7,8,9,10,11].

At this paper is examined how the water vapors effects the gas emissions (smoke, CO, HC, NO) in a four stroke diesel engine.

II. INSTRUMENTATION AND EXPERIMENTAL RESULTS

For the tests used four-stroke air cooled diesel engine, with one cylinder, named Ruggerini type RD-80, volume 377cc with one cylinder and max power 8.2hp/3000rpm. The engine was connected with a centrifugal water pump.

The engine functioned under different rounds and conditions. Spraying of water made by injector (beck) which it was connected with a pump. During the measurements it was recorded apart from the content of exhaust in smoke, CO, HC, NO, and the water supply, the consumption of fuel, the gas emissions temperature in the exit of evaporation before and afterwards the injector of spraying of water.

During the experiments, it has been measured, the %,CO the HC(ppm), the NO(ppm), the % smoke, the water supply, the fuel consumption, the gas emissions temperatures (evaporation before and afterwards the injector of spraying of water) and the rounds of engine. The measurement of rounds/min of the engine was made by a portable tachometer (Digital photo/contact tachometer) named LTLutron DT-2236. Smoke was measured by a specifically measurement device named SMOKE MODULE EXHAUST GAS ANALYZER MOD 9010/M, which has been connected to a PC unit. The CO and HC emissions have been measured by HORIBA Analyzer MEXA-324 GE. The NO emissions were measured by a Single gas analyzer SGA92-NO. The experimental layout appears in the following figures:

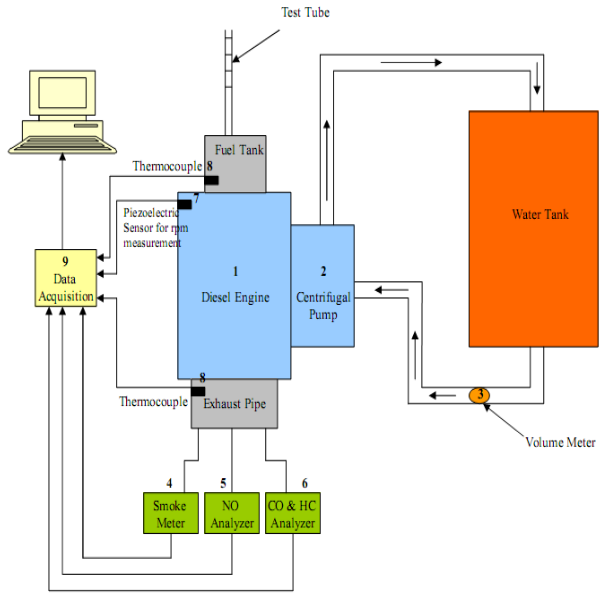

Figure 1. Experimental layout

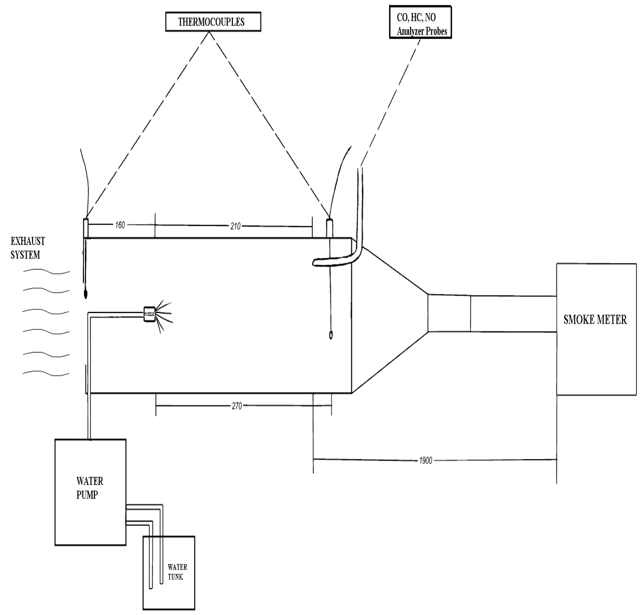

Figure 2. Layout of exhaust with the injector (beck) internal.

The main aim of the measurements was to find out the effects of water vapors in the gas emissions. Initially, we made measurements without spraying of water and then with simultaneous spraying of water, in order to compare the results.

In both cases the measurements were made under 1000, 1500, 2000, 2500 rpm and then without interrupting the operation of engine were continued descending on 2000, 1500, 1000 rpm. In every round we stopped for 3 minutes and afterwards we continued in the next round.

Simultaneously we made measurements of water supply in the diesel engine and the consumption of diesel. When the measurement of spraying of water finished, we reduced to zero the meters and then followed the measurements without spraying. During the whole experiment the spraying of water was made by 4 bar pressure. It can be noticed that the water supply was 1.15 lit/h. It is bigger enough from the supply that we calculated that it needs for the maintenance of gas emissions temperature over 100^{o}C, particularly for the lower rounds of engine.

With this particular supply on 1000 and 1500 rpm we will not have full water vaporization, as part of it will remain liquid. It is possible that on 2000 and 2500 rpm will potentially become better mixture of water and gas emissions, as will become water vaporization completely.

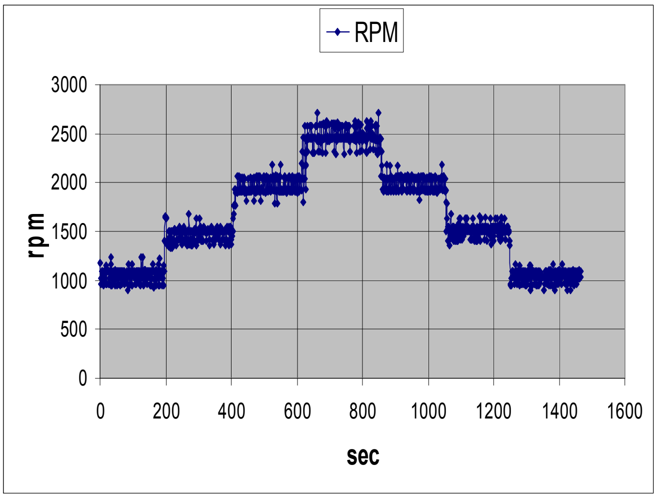

Figure 3. The rpm variation

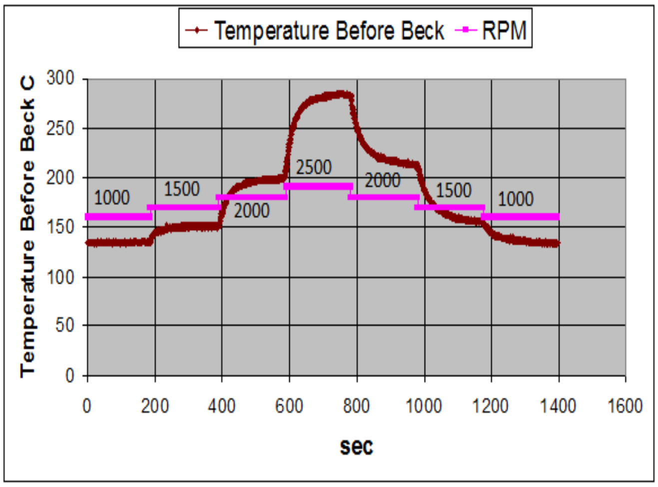

Figure 4. Gas emissions temperature before beck, without spraying of water, in relation to time in seconds and rounds in rpm.

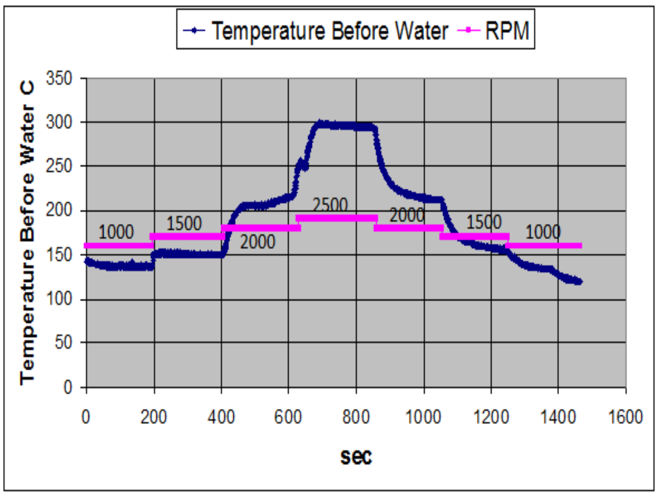

Figure 5. Gas emissions temperature before beck, with spraying of water, in relation to time in seconds and rounds in rpm.

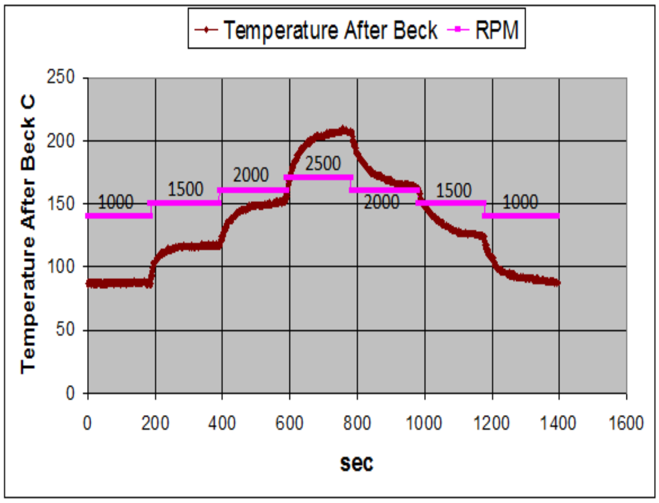

Figure 6. Gas emissions temperature after beck, without spraying of water, in relation to time in seconds and rounds in rpm.

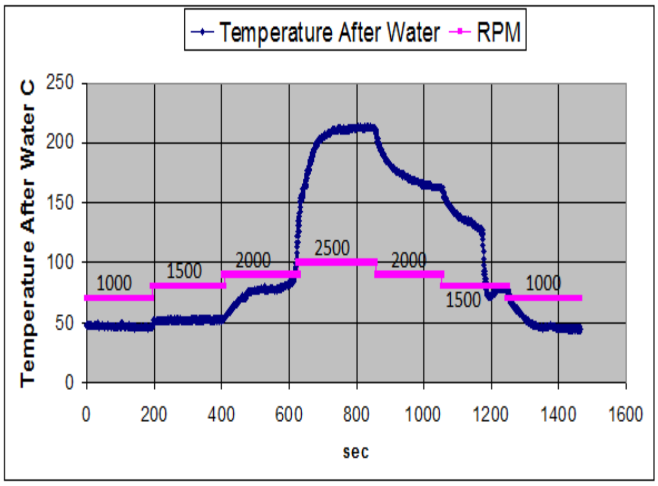

Figure 7. Gas emissions temperature after beck, after spraying of water, in relation to time in seconds and rounds in rpm.

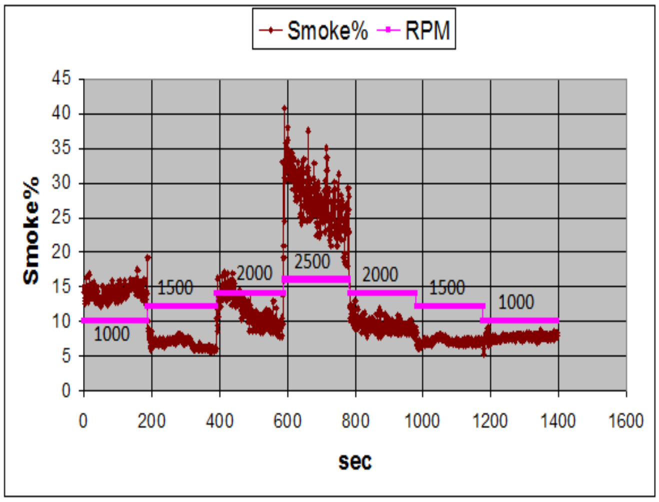

Figure 8. The percentage (%) of smoke emissions, without spraying of water, in relation to time in seconds and rounds in rpm.

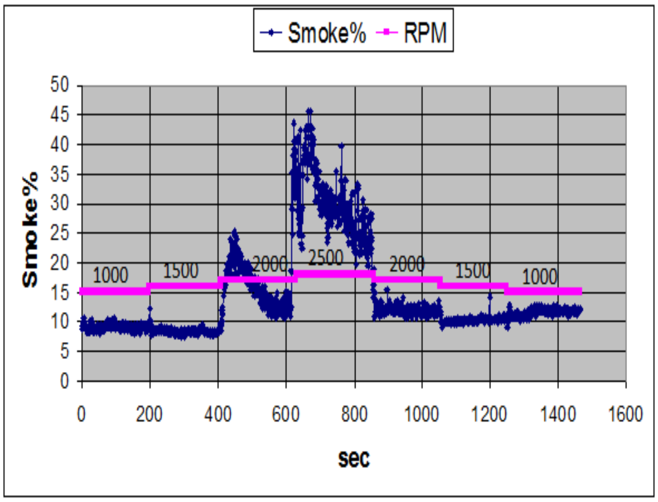

Figure 9. The percentage (%) of smoke emissions, with spraying of water, in relation to time in seconds and rounds in rpm.

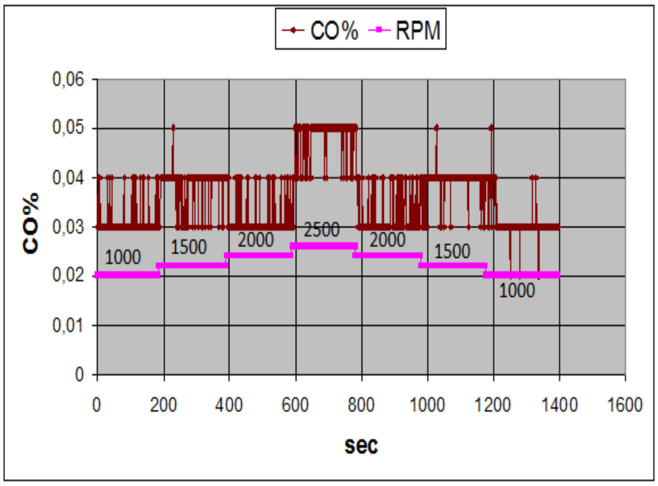

Figure 10. The percentage (%) of CO emissions, without spraying of water, in relation to time in seconds and rounds in rpm.

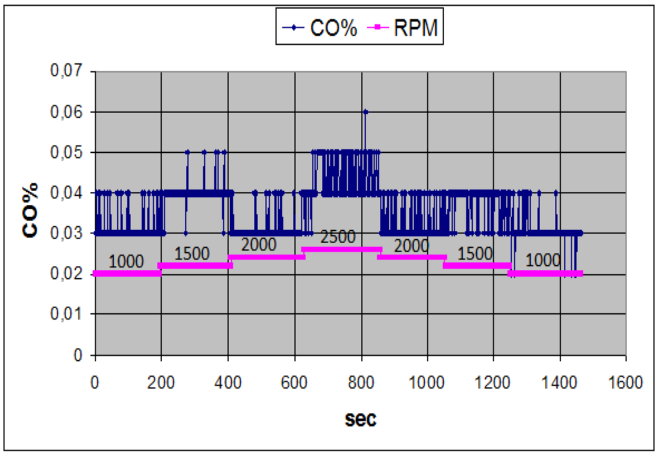

Figure 11. The percentage (%) of CO emissions, after spraying of water, in relation to time in seconds and rounds in rpm.

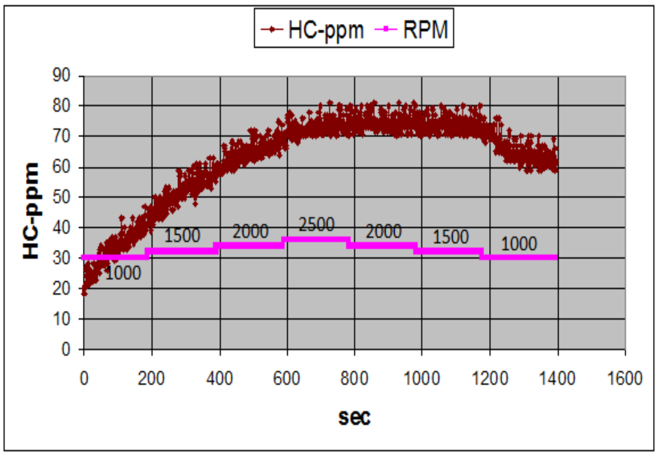

Figure 12. The HC-ppm of gas emissions without spraying of water in relation to time in seconds and rounds in rpm.

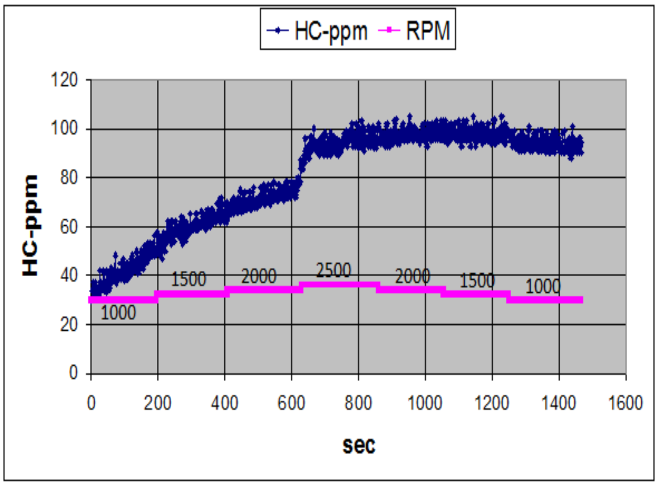

Figure 13. The HC-ppm of gas emissions with spraying of water in relation to time in seconds and rounds in rpm.

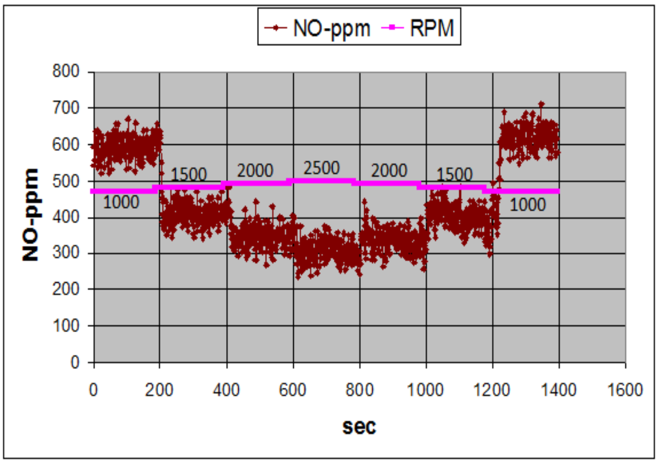

Figure 14. The NO-ppm of gas emissions without spraying of water in relation to time in seconds and rounds in rpm.

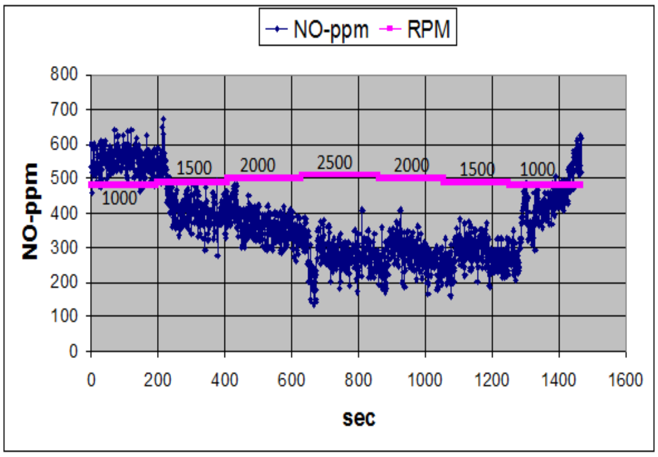

Figure 15. The NO-ppm of gas emissions with spraying of water in relation to time in seconds and rounds in rpm.

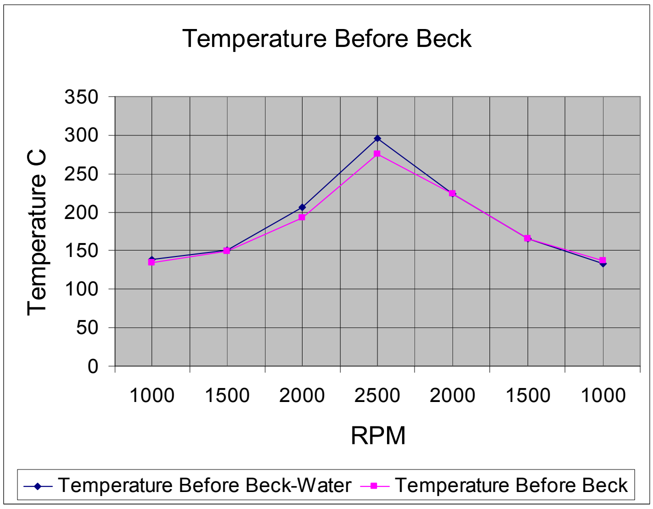

Figure 16. The average mean value of gas emissions temperature before injector (beck) with and without spraying of water, in relation to rounds in rpm.

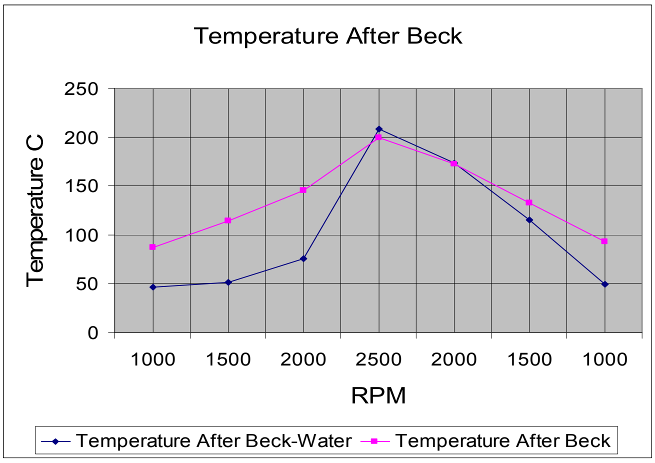

Figure 17. The average mean value of gas emissions temperature after injector (beck) with and without spraying of water, in relation to rounds in rpm.

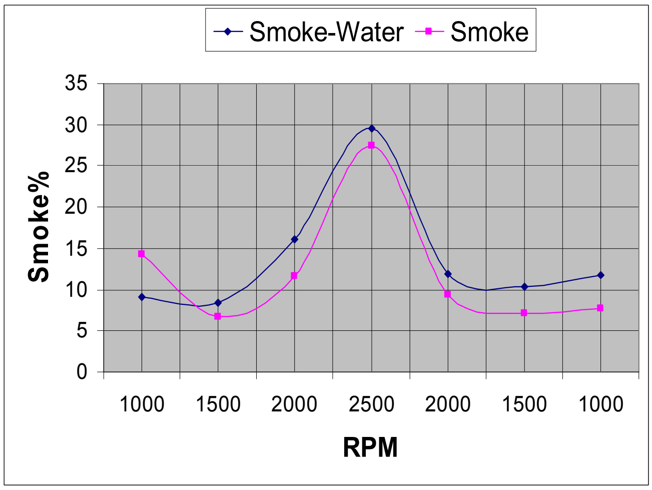

Figure 18. The average mean value of smoke % emissions with and without spraying of water, in relation to rounds in rpm.

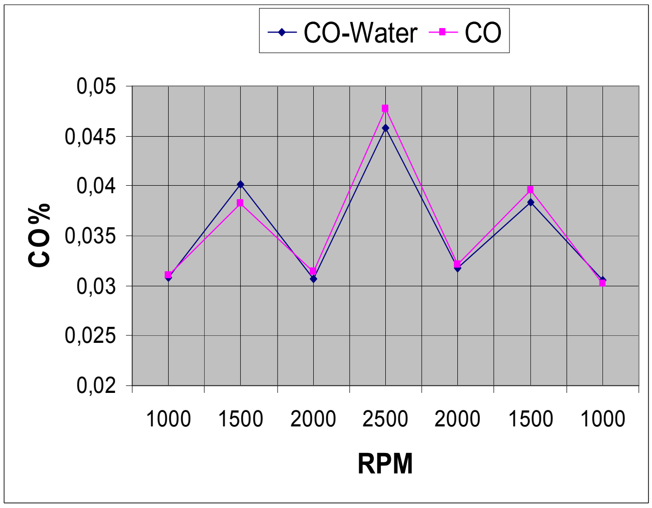

Figure 19. The average mean value of CO % emissions with and without spraying of water, in relation to rounds in rpm.

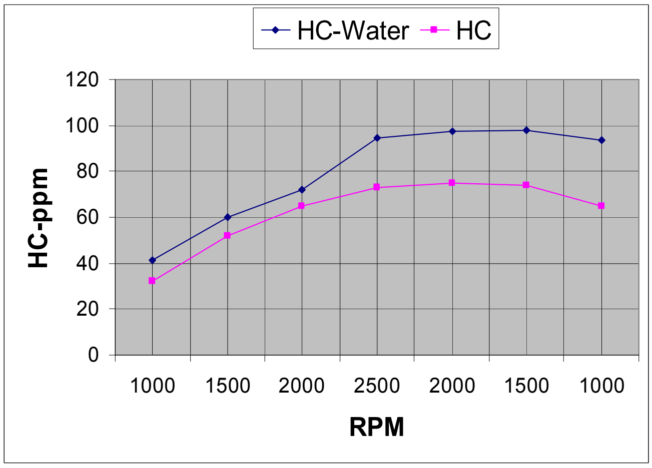

Figure 20. The average mean value of HC-ppm emissions with and without spraying of water, in relation to rounds in rpm.

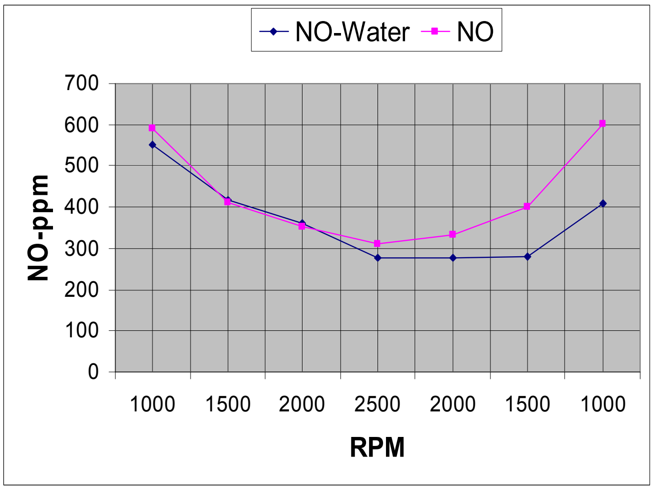

Figure 21. The average mean value of NO-ppm emissions with and without spraying of water, in relation to rounds in rpm.

From figure 4, it can be noticed that the gas emissions temperature before beck and without spraying of water at 1000rpm is 140^{o}C, then at 1500rpm is increased at 150 ^{o}C. As the rounds increase at 1500 and 2500rpm, the temperature is increased progressively at 200^{o}C and 290^{o}C respectively. While the experiment is continued, the engine rounds are decreased at 2000, 1500 and 1000 rpm, the temperature is decreased progressively and falls again at 150 ^{o}C.

In figure 5, it can be seen that the gas emissions temperature before beck and with spraying of water at 1000 rounds is round to 140 ^{o}C, then at 1500 rpm increases to 150 ^{o}C and as engine rounds increase to 1500 and 2500rpm the temperature is increased progressively at 210^{o}C and 300 ^{o}C respectively. While the experiment is continued, the engine rounds are decreased at 2000, 1500 and 1000 rpm, the temperature is decreased progressively and falls at 120 ^{o}C.

In figure 6, it appears that the gas emissions temperature after the beck and without spraying of water at 1000rpm is 90^{o}C, then at 1500rpm is increased to 120^{o}C and as the rounds increase to 1500 and 2500rpm, the temperature is increased progressively at 150^{o}C and 210^{o}C respectively. While the engine rounds are decreased at 2000, 1500 and 1000rpm, the temperature is decreased progressively and falls again at 90^{o}C.

In the following figure, it seems that the gas emissions temperature after the beck with spraying of water, at 1000rpm is 50^{o}C, then at 1500rpm is increased to 55^{o}C and as the rounds increase to 1500 and 2500rpm, the temperature is increased progressively at 75^{o}C and 210^{o}C respectively. While the engine rounds are decreased at 2000, 1500 and 1000rpm, the temperature is decreased progressively and falls again at 50^{o}C. The sudden increase of temperature after 2000 rpm is due to the fact that the water supply is 4 bar, lower from the supply that we needed in order to keep the temperature near to 100^{o}C. However, we didn't increase the water supply at 2500rpm because we wanted to keep the same conditions in all engine rounds during the experiment.

In figure 8, it can be seen that the percentage of smoke in gas emissions without spraying of water at 1000 rpm is near to 15%, then at 1500rpm decreases to 6% - 7%, at 2000rpm increases to 10% - 15%, at 2500rpm increases to 25% - 35% and then at 2000rpm decreases to 9% - 10% and at 1500 and 1000rpm is near to 7% - 8%.

At figure 9, the percentage of smoke in gas emissions with spraying of water, at 1000rpm is near to 10%, then at 1500rpm decrease to 9%, at 2000rpm sudden increase to 25% and gradual decrease near to 10%. At 2500 rpm increase to 44% and fall to 25% - 30% and then again at 2000rpm fall to 12% - 13% and at 1500 and 1000rpm is round to 11% - 12%.

In figure 10, the percentage of CO in gas emissions without spraying of water at 1000, 1500, 2000rpm is between 0.03% and 0.04%. At 2500rpm the percentage of CO vary from 0.04% to 0.05%.

In figure 11, the percentage of CO in gas emissions with spraying of water, vary from 0.03% to 0.04% at 1000 rpm. At 1500 rpm the percentage of CO is 0.04%, at 2000 rpm is 0.03% - 0.04%, but at 2500rpm the percentage increases to 0.04% - 0.05%. Afterwards, at 2000 and 1500rpm the percentage is between 0.03% - 0.04% and finally at 1000rpm it is mainly at 0.03%.

In figure 12, it can be seen the HC content in gas emissions without spraying of water. It can be noticed that there is a gradual of HC content while the number of engine rounds is increased. Thus in the 1000 rpm the content begins at 20ppm and reaches at 40ppm. At 1500rpm increases to 60ppm, at 2000rpm increases to 70ppm and at 2500rpm increases to 75ppm where it stables until 1500rpm and then decreases to 65ppm at 1000rpm.

In figure 13, it is observed that there is a gradual increase of HC in gas emissions while the rounds of engine are increased, when spraying of water. Specifically, at 1000rpm the content of HC in gas emissions starts at 30ppm and goes to 55ppm. At 1500ppm increases to 68ppm, at 2000rpm goes up to 78ppm and at 2500 rpm it abruptly goes up to 100ppm in where it is constant until 1500rpm. Finally at 1000rpm drops to 95ppm.

From figure 14 it can be seen that the content of NO emissions without spraying of water at 1000rpm is 550ppm – 600ppm, at 1500rpm goes down to 400ppm, at 2000rpm goes even more down to 350ppm and at 2500rpm reaches to 300ppm. At 2000rpm the content of NO remains to 300ppm, at 1500rpm increases to 400ppm and finally at 1000rpm goes up to 610ppm. While the number of engine rounds is increased the content of NO is decreased.

In figure 15, it appears that the content of NO emissions when we spraying of water at 1000rpm is round to 550ppm, at 1500rpm goes down to 400ppm, at 2000rpm goes even lower to 350ppm, at 2500rpm drops to 250ppm – 300ppm. Then at 2000rpm the content of NO is still near to 250ppm – 300ppm as well as it is at 1500rpm and finally at 1000rpm goes up progressively to 550ppm – 600ppm. It can be said that when spraying of water the content of NO is decreased while the number of engine rounds is increased.

In figure 16, it can be seen that temperature in both experiments (with and without spraying of water) is increased progressively from 140 C^o at 1000rpm up to 270^{o}C at 2500rpm for the experiment without spraying of water and up to 290^{o}C - 300^{o}C for the experiment with spraying of water. Then in both experiments the temperature fell progressively once again to 140^{o}C at 1000rpm.

From figure 17, it can be concluded that the temperature after beck goes up progressively. At 2000rpm the temperature in the experiment with spraying of water is lower than the one without spraying of water. After 1500rpm the temperature difference exceeds 50^oC and maintains until the end of 2000rpm, in where both temperatures goes up and equate to 200^oC at 2500rpm. Then both temperatures fall progressively and mainly the temperature in the experiment with spraying of water is lower regarding to the other one without spraying of water. In the end of the experiment their difference reaches once again 50^oC at 1000rpm.

In figure 18, the percentage of smoke in 1000rpm is higher than in 1500rpm for both experiments (with and without spraying of water). In the experiment with spraying of water the percentage of smoke is lower than the one without spraying of water. As the number of engine rounds increases, the percentage of smoke in gas emissions is increased progressively up to 30% in case of spraying of water and up to 27% without spraying of water at 2500rpm. Then as the number of engine rounds is decreased, the percentage of smoke is decreased as well. Concluding, it can be mentioned that the percentage of smoke in gas emissions is higher in the experiment with spraying of water than this without water, with the exception of 1000rpm.

In figure 19, it appears that the percentage of CO in all rounds is almost the same for both experiments (with and without spraying of water). It is remarkable the fact that the percentage of CO is near to 0.03% at 1000rpm, then it goes up to 0.04% at 1500rpm, then goes down to 0.03% at 2000rpm and again goes up to 0.045% at 2500rpm. At 2000rpm goes down to 0.03%, then it goes up to 0.04% at 1500rpm and finally goes down to 0.03% at 1000rpm. Summarizing, it can be said that spraying of water has no influence in the percentage of CO in gas emissions.

In figure 20, the HC content in gas emissions increases progressively as the number of engine rounds is increased and time passes as well. Also it has been observed that HC content in gas emissions in the experiment with water is higher than the one without water. As the number of engine rounds is increased, the difference of HC content in gas emissions in both experiments is increased as well. From 1000rpm till 2000rpm the difference is near to 3 – 4ppm and at 2500rpm the difference goes up to 20ppm, in where it remains till the end of the experiment.

Finally, in figure 21 it is observed that NO content in gas emissions decreases as the number of engine rounds is increased, by reaching the minimal value in 2500rpm. Then it goes up as engine rounds goes down. Initially there was no big difference of NO content in gas emissions among the two experiments (with and without spraying of water). However, after 2500rpm there is a difference of 20ppm, which it goes up during the experiment and reaches 200ppm at 1000rpm. At the end of the experiment, it has been noticed that NO content in gas emissions is lower in the case of the experiment with spraying of water.

III.CONCLUSION

By taking into consideration all the above, it can be understood that water vapor affects gas emissions. Specifically affects the following[12]:

- Gas emission temperatures after spraying of water have big difference specifically on lower engine rounds, in where temperature might be over $50\,C^o$ lower regarding to gas emissions temperature without spraying of water.
- Smoke percentage goes down only at 1000rpm in case of spraying of water regarding to smoke percentage without spraying of water. But in all other engine rounds the percentage is increased.
- As it can be seen from figures 10 & 11, there is no significant difference among diagrams regarding to the percentage of CO before and after spraying of water. Therefore it can be assumed that spraying of water does not influence CO percentage.
- After spraying of water, HC content in gas emissions has been increased in all rpm
- NO content in gas emissions is lower in case of spraying of water regarding to the one without spraying of water. This difference is bigger when the engine loads at higher rpm.
- The consumption of fuel remains stable during the experiment of spraying of water in relation to the one without spraying of water.

REFERENCES:

[1] Aldritton D. L., Monastersky R., Eddy J. A Hall J. M. , and Shea E. (1992) Our Ozone Shield Reports to the Nation on Our Changing Planet. Fall 1992. University Cooperation for Atmospheric research office for interdisciplinary studies Boulder, Colorado.

[2] Keith Owen and Trevor Coley "Automotive Fuels Reference Book" Second Edition, Published by SAE, 1995.

[3] Faeth G.M., Hsiang L.-P., Wu P.-K., “Structure and Breakup Properties of Sprays”, International Journal of Multiphase Flow, Vol. 21, Suppl., 1995

[4] Gelfand B.E., “Droplet Breakup Phenomena in Flows with Velocity Lag”, Prog. Energy Combust. Sci., vol. 22, pp. 201-265, 1996

[5] Gelfand B.E., “Droplet Breakup Phenomena in Flows with Velocity Lag”, *Prog. Energy Combust. Sci*., vol. 22, pp. 201-265, 1996

[6] Hsiang L.-P., Faeth G.M., “Drop Properties after Secondary Breakup, Int. J. Multiphase Flow”, Vol. 19, No. 5, pp. 721-735, 1993

[7] Tanner F.X., “Development and Validation of a Cascade Atomization and Drop Breakup Model for High-Velocity Dense Sprays”, Atomization and Sprays, Vol. 14, No. 3, 2004

[8] Pollution Science Edited by Ian L. Pepper, Charls P.

Gerba, Mark L. Brusseau, 1996

[9] Dust Suppression, Prevention E.M. Okonkwo and O. Ofoegbu, Renewable Eco-Friendly Material for Road Dust Suppression and Prevention, ´´, Proceedings of 2nd WSEAS/IASME International Conference on Renewable Energy Sources(RES'08), Corfu, 2008.

[10] Ognyan Bozhkov, Christina Tzvetkova and Temenuzhka Blagoeva, An Approach to Rhenium Phytorecovery from Soils and Waters in Ore Dressing Regions of Bulgaria, ´´, Proceedings of 2nd WSEAS/IASME International Conference on Renewable Energy Sources(RES'08), Corfu, 2008.

[11] C. Arapatsakos, D. Christoforidis, A. Karkanis, K. Mitroulas, ´´SOY OIL AS FUEL AND ITS ENVIRONMENTAL IMPACT´´, Proceedings of the 6th WSEAS International Conference on Heat Transfer, Thermal Engineering and Environment(THE' 08) Rodos 2008 .

[12] C. Arapatsakos, A. Dratzidis, A. Karkanis, The water vapor effect in the gas emissions, Proceedings of WSEAS International Urban Planning and Transportation Conference, Corfu 2011.