Experimental research regarding the influence of AdBlue solution temperature on internal combustion engines pollutants

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Abstract. The constraints related to the environment, the vehicle's pollution, as well as the increase in the number of the registered vehicles have to lead to the development and implementation of complex systems for the treatment of exhaust gases. The pursued purpose of the given regulations and environment norms has been the decrease of the main pollutants measured at the vehicle's exhaust pipe, that is: the nitrogen oxides, particles, carbon monoxide. This paper presents the experimental research and the results obtained on the influence of the solution AdBlue on the pollution performances – studies that have been achieved at Volvo Romania SRL. Thus, taking into consideration the evolution of the temperature of the reductant from -40°C to +40 °C, there are underlined the performances insured by SCR and the dependency of the pollutants on these temperatures, fulfilling the usual usage measures. The variations recorded for nitrogen oxides (after the catalyzer for catalytic reduction), the reductant consumption and the efficiency of SCRtransformation at different values of the AdBlue solution are being presented using graphic representations.

1. Introduction

The modern commercial vehicles benefit from complex and performant systems for treating the exhaust gases. Besides the optimization solutions of the ignition process, they also have oxidation catalyzers for the reduction of CO, particles filters for diminishing the PM evacuated in the atmosphere, catalytical reduction catalyzers (SCR) and EGR for diminishing NO_x, as well as catalyzers for the reduction of the ammonia excess that comes from the catalytic reduction reactions [1, 2, 3].The proposed experimental studies focus on the analyses of the efficiency of transforming the SCR catalyzer in the way of reducing NO_x by changing the AdBlue's temperature. The complexity of the paper is to maintain all the elements function within the standard usage limits, to ensure the flow of the exhaust gases constant throughout the tests and at the same value for each of the tests.

2. The experimental installation. Equipment description, and the evolution of the experiments

In order to underline the dependency of the efficiency of the transformation reaction of NO_x in the SCR catalyzer in conditions as real as possible, the tests have been achieved on a Volvo truck, model FH(4), produced in 2018, equipped with a 13 liters engines (D13K of 500 HP), figure 1. The truck is Euro6 phase C, being equipped with a recirculation system for exhaust gases (EGR) as well as with a system for further treatment of the exhaust gases that acts mechanically, thermically and chemically on the exhaust pollutant products in the sense of diminishing and neutralizing them.

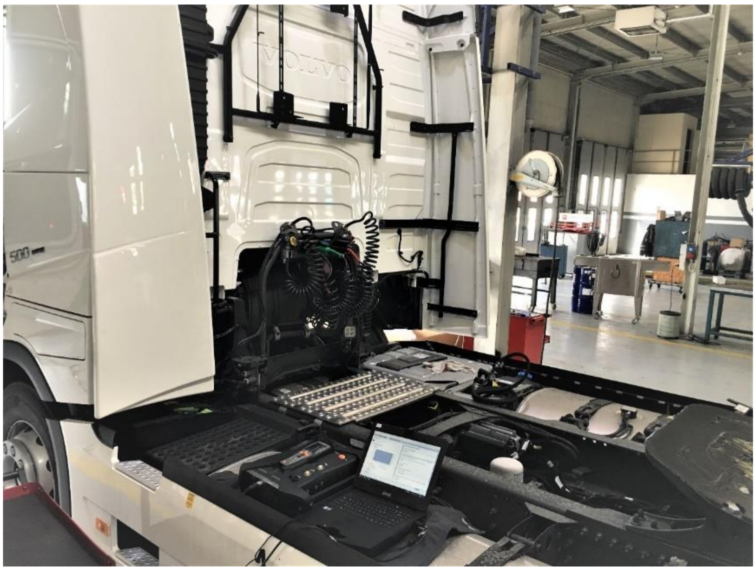

Figure 1. Preparing equipment of the experimental installation.

The experiments have involved the feeding of the SCR system with an AdBlue solution at different temperature, pursuing the performances of the selective reduction catalyzer and the consumption of reductant for each test. The reductant quantity for each test has been measured with a glass graded cylinder, using 200 ml of AdBlue solution. Two measurements have been achieved for each experiment, the first with the initial quantity of 200 ml and the second, after the test, with the remained quantity, in order to determine the consumption.

The quantity of the reductant has been warmed up and cooled down in order to reach the proposed temperature for the tests. For the conclusive results the starting temperature of the reductant was -10 ^{0}C, testing every 5 ^{0}C up to 50 ^{0}C. The chosen interval has been based on the freezing limit of the reductant, which is -11 ^{0}C, respectively 50 ^{0}C to avoid reaching the temperature where the risk of decomposing the AdBlue solution appears [4, 5].

Fueling the installation has been achieved from a thermos-isolated recipient in order to maintain a constant temperature. For each test there were two measurements, before and after, being accepted deviations of maximum 1^{0}C to the proposed value.

To reduce the alteration of the reductant's temperature, the heating system of the truck (SCR) has been eliminated by disconnecting the electrical resistances of the Ad-blue solution admission pipes and by the short of the heating serpentine within the pumping unit. Even more, water at the reductant's temperature has been circulated though the heating serpentine of the pumping unit, thus having a constant temperature of the reductant. For the negative temperatures of the ad-blue solution carbonic ice tampons have been used on the external surface of the pumping unit.

For determining the efficiency of the SCR transformation at different temperatures a test offered by the diagnosis computer Tech Tool has been used, the conversion test NO_x. The advantages of the conversion test NO_x are given by the fact that NO_x has a relative constant value throughout the injection of the reductant (1000-1300ppm), being able to follow up the way in which the dosage is being done, as well as the quantity of reductant and the time passed from the beginning of the injection up to the threshold of 75% for the transformation's efficiency.

For a correct determination of the quantity of consumed reductant for each test, before doing the next test, the SCR catalyser has been cooled up to the functioning temperature. Thus the reductant's injection has been prevented at the start of the engine, before starting the actual transformation NO_x test. Pursuing the thermal state in the exhaustion pipe has been possible with the diagnosis computer TechTool by reading the values measured with the exhaust temperature sensors. The tests have been restarted only when the temperature in the SCR has dropped below 150^{0}C.

The validation of the measurements of reading NO_x at the exit from the catalyzer has been achieved by comparing the information offered by the NO_x sensor and the analyses apparatus for emissions Testo 350, figure 1. Installing the measurement probe has been done by adjusting a visitation window within the evacuation pipe of the truck's exhaust system, the flow of the evacuation gases being on the measurement probe's direction.

3. The analyses and interpretation on the results

The NO_x reduction process and the achievement of the efficiency target of conversion have been done by dosing an initial quantity of reductant, a dosage that has been adjusted according to the quantity of NO_x at the entrance in the catalyzer and the efficiency of transformation, figure 2.

As the quantity of the reductant increases, it can be noticed an acceleration in the transformation's efficiency. The NO_x upstream to the catalyzer is the basic element in choosing the quantity initially dosed, a smaller value of NO_x determining a smaller dosage of reductant and vice versa.

The period of time of the test has been determined by reaching the 75% for the efficiency of the conversion. It has been noticed experimentally that there is a direct link between the quantity of reductant and the period of the test, thus a smaller quantity makes a higher time.

For each of the tests the following have been determined: the reductant's temperature; the reductant's consumption (the difference between the quantity of 200 ml and the quantity measured after the test); the period of time for the test (directly determined from the test's graph); the quantity of treated NO_x (summing up the values given by the NO_x sensor at the entrance of the catalyzer with the time in which it was produced); the maximum limit of reductant for finalizing the transformation. Some NO_x transformation graphs at different temperatures are presented in figures 2 to 4.

If we refere to the maximum quantity of reductant in order to reach the target of transformation for $NO_{x,}$ where we can notice a decrease from 30 ^{0}C. Meanwhile, the time for dosing the maximum quantity of reductant decreases with the increase of its temperature.

The consumption of reductant used to neutralize NO_x decreases with the increase of its temperature. Figure 5, underlines the evolution of the reductant's consumption according to its temperature.

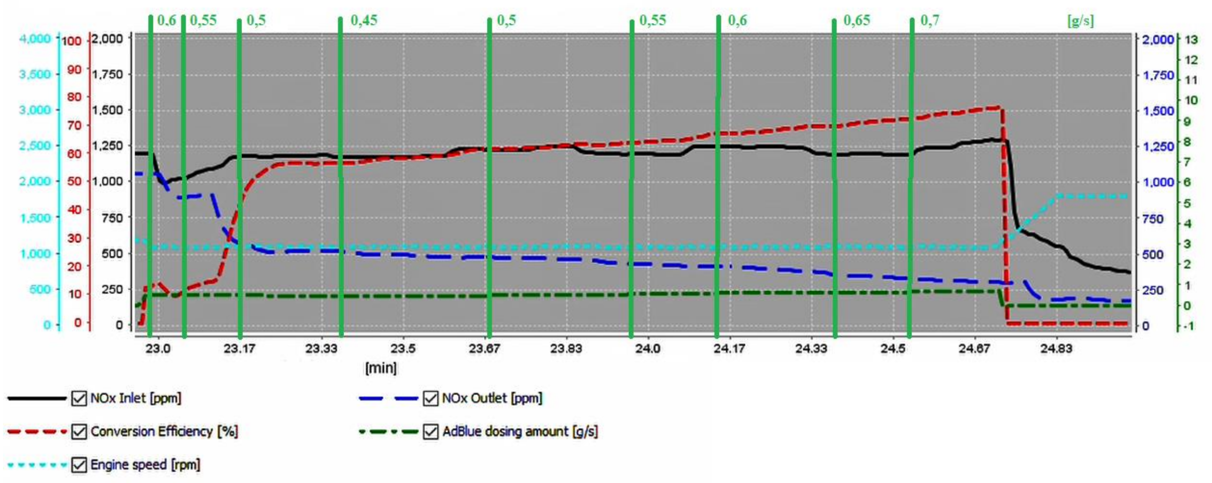

Figure 2. The development of the NO_x reduction process, reductant temperature -10 ^{0}C.

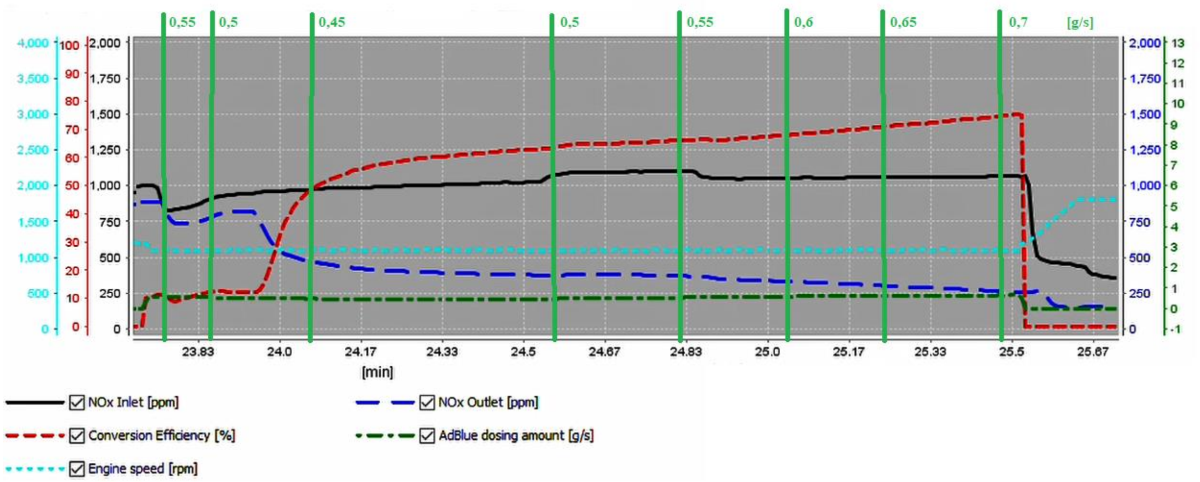

Figure 3. The development of the NO_x reduction process, reductant temperature 25 ^{0}C.

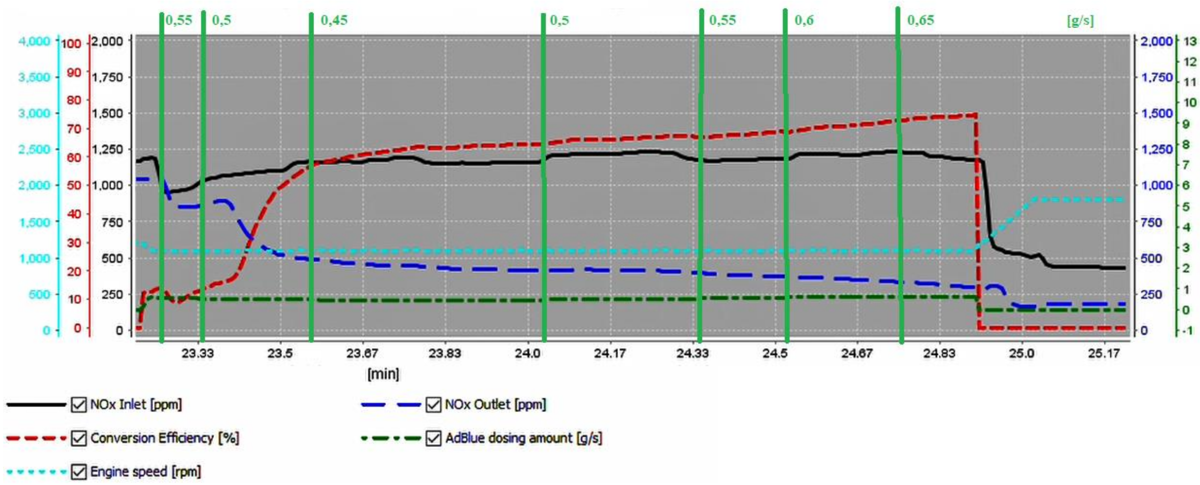

Figure 4. The development of the NO_x reduction process, reductant temperature 45 ^{0}C.

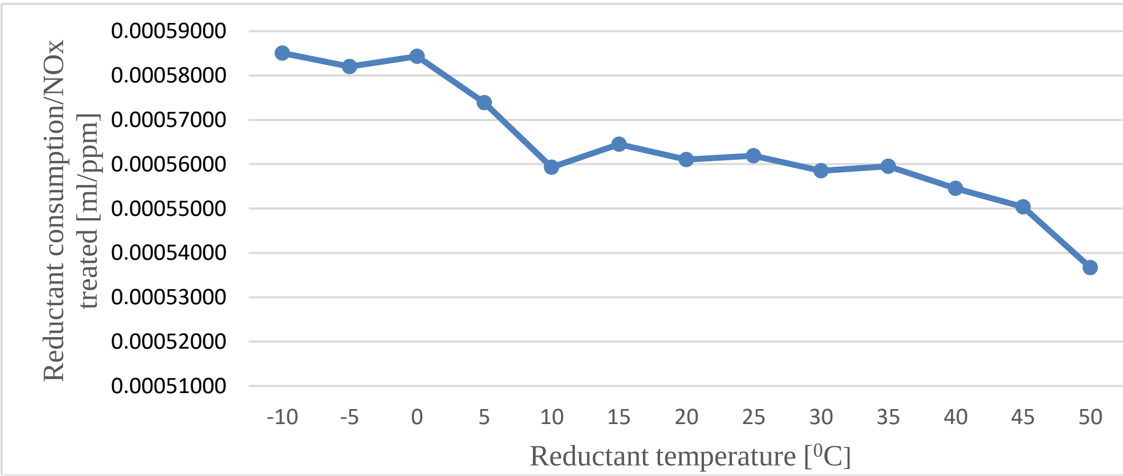

Figure 5. The variation of the reductant's consumption according to its temperature.

It can be noticed a significant decrease of the reductant's consumption between -10 ^{0}C and 10 ^{0}C, respectively 35 ^{0}C and 50 ^{0}C, intervals between which it maintains at a relatively constant value.

For negative temperatures, below 0 ^{0}C, it can be noticed an increase in density of the AdBlue solution, the appearance of solidification cristals being noticeable from -5 ^{0}C. The use of the reductant at these temepratures can deteriorate the SCR system by clogging the line from the tank through the pumping unit up to the injector.

The AdBlue solution, as it resulted from the laboratory determinations, starts to decompose at temperatures higher than 30 ^{0}C. The danger appears in the usage of the reductant at high temperatures if it decomposes before it is injected into the catalyser, thus shuterring its evacuation. The injector's warming up due to the increase of the temeprature of exhaust gases determines the overheating of the reductant, thus blogking it with decomposed solution

4. Conclusions regarding the experimental studies

The experiments have proved, at least for the SCR catalyser copper-zeolite, the existance of a link between the temperature of the reductant when injected into the SCR catalyser and the transformation performances for NO_x reduction. As underlined in figure 5, two lines of sustained reduction of AdBlue solution can be noticed: between -10 ^{0}C and 10 ^{0}C, respectively 35 ^{0}C and 50 ^{0}C. A level-headed reduction is uderlined outside these intervals.

It has been proven experimentally an increased efficiency with the increase of the reductant's temperature, but this is limited by its decomposition level. Even if the results of the transformation reach maximum limits at high temperatures of the reductant, the system's fiability and the protection of the components of the SCR system have to have the precedence.

When choosing the optimum temperature of the reductant, more studies are required related to the heating temperature of the AdBlue injector, respectively the possibility to cool it when overheated.

The minimum temperature at which the SCR copper-zeolite catalyser is able to facilitate the reaction of selective reduction is 190 ^{0}C [6]. The temperatures measured with the sensors from the truck's exhaustion have underlined temperatures between 230-260 ^{0}C at the entrance, after each test. Another interesting subject whould be to determine the optimum temperature of the SCR catalyser for a maximum efficiency of NO_x transformation.

By analyzing the results obtained for low temperatures of the reductant (-10 ^{0}C and 0 ^{0}C) we might say that this interval is also to be avoided, besided from the low performances related to the transformation of NO_x, the major danger being the appearance of solidification crystals and the increase in the solution's density. The sensitive elements of the pumping unit can be affected by this, the result being the blockage of the catalyzer's feeding with reductant and the alteration of NO_x transformation.

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