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INFLUENCE OF OPERATING TEMPERATURE AND FUEL CONSUMPTION ON ADBLUE® CONSUMPTION DURING SOWING OF SILAGE CORN

Galin TIHANOV[1], Galya HRISTOVA[1], Ivan GADZHEV[1], Manol DALLEV[2]

[1]Trakia University, Faculty of Agriculture, Department of Agricultural Engineering, 6000 Stara Zagora, Bulgaria
[2]Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: galin.tihanov@abv.bg

Abstract

The study is based on a Polish experiment (2021) in the territory of the Plovdiv region in the central part of the Republic of Bulgaria. The study was conducted with a nine-meter precision seed drill, aggregated to a 302 kW tractor when sowing silage corn. Using the service diagnostic program, graphic dependences describing the consumption of AdBlue® in relation to the operating temperature and the consumed diesel fuel have been extracted. Factors influencing AdBlue® consumption were monitored: operating temperature, diesel quality, and tractor engine load. It has been found that any drop in temperature, whether influenced by external factors or by the tractor engine, appears to be a determining factor for AdBlue® dosing. The consumption of AdBlue® for 8 hours of working change of the machine-tractor unit was monitored and it was found that the consumed amount of liquid reagent is 37.5% of the entire tank and the consumption of diesel fuel is 68.75%.

***Key words**: sowing unit, silage corn sowing, service diagnostic program, fuel consumption, AdBlue® consumption*

INTRODUCTION

The impact of car traffic on local air quality is a global problem. This requires the industry to focus on improving key technologies in vehicles (cars, tractors, trucks, etc.) and fuels, reducing emissions through traffic management, and seeking improvements through the application of advanced systems and modified emission control software. (Jääskeläinen, 2007; Auld et al., 2017; Laurikko et al., 2020; Komitov, 2020). In recent decades, tighter regulations on exhaust emissions have dominated the automotive industry and encouraged manufacturers to innovate (Giakoumis et al., 2012). They are developing the Selective Catalytic Reduction (SCR) system, which has different names according to the manufacturers: BlueTEC, *AdBlue*, DeNOxtronic, and others. These systems consist of the following main components: a particulate filter, a *NOx* catalytic converter, an engine control unit, and an *AdBlue* fluid reservoir (Frandsen, 2018; Demir et al., 2022). They remove up to 98% of the NOx produced. Fleedguard, 2016 defines SCR as a technology that uses urea-based diesel exhaust fluid (known as *AdBlue* or DEF) and a catalytic converter to significantly reduce nitrogen oxide (*NOx*) emissions. *AdBlue* is the reagent needed for the SCR system to function. *AdBlue* is an aqueous solution of urea with 32.5%, synthetic urea, and 67.5% deionized water. *AdBlue* consumption needs to be about 5% of the consumed diesel fuel (4-6% range depending on the application conditions). With 5% of the diesel consumed, the fuel to *AdBlue* ratio is 20 to 1. With 100 liters of diesel consumed, approximately 5 liters is the expected consumption of *AdBlue*. If the average fuel consumption of the vehicle is known, then *AdBlue* consumption can be easily calculated. A number of authors are looking for solutions to reduce NOx emissions (Str¨om et al., 2009; Liao et al., 2015; Arnaudova et al. 2020; Fontanarosa et al., 2021; Demir et al., 2022). Lambert et al., 2001 performed tests to monitor diesel fuel economy and investigate the efficiency of the (SCR) system at higher exhaust temperatures. In a study by Demir et al., 2022, they examined the effects of commercial *AdBlue*, urea-pure water, and urea-pure water-citric acid mixtures as additives to diesel fuel on exhaust emissions and diesel single-cylinder performance.

MATERIALS AND METHODS

The study was conducted in the spring of 2021 in the Plovdiv region, central Bulgaria. The soil type is leached chernozem resin. The experiments were performed on a field with an area of 108,2 ha shown in Figure 1. The slope of the terrain is 2%.

Figure 1. The experimental field, Plovdiv region, Central Bulgaria

The study was conducted with seed drill for precision sowing *Amazone EDX 9000-TC*, mounted on a *Claas Axion 950* tractor shown in Figure 2. The crop sown in the experimental field is silage corn of Balasco variety with a sowing rate of 6600 *pcs/da*.

Figure 2. Machine-tractor unit consisting of Claas Axion 950 and Amazone EDX 9000-TC

During the operation of the machine-tractor unit, data on the consumption of *AdBlue*® in relation to the operating temperature and fuel consumption were extracted from the service diagnostic program of the tractor. The change of the reagent consumption during sowing at the most optimal speeds of the tractor engine was monitored. Of course, the consumption cannot be indicative of this field, as a number of other factors are affected: outdoor temperature, the movement of the sowing unit in the field, sowing quality, fuel consumption, and many other factors.
To accurately determine the consumption of urea, an individual study was performed for the studied parameter, excluding the influence of other factors during sowing.
In Figura 3 presents the system for reduction of the exhaust gases of the tractor participating in the study with European standard *Tier 4F* (Claas Axion, 2020).

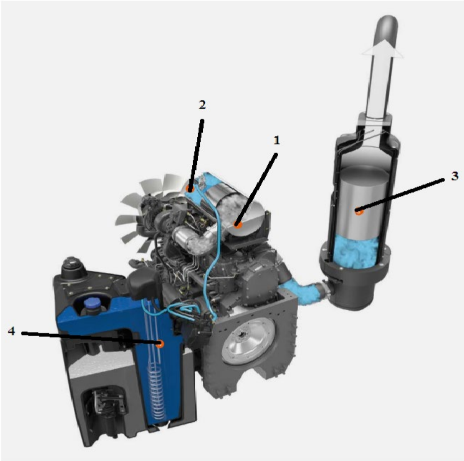

Figure 3. Tractor exhaust reduction system Claas Axion 900 with European standard Tier 4F: 1 - diesel oxidation catalyst (DOC); 2 - injection nozzle for urea; 3 - catalyst (CSR); 4 - heated urea tank

Despite the fact that the exhaust gas reduction systems of tractors work with a very small percentage of defects, farmers accept it with distrust. They define this system as inefficient, and as an additional cost. In the Republic of Bulgaria, the consumption of *AdBlue*® for tractors is more focused on protected machines in Western European countries. This is influenced by some external factors:
The sulfur content of diesel fuel according to European standards is accepted to be S < 15 mg/kg. In Bulgaria, this standard cannot be achieved, as fuels of dubious origin are often used at a lower price.

A sticker showing the sulfur content of diesel fuel is affixed to each new energy machine manufactured in Europe, Figure 4.

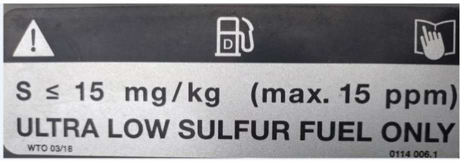

Figure 4. Information on the sulfur content in diesel fuel according to European standard

The content of urea in the aqueous solution for the preparation of the reagent is 32.5%. It is not in vain that it is reflected on all packages that the shelf life after opening is six months, but this is not always observed and is used after this period and the percentage of urea decreases. This in turn leads to less cleaning efficiency.

Another no less important factor is the maintenance and servicing of the system for reduction of exhaust gases from the engine after reaching the service interval.

RESULTS AND DISCUSSIONS

In Figure 5 presents the basic scheme of connecting the diagnostic program to the agricultural machine used in our study. The sequence of signal transmission from the tractor to the diagnostics, which is installed on a laptop, is indicated.

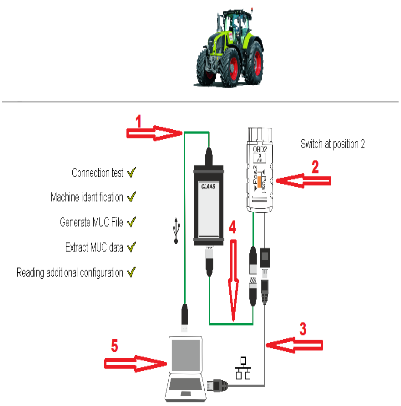

Figure 5. Schematic diagram of connecting the diagnostic program to the drill:
1 - CAN decoder; 2 - OBD socket for connection to the diagnostic terminal of the tractor; 3 - LAN transition; 4 - connecting bridge OBD → CAN; 5 - computer with diagnostic program

The figure shows the sequence of signal transmission from the tractor to the diagnostics, which is installed on the laptop. It recognizes the CAN decoder 1. Once it is recognized, it connects to the agricultural machine via the OBD socket for connection to the diagnostic terminal of the tractor 2 and starts the process of recognizing the ECU from the diagnostic program.

Electronic Calculator Unit/ECU/ as a general concept is an electronic controller, whose function is to monitor changes in the set parameters in its memory.

The information about the monitored parameters from the ECU comes from the sensors and sensors mounted on the components that are set to be monitored and after the corresponding processing information is received about the real-time operation in the form of graphs or numbers.

Any modern agricultural or harvesting machine that is equipped with an ECU can be connected to the service program and be diagnosed, programmed, replace damaged controllers or update the programs in the ECU with newer versions in order to quickly process information or implementation of new parameters.

1. Consumption of *AdBlue*® in relation to the operating temperature

Figure 6 shows graphically the consumption of *AdBlue*® in relation to the operating temperature in real production conditions of the sowing unit. From the data taken from the service diagnostic program, we find that the correctly selected engine speed of the tractor during the technological operation "sowing" affects the uniform consumption of *AdBlue*®.

The abscissa of the graph in Figure 6 shows the time, with each unit of the graph corresponding to a time in seconds. The ordinate of the graph shows the parameters: engine speed and temperature, data for *NOx* nitrogen oxides from the sensors at the input and output of the SCR, ie. before and after treatment with urea, and the amount of urea injected. Each parameter is reflected in the figure with colored lines. A red line shows the set engine speed of the tractor. They are set in the *Cebis* control terminal together with the actual operating speed that we need to maintain. The purple line shows the temperature of the exhaust gases coming from the tractor engine into the SCR, ie. the flue gas treatment area. The orange line shows the data from *NOx* nitrogen oxides and the SCR inlet and outlet sensor before urea treatment, and the green line shows the data after urea treatment. The blue line shows the cost of *AdBlue*® during the operation of the sowing unit.

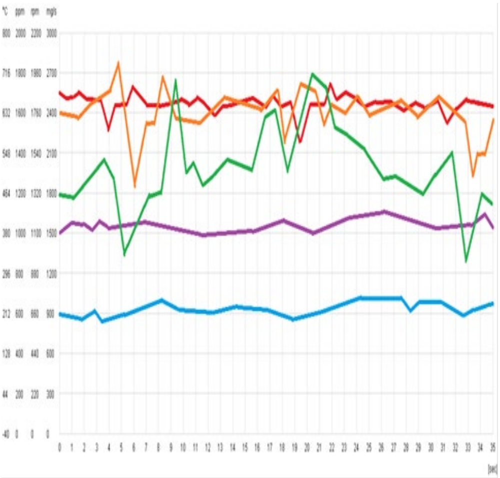

Figure 6. Influence of *AdBlue*® consumption on operating temperature

Figure 6 shows that the smooth operation of the sowing unit maintains a constant consumption of *AdBlue*®. The peak torques of the tractor engine are kept to a minimum.
The values of nitrogen oxides *NOx* at the input and output of *SCR* are a determining factor for the dosing of *AdBlue*® in the system. Although peak periods are observed on the chart, *AdBlue*® dosing remains unchanged. This is due to the period during which the data were collected. It does not affect the overall determination of the reagent dose, but it is determined by an individual algorithm, taking data for a longer cycle of time.
Another parameter shown in Figure 3 is the exhaust gas temperature in the *SCR*. It appears to be the determining factor. The process of flue gas treatment with *AdBlue*® becomes feasible at an optimum temperature of about 3600°*C*. In conclusion, it can be noted that any drop in temperature, regardless of whether it is influenced by external factors or engine performance is the determining factor for dosing.

2. *AdBlue*® fuel consumption versus fuel consumption

Figure 7 graphically presents the consumption of *AdBlue*® compared to the consumption of diesel fuel in real production conditions of the sowing unit.
The abscissa of the graph also shows the time, with each unit of the graph corresponding to a time in seconds. According to the ordinate of the graph, three parameters are presented: tractor engine speed (min^{-1}), diesel fuel consumption (l/h), and *AdBlue*® consumption (mg/s). The red line shows the engine speed of the sowing unit. The green line shows the consumption of diesel fuel, and the blue line shows the consumption of *AdBlue*®.
Diesel fuel consumption is an extremely important indicator of the urea consumption rate. Higher fuel consumption leads to higher temperatures in SCR and more concentrated gases in nitrogen oxides *NOx*. In SCR, nitrogen oxides are converted to water and pure nitrogen by means of the synthetic aqueous urea solution (*AdBlue*®), which is added to the tractor's auxiliary tank.
Despite slight fluctuations in fuel consumption, we note that urea consumption remains almost unchanged. This is due to the correctly selected engine speed of the tractor, the maintenance of a constant actual working speed of the sowing unit, the constant temperature in the SCR, and last but not least the amount of diesel fuel consumed.

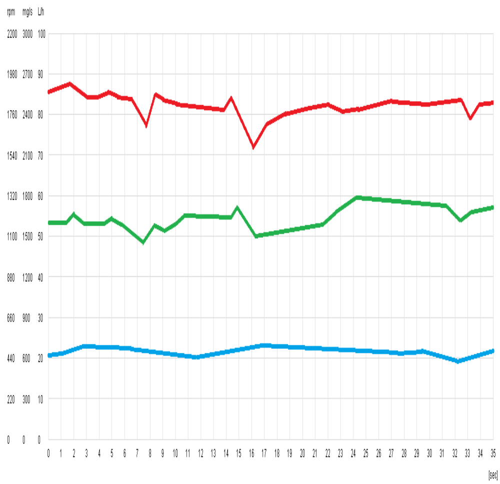

Figure 7. Effect of *AdBlue*® consumption on fuel consumption

From the data in Figure 7, we can summarize that theoretically the consumption of urea is considered satisfactory if the ratio is one to two (1:2). Virtually, it is considered that one *AdBlue*® tank is necessary to supply two tanks of diesel fuel to the tractor. In case of incorrect dosing of the reagent in the system and obtaining large differences, we find that there is a problem that must be resolved. From the obtained values reflected in the graph for the consumed amount of diesel fuel and *AdBlue*® at the time of the study during sowing, we determine the ratio in the following sequence:

After converting the average values for *AdBlue*® injection shown in Figure 4, we obtain 2.59 l/h x 8 h = 21 liters of *AdBlue*® for one working change of the unit. From the manufacturer of the tractor, we have data on the capacity of the reagent tank, which is 56 l. From there we determine its percentage ratio to the amount of reagent consumed for 8 hours of operation of the machine-tractor unit and we get:

$$21\ \text{l} / 56\ \text{l} = 37.5\% \tag{1}$$

From the technical data for the tractor, the fuel tank is 640 liters. According to data from Figure 4, we calculate the consumption of diesel for 8 *h* of operation of the machine-tractor unit, obtaining an average of 55 l/h x 8 h = 440 liters. Therefore, we also determine the percentage of diesel fuel in the tank in relation to the amount of fuel consumed:

$$440\ \text{l} / 640\ \text{l} = 68.75\% \tag{2}$$

After calculating the percentage of *AdBlue*® consumed and the amount of diesel consumed, we divide the two ratios and get:

$$37.5\% / 68.75\% = 1.83 \tag{3}$$

From (3) we find that the ratio of the amount of reagent consumed to the consumed diesel fuel is obtained (1:2), i.e. one *AdBlue*® tank will supply two diesel tanks to the tractor.

CONCLUSIONS

As a result of the study, the following conclusions can be drawn: (i) using the data from the service diagnostic program, the consumption of *AdBlue*® in relation to the operating temperature, and the consumed diesel fuel has been determined; (ii) the factors influencing the *AdBlue*® consumption have been found to be: operating temperature, diesel quality and tractor engine load; (iii) *AdBlue*® consumption calculations show that one reagent tank can supply two tanks of the diesel tractor. These data fully meet the parameters set by the manufacturer.

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