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Assessment of average exhaust emissions from a farm tractor operating in a livestock building

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Summary. The results of investigations of exhaust emissions in a livestock building from a farm tractor coupled with a feed wagon have been presented. The investigations were performed in an open space building divided into boxes with the livestock count of 60 cows.

Key words: microclimate, livestock building, engine load, exhaust emissions.

INTRODUCTION

Maintaining appropriate microclimate in the cow house is an important element of the livestock breeding system that influences its health and efficiency. Maintaining of the optimum conditions depends on many factors such as: breeding technology, feeding methods, design of the building, proper care and hygiene [7, 8].

Animals in the livestock buildings generate heat, carbon dioxide and water vapor to the environment. The level of these emissions depends on: animal weight, animal metabolism and ambient temperature [1]. The reduction of the emission of gases in farm production (flora and fauna) as well as the reduction of the emission from farm machinery have been addressed in the recommendations related to the admissible emissions contained in The UN Convention on Climatic Change [9].

The main parameters determining the microclimate of the livestock buildings are:

- temperature and relative humidity of the air,
- concentration of harmful gases,
- light intensity,
- ventilation and air exchange speed.

Aside from the main parameters determining the microclimate in the building the level of air contamination in the cow house also plays an important role. Admissible concentrations of gases deemed as most harmful in the livestock building are shown in Table 1.

Table 1. Admissible concentrations of air pollutants [Romaniuk, Overby 2004]

Gas	Concentration [mg×m^{-3}]	Amount [ppm]
Ammonia (NH_3)	15,4	20
Carbon dioxide (CO_2)	5930	3000
Hydrogen sulfide (H_2S)	7,5	5
Dust	10,0	¾

One of the sources of pollution in a livestock building is a farm tractor coupled with machinery servicing a group of animals in that building. The machinery operating with the tractor affects its exhaust emissions depending on the engine loads [5]. Aside from the loads that influence the emissions the technical condition of the tractor also plays an important role, particularly the piston-cylinder-ring assembly not to mention the injection system [11,10]. That is why it is important to properly select the feed wagon to the animal count and the tractor that a given farm owns.

RESEARCH METHODS

For the tests a farm tractor MF255 was used fitted with an straight engine AD3.152UR (table 2) combined with a feed wagon JF-STOLL VM 10-IS of the capacity of 10 m^3 and power demand of 45 kW. The measurements were realized in an open space building divided into boxes with the livestock count of 60 cows.

Table 2. Technical specifications of the AD3.152 UR engine

Basic technical specifications of the AD3.152 UR engine		
Parameter	Unit	Value
Number of cylinders, c	-	3
Engine displacement, V_{ss}	dm^3	2,502
Engine rated power, N_e	kW	34,6
Engine speed at rated power, n_N	Rpm	2250
Engine maximum torque, M_o	Nm	165,4
Engine speed at maximum torque, n_M	Rpm	1300,1400
Unit fuel consumption, g_e	$g \times kW^{-1} \times h^{-1}$	234

During the operation of the tractor coupled with the feed wagon load states were recorded through a TRS system *(Tractor Recording System)* [2]. Then, the most frequently occurring engine load ranges were obtained and a substitute simulation research cycle was determined. The measurements of the exhaust emissions were carried out on a chassis dynamometer through a multi-component exhaust gas analyzer CAPELEC CAP 3201IG/GO for each of the characteristic load ranges of the tested tractor. For the determination of the emissions of the individual exhaust gas components a specially developed methodology was applied [3].

RESEARCH RESULTS

Following the data recording the authors obtained 3175 records on the engine loads corresponding to 26,5 hours of work. The most frequently used engine speeds and loads of the tested tractor have been presented in the form of a two-dimensional probability distribution (Fig. 1).

The authors have observed that such auxiliary actions as u-turns, charging, wagon coupling are done outside of the building. For the calculations and analysis only those load states were selected that pertained to the tractor operating inside of the livestock building. In the presented graph it is the speed of n_s 2000 [rpm].

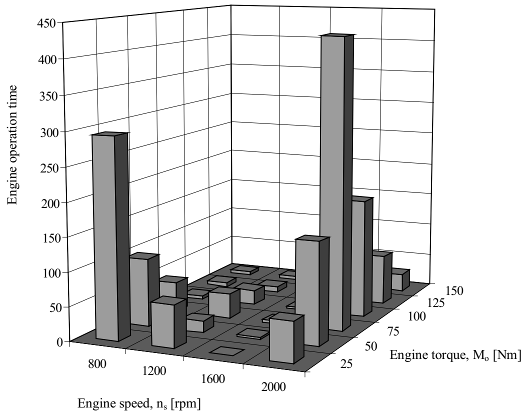

Fig. 1. Two-dimensional distribution of the operating time of the tractor engine (MF255)

Based on the above-presented results it has been ascertained that the substitute, simulating research cycle will have six different phases (sequences of loads) at the same engine speed (Table 3). The individual ranges of loads were assigned weight coefficients that were related to the operating time of the tested engine under the measured load.

Table 3. Substitute, simulation load cycle of the tested tractor

Number of phase		1	2	3	4	5	6
6 phase cycle	n_s [rpm]	2000	2000	2000	2000	2000	2000
	M_o [Nm]	55	60	70	80	90	100
	Weight coefficient	0,05	0,1	0,45	0,15	0,2	0,05

Based on the developed substitute engine cycle tests were performed on a chassis dynamometer where the emissions of the following were determined: CO_2, CO HC, NO_x as well as unit fuel consumption. In Fig. 2 the dependence of the unit fuel consumption on the effective power has been presented.

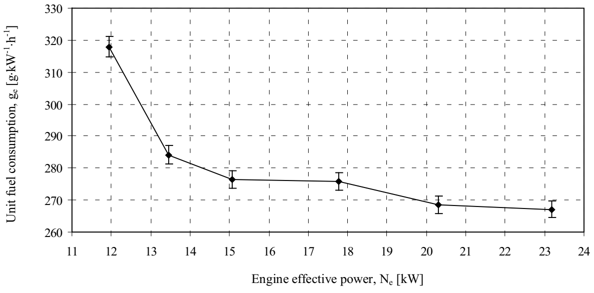

Fig. 2. Dependence of the unit fuel consumption on the tested engine effective power (AD3.152UR)

The authors observed that the lowest unit fuel consumption i.e. 267 $g \times kW^{-1} \times h^{-1}$ the tested engine achieved in the sixth phase of the cycle. The greatest unit fuel consumption was recorded in the first phase of the cycle. Along the subsequent phases the fuel consumption decreased. Also, in the sixth phase of the cycle the greatest emission of CO_2 was recorded - 8,3 $m^3 \times h^{-1}$ (Fig. 3). The smallest emission of the latter - 5,96 $m^3 \times h^{-1}$ was recorded for the first cycle.

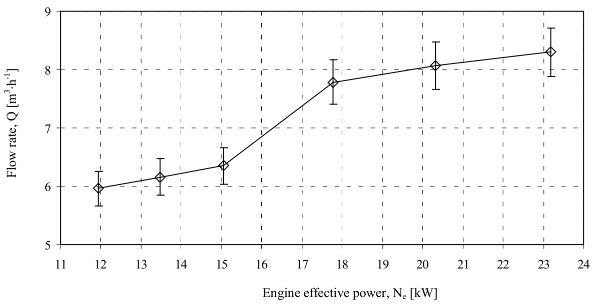

Fig. 3. Dependence of the CO_2 emissions on the tested engine effective power

Te subsequent phases of the research cycle showed an increase in the emission of CO_2 yet, for the first three cycles this increase is miniscule (amounts to approximately 0,35 m^3×h^{-1}). A significant growth of CO_2 was recorded between cycles three and four (1,45 m^3×h^{-1}). Then, the growth between cycle four and six amounted to approximately 0,5 m^3×h^{-}1. The sixth phase of the substitute cycle also showed the greatest emissions of the outstanding exhaust gas components i.e. CO, HC and NO_x (Fig. 4, 5).

An increase in the exhaust emissions was observed as the engine effective power of the tested engine grew, which is confirmed by investigations of other authors e.g. [Wasilewski 2004]. In cycles 1-4 the emission of CO was in the range from 0,02÷0,026 m^3×h^{-1}. In further cycles the emission of CO grew to reach 0,077 m^3×h^{-1} in the sixth cycle, which is almost a double of the fourth cycle.

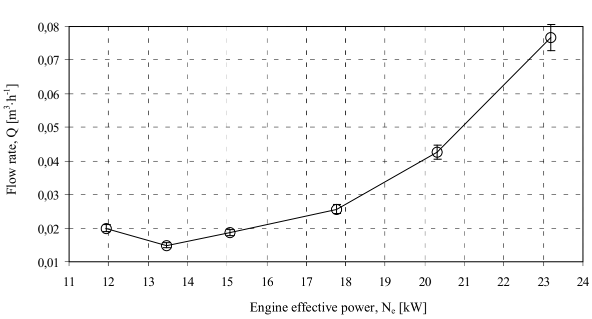

Fig. 4. Dependence of CO emission on the tested engine effective power

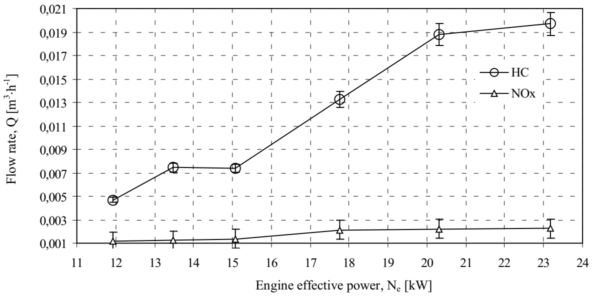

Fig. 5. Dependence of HC and NO_x emissions on the tested engine effective power

Similarly to $CO_{2,}$ a significant increase in the emissions of HC and NO_x was recorded between cycles three and four. The emission of HC grew almost three times from 0,0074 m^3×h^{-1} in cycle three to 0,0197 m^3×h^{-1} in cycle six. The emission of NO_x doubled in the ranges analogical to HC.

In Table 4 the weighed averages have been listed of all the exhaust components measured in the test.

The use of a farm tractor coupled with farm machinery used in livestock buildings should be preceded by an analysis of the power demand in order to avoid elevated exhaust emissions including PM (particulate matter) to the ambient air in the building. Farm tractors used for the propulsion of the farm machinery inside livestock buildings should be fitted with modern aftertreatment systems [4]. Going on the assumption that CO_2 is not a toxic gas for living organisms (it only contributes to the greenhouse effect) we can state that all other exhaust gas components are of paramount importance. Based on the measurements of the amount of these gases in the air we can assess the real threat for the animals and humans directly exposed to the exhaust gases while feeding livestock with the use of a feed wagon in the livestock building. When comparing the exhaust emissions of farm tractors with other vehicles used in transport we must state that they have much higher exhaust emissions [6].

CONCLUSIONS

During the investigations the authors observed that the farm tractor operating in a livestock building generates high amounts of CO_2 as well as other exhaust components that are inhaled by the animals. This particularly pertains to NO_x and HC that can affect the animal health and the quality of meat and milk.

1. Besides, the method of assessment of the average values of exhaust emission proposed in the paper could be useful when designing the livestock building ventilation as this method takes into account the additional volume and type of exhaust gases coming from the operating tractor engine.
2. The developed substitute load cycle can serve to determine the optimum value of the effective power demanded by the tractor-wagon aggregate for the better welfare of livestock (optimum exhaust emission level).
3. The performed investigations showed that for the tested engine the optimum effective power amounts to 15 kW, which corresponds to the third load cycle. For these values of effective power the emissions of CO, CO_2, NO_x, HC are still low and the unit fuel consumption g_e is moderate.

Table 4. Weighed averages of the exhaust emissions obtained during the tests of the AD3.152.UR engine

Phase number		1	2	3	4	5	6	Weighed average
Emission, Q [m^3×h^{-1}]	CO_2	5,9591	6,1604	6,3477	7,7877	8,0685	8,304	6,9675
	HC	0,0047	0,0074	0,0074	0,0133	0,0188	0,0197	0,011
	CO	0,02	0,0149	0,0187	0,0257	0,0427	0,0767	0,0271
	NO_x	0,0012	0,0012	0,0014	0,0021	0,0022	0,0022	0,0017

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OCENA ŚREDNIEJ EMISJI SPALIN Z CIĄGNIKA PRACUJĄCEGO W BUDYNKU INWENTARSKIM

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Słowa kluczowe: mikroklimat, budynek inwentarski, obciążenie silnika, emisja spalin.