UNIT EMISSION OF THE EXHAUST GAS COMPONENTS DETERMINED BY MEANS OF THE SIMPLIFICATION METHOD

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Summary

Toxicity of the combustion engines is determined by means of the procedures that result from their size group and appropriation, determining a measurement mode (a type of test) and a calculation method, and lead to the determination of the so-called unit emissions of the particular components. The paper aims at presenting the differences in the unit emission value determined for a compression-ignition engine complying with the full procedure which includes the corrections resulting from a state of atmosphere and a type of the component observed, and are calculated in a simplified way omitting corrections.

***Key words**: combustion engines, toxicity, unit emission, and calculations*

1. Introduction

Nowadays, the research on the exhaust gas emissions is carried out based on the rules presented in the Polish standard: Measurement of the exhaust gas emissions; Measurement of emissions of the gas components and stable particles in a research station (PN-EN ISO 8178-1), which is identical with EN ISO 8178-1:1996, and the standard PN-EN ISO 8178-2: Measurement of the exhaust gas emissions; Measurement of emissions of the gas components and stable particles at an installation place.
In order to assess the possibility of simplification of the calculation procedures, the calculations have been performed which have enabled estimation of the differences resulting from the assumed different types of procedure.

2. Research

The results of the research on a propulsion motor of a river pusher-tug have been assumed as the basis. The research has been realized according to a cycle of an E3 type (heavy-duty motors intended for ship drive; PN-EN ISO 8178-4: Measurement of the exhaust gas emissions; Research cycles of the engines of different applications).
The research cycle phases and weight coefficients have been specified in Table 1.

Tab. 1 Research cycle components

Phase number	1	2	3	4
Rotational speed, %	100	91	80	63
Power, %	100	75	50	25
Weight coefficient	0.2	0.5	0.15	0.15

The permissible deviations of the instruments intended for measurement of the motor operation parameters have been specified in Table 2.

Tab. 2 Permissible deviations of the measuring instruments

Specification	Permissible deviation	
	acc. to 8178-1	acc. to 8178-2
Motor rotational speed	± 2 %	± 2 %
Torque	± 2 %	± 5 %
Power	± 2 %	± 5 %
Fuel consumption	± 2 %	± 4 %
Expenditure of air	± 2 %	± 5 %

The standard PN-EN ISO 8178-2 determines accuracy of determination of the gas component emissions provided in g/kWh at a level of ± 9 %.
The conditions and results of the research and calculations have been specified in Table 3.

3. Result analysis

Fuel typical coefficient for the calculation of F_{FW} wet exhaust gas flow

Pursuant to Appendix A to the Standard 8178-1, the F_{FW} coefficient can be calculated from the following equation (A.51):

$$FFW = 0.05557 \times ALF - 0.00011 \times BET - 0.00017 \times GAM +$$
$$+ 0.0080055 \times DEL + 0.006998 \times EPS$$

where:

ALF – H content in fuel, % (m/m); for diesel oil (ON) H = 13.6 (Table 7)
BET – C content in fuel, % (m/m); for ON: C = 86.2
GAM – S content in fuel, % (m/m); for ON: S = 0.17
DEL – N content in fuel, % (m/m); for ON: N = data missing
EPS – O content in fuel, % (m/m); for ON: O = 0,
or to assume a value of 0.749 (PN-EN ISO 8178-1 Table. 7).

The value calculated according to the formula (A.51), with an assumption that DEL = 0, amounts to FFW = 0.746 (for three decimal places).
Simplification of the formula (A.51) to the following form:
FFW = 0.0556 x ALF – 0.0001 x BET – 0.0002 x GAM + 0.0080 x DEL + 0.0070 x EPS
gives a value of FFW' = 0.748.
A relative error of the value calculated in such a way (0.748) compared to the value 0.749 amounts to 0.13 %, and compared to the value 0.746 – 0.27 %, respectively.

Humidity correction coefficient for NO_x, K_{HDIES}

A humidity correction coefficient for NO_x is described in chapter 13.3 of the Standard.
A value of the coefficient for the reference humidity amounting to 10.71 g/kg proposed by the standard originator amounts to K_{HDIES} = 0.9914**.**

Tab. 3 Conditions and results of the research

Phase number	1	2	3	4	Remarks
Rotational speed, %	100	91	80	63	
Maximum power for a given motor rotational speed P_m, kW	147	110	74	37	
Volumetric intensity of wet inlet air flow V_{AIRW}, m^3/h	599.4	547.5	479.5	379.6	
Volumetric intensity of wet exhaust gas flow V_{EXHW}, m^3/h	620.1	564.5	487.9	384.5	
Mass intensity of fuel flow G_{FUEL}, kg/h	27.7	22.8	11.2	6.5	
Typical fuel coefficient for the calculation of wet exhaust gas flow F_{FW}, 1	0.749	0.749	0.749	0.749	
CO concentration $conc_{CO}$, %	0.44	0.14	0.10	0.085	
NO_x concentration $conc_{NOx}$, %	0.088	0.098	0.106	0.098	
Atmospheric absolute pressure p_B, kPa					101.3
Steam saturation pressure in the inlet air p_a, kPa					3.166
Absolute temperature of the inlet air T_a, K					298
Relative humidity of the inlet air R_a, %					50
Humidity correction coefficient for NO_x, K_{HDIES}, 1					0.9914
Mass intensity of CO emissions $M_{GAS\ CO}$, kg/h	3411	988	610	409	
Mass intensity of NO_x emissions $M_{GAS\ NOx}$, kg/h	1120	1136	1062	774	
w coefficient for CO for NO_x	0.00125 0.002053	0.00125 0.002053	0.00125 0.002053	0.00125 0.002053	
CO unit emission GAS_{CO}, g/kWh	-	-	-	-	11.96
NO_x unit emission GAS_{NOx}, g/kWh	-	-	-	-	9.60
Accuracy, %					± 9

The permitted possibility of inclusion of the measurement conditions (for the presented example, the value of the reference humidity amounts to 9.88 g/kg) results in changing to the value of $K'_{HDIES} = 1.0007$.

The relative error for the suggested value of $K_{HDIES} = 1$

compared to $K'_{HDIES} = 1.0007$ amounts to 0.07 %

and, compared to $K_{HDIES} = 0.9914$ amounts to 0.86 %.

Thus, $K_{HDIES} = 1$ can be assumed, which means resignation from such a coefficient.

'w' correction coefficient

The 'w' correction coefficient amounts, respectively, to:

CO: w = 0.00125;

NO_x: w = 0.002053.

The suggested 'rounded' 'w' values and the corresponding relative error amount to:

CO: w' = 0.0013; error 4 %,

NO_x: w' = 0.0021; error 2.3 %.

The permissible deviations of the instruments intended for measurement of the motor operation parameters have been specified in Table 4.

Tab. 4 Permissible deviations of the measuring instruments

Item	Specification	Permissible deviation referred to maximum motor values
1	Motor rotational speed	± 2
2	Torque	± 5
3	Power	± 5
4	Fuel consumption	Diesel oil: ± 4
5	Expenditure of air	± 5
6	Component concentration	± 5

Assuming an unfavourable coincidence, the calculations of the unit emission for the permissible values of the measurement instruments have been carried out.. Their impact on the unit emission values has been provided in Table 5.

Tab. 5 Impact of the deviations on the unit emission values

Item	Specification	Deviation, %	Unit emission change, %	
			CO	NO_x
	Power	- 5	+ 2.04	+ 2.04
	Fuel consumption	+ 4	+ 2.16	+ 2.15
	Expenditure of air	+5	+ 7.11	+ 7.12
	Component concentration	+5	+ 12.47	+ 12.47

In the presented situation, the maximum deviation of the determined unit emission exceeds 12.4 % at an accuracy, assumed pursuant to the standard (or permissible dispersion) at a level of 9 %.

4. Conclusions

1. The maximum deviation of the determined unit emission in g/kWh exceeds 12.4 %.
2. Determined by the standard PN-EN ISO 8178-2, the accuracy of determination of the gas component emissions provided in g/kWh, at the level of ± 9 % is insufficient.
3. In order to make the unit emission determination procedures more user-friendly, they can be simplified through reduction of the significant decimal places in the humidity correction coefficient or, alternatively, through assuming the value of 1 for the coefficient and reduction of the significant decimal places in the 'w' correction coefficient.

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