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EVALUATION OF THE SMOKE DEGREE AND CO_2 EMISSION IN CORRELATION WITH THE DISTANCE COVERED BY ROAD VEHICLES

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Abstract
The paper presents the evaluation of the smoke degree in correlation with distance covered by a road vehicle, based on experimental measurements and theoretical modellations through mathematical functions. The evolution of CO_2 emission is avaluated using a specific software (DEKRA)
Key words:
smoke degree, CO_2 emission, DEKRA

1. GENERAL NOTES

The particles emitted by diesel engines consist mainly of soot, generated during the combustion (carbon graphite) and hydrocarbons adsorbed or condensed. Particles are defined in the law of the material (except water) that is collected on a Teflon filter to shift gas emitted by motor burned, previously diluted with filtered air, dilution with clean air is provided to meet the filter temperature be less than 52° C to avoid volatilization of hydrocarbons and water condensation.

Measurement of particle is based on previous definition and involves a complicated procedure, which involves diluting the exhaust gas (or part of them), the precise measurement of the ratio of dilution, weighing filters before and after sampling in a controlled atmosphere, knowing the exact diluted gas flow passing through the filter during sampling.

Since particle measurement is an operation with many phases, expensive and lengthy, there were many attempts to correlate measurements with gravimetric particle measurements of smoke index, using ordinary smoke-meter (Bosch, Hartridge) or other instruments not placed on the market. Most studies on this subject have obtained correlations between the numbers of smoke and soot concentration measured in undiluted exhaust emissions. Therefore, it will applicability existing correlations in smoke-soot mass emission estimates for particulate matter and will investigate the relationships between particles, soot and smoke, and in correlation with the distance traveled by vehicles.

2. MEASURED VALUES

Measurements were made on a car brand Vokswagen Sharan - 1.9 TDI with measuring devices owned by two measuring stations, measuring smoke according with TÜV - Germany rules, in connection with Annexes XIa and IXa StVZO (a), respectively the tests in relation with Annex VIIIa and IXa StVZO (b).

For the two types of tests, the following values were selected:
- at relanti speed: according to (a) – n_o = 700 ... 950 rpm
  according to (b) – n_o = 770 ... 940 rpm
- at rated speed: according to (a) – n_n = 4700 ... 5200 rpm
  according to (b) – n_n = 4800 ... 5200 rpm
- for absorption coefficient KM: according to (a) – K_M = 0.43 m^{-1}
  according to (b) – K_M = 1.85 m^{-1}
- number of kilometers covered: 20.000 km

Table 1 and figure 1 presents data for the smoke, estimated by the coefficient of absorption K_M, depending on the number of km traveled.

Table 1

Crt. no.	Absorption coefficient Hartridge K_M [m⁻¹]	Traveled distance [km]
1.	0,43	20.000
2.	0,9	30.000
3.	1,25	40.000
4.	1,51	50.000
5.	1,751	60.000
6.	2,0	70.000

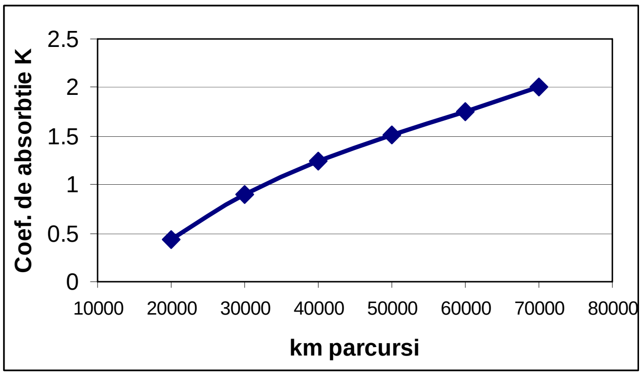

Figure 1. The absorption coefficient evolution vs. traveled distance

Table 2 give the data obtained through the exploitation of the DEKRA Soft Programme - Germany - 2007, for the route fuel consumption Cc [l/100km], specific CO_2 emissions - E_{CO2} [g / km], that the total mass of CO_2 exhausted - M_{CO2} [kg], depending on the number of km traveled by car.

Table 2

Crt. no.	Route fuel consumption C_c [l/100km]	Nr. of km traveled [km]	Specific emission of CO_2 E_{CO2} [g/km]	Absolute emission of CO_2 M_{CO2} [kg]
1.	6,8	20.000	180,2	3604,8
2.	6,9	30.000	182,9	5485,5
3.	7,0	40.000	185,5	7420,0
4.	7,1	50.000	188,1	9407,5
5.	7,2	60.000	190,8	11448,0
6.	7,3	70.000	193,9	13541,5

3. MATHEMATICAL MODELS

In all technical fields and not only, for studying of a certain process for establishing of a mathematical model, as a form of expression of the synthetic target and deployment process, that can later be used in different theoretical approaches. It follows that establishing the mathematical model based on experimental data is one of the main aims pursued by carrying out tests which should not be so to be repeated.

Obtaining non-linear models is more difficult due to the lack of a general theory that the uniform linear, therefore, most often resulting study nonlinear processes in particular cases. There are some treatment unit and the non-linear models, but still only valid for certain special cases, such as the polynomial models.

Thus, the size of the result y and x variable factorial model has polynomial general form:

$$y = \sum_{i=0}^{m} a_i x^m \qquad (1)$$

For example, for a two-degree polynomial expression (1) becomes:

$$y = a_2 x^2 + a_1 x + a_0 \qquad (2)$$

Relations were presented in full polynomial structure, so with all the expression characteristics terms. If using an unfully polynomial structure, missing at least one term, for example, in absence of the free term model (2) becomes:

$$y = a_2 x^2 + a_1 x \qquad (3)$$

Using a cubic polynomial expression, relation (1) takes the form:

$$y = a_3 x^3 + a_2 x^2 + a_1 x + a_0 \qquad (4)$$

Obviously, if considered a linear model, then the relationship (1) became:

$$y = a_1 x + a_0 \qquad (5)$$

Starting from data presented in Table 1, considering the evolutionary curve of the absorption coefficient Hartridge K_M according to the distance D traveled by the vehicle as a parable of second degree and applying relation (2), the following relationship which considers the evolution of K_M is obtained:

$$K_M = -0{,}023 \cdot D^2 + 0{,}521 \cdot D - 0{,}52 \qquad (6)$$

The coefficients a_0, a_1 şi a_2 of the relationship (20 were obtained by applying the experimental results. Thus were obtained the following values:

$$a_0 = -0,52 \; ; \; a_1 = 0,521 \; ; \; a_2 = -0,023$$

There was not found major deviations from the experimental curve (Figure 1), the calculation curve is well overlapped above the theoretical, obtained by mathematical modeling - fig. 2.

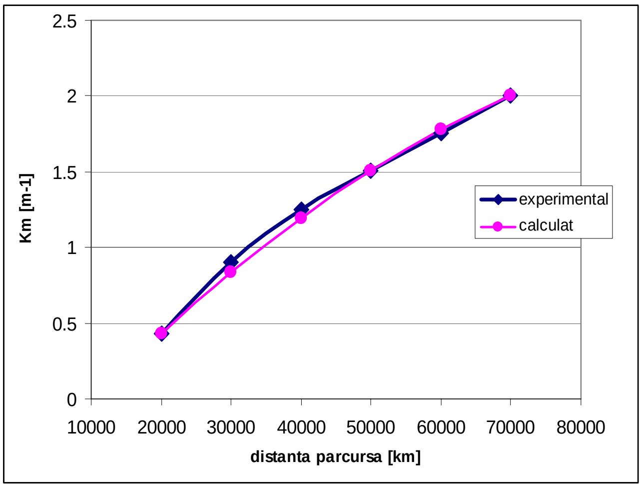

Figure 2. Comparison between absorption coefficient – experimental and calculated

For the intermediate points, i.e. those who have not served for establishing the constants a_0, a_1, a_2, there was obtained deviations between 1.52 ... 4.32%, which are acceptable from a technical standpoint.

Accepting the mass particle content (GFC) evolution as a parable of a second degree, with the coefficients a_0, a_1, a_2 determinates as reasoning presented above (a_0 = - 0,016; a_1 = 0,062 ; a_2 = - 0,002), the following function is obtained:

$$GFG = -0,002 \cdot D^2 + 0,062 \cdot D - 0,016 \quad (7)$$

In Figure 3 presents graphically dependence GFG = f(D). Deviations between theoretical and experimental points are below 2%, which corresponds to the aim pursued.

Table 3

Crt. no.	No. of km traveled D [km]	Absorbtion coefficient K_M [m^{-1}]	Mass particle content GFG [g/m^3]	Hartridge smoke degree HSU [%]
1.	20.000	0,43	0,10	1,0
2.	30.000	0,90	0,16	1,4
3.	40.000	1,25	0,20	1,9
4.	50.000	1,51	0,24	2,3
5.	60.000	1,75	0,28	2,5
6.	70.000	2,00	0,32	2,7

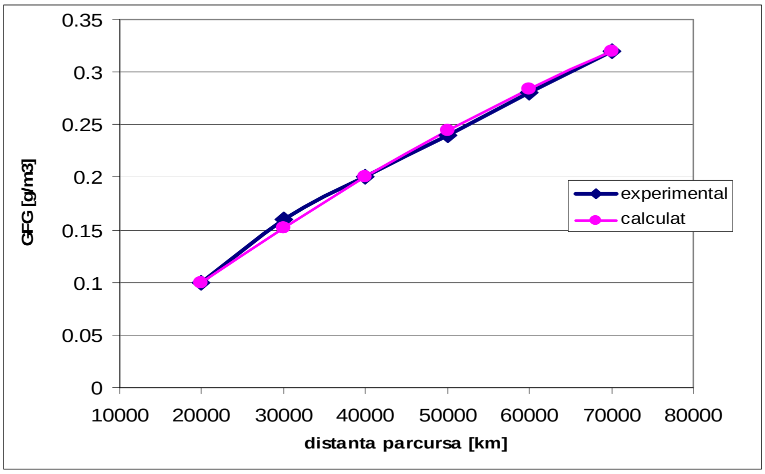

Figure 3. Comparison between mass particle content (experimental and calculated) vs. traveled distance

Table 4

Nr. crt.	Route fuel consumption C_c [l/100km]	Nr. of km travelled D [km]	Specific emission of CO_2 E_{CO_2} [g/km]
1.	6,8	20.000	180,2
2.	6,9	30.000	182,9
3.	7,0	40.000	185,5
4.	7,1	50.000	188,1
5.	7,2	60.000	190,8
6.	7,3	70.000	193,9

Modelling the evolution of CO_2 emission and route fuel consumption in relation to distance travelled for the analyzed car was realized also by functions. Experimental data for calibration are presented in Table 4.

Specific emission of CO_2 - estimated through DEKRA 2007 software, the function which describes the evolution is linear type:

$$E_{CO2} = 2{,}66 \cdot D + 174{,}88 \quad (8)$$

Is founds a good correlation of experimental data with those obtained by mathematical modeling with functions, deviations were recorded are virtually negligible.

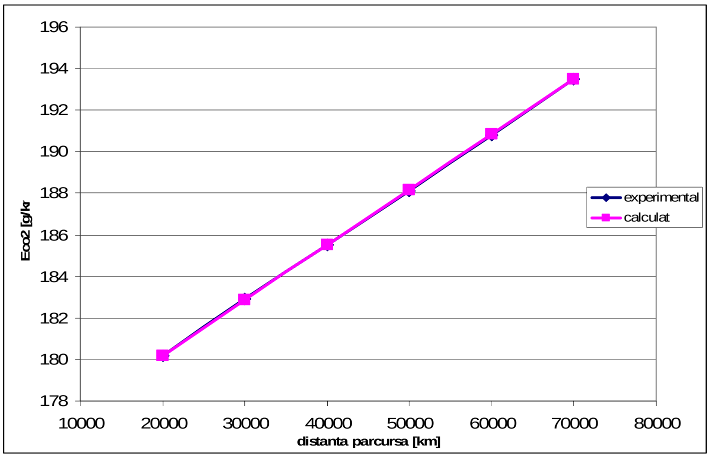

Figure 4. CO_2 emissions in correlation with travelled distance

4. CONCLUSIONS

Based on own measurements, there were established the evolution the level of smoke degree and particles emissions in relation to the distances covered. Experimental researches are performed on the smoke opacity measured in relation with the distance travelled by the car equipped with a diesel engine. There are presented graphically and tabular variations for K_M absorption coefficient based on the distance travelled. These allow establishing how the distance travelled values influence this factor.

Using the DEKRA - Germany 2007 software, it could be determinate the evolution of route specific fuel consumption, the specific and absolute emission of CO_2 according with the distance travelled by an automotive car, with an concrete example of calculation.

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