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THE STUDY OF THE DIESEL MOTOR POLLUTION USING THE FUZZY LOGIC AND FAHP ALGORITHM

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Abstract: *Through this paper we introduce a calculation procedure of the harmful (pollutant) substances produced by diesel motors in their operating process. This new procedure implies the use of experimental data (of the measurements made in the laboratory or test stands) with the help of which weighted averages are formed. The calculation of the weights is realized through the FAHP method ("FUZZY ANALYSIS HIERARHICAL PROCESS") using the triangular cut fuzzy numbers. It is known the fact that in a weighted average, the weights can be chosen in more ways than one and that there exists a series of weights of the best approximation, so they obtained weighted average is a regression. The series of weights of the best approximation is materialized through the eigenvalues and eigenvectors methods. The embedding of the fuzzy numbers in the fuzzy number lot is realized through a convex combination procedure, which together with the cut fuzzy number provide us with 2 parameters, that can be than used for the choosing of situations as close as possible to reality. The paper ends with a case study in which the pollution is produced by more types of auto vehicles equipped with diesel motors (cars, minibuses, motorbuses and trucks). Beforehand a study is realized regarding the optimization of the mixture of the fuel with the air (fresh load).*
Key words: *study pollution, Diesel motor, Fuzzy logic, FAHP algorithm*

1. INTRODUCTION

The pollution of the motors is caused mainly by the following exhaustions: hydrocarbons (HC), nitrogen oxides (NO_x), carbon monoxide (CO), solid particles and noise. In the last few years the development of the car production drove to alarming harmful effects, so that the pollution problem is stringent.

There are two types of hydrocarbons: hydrocarbons derived from diesel and the ones derived from oil (engine lubricant). The causes of hydrocarbons production are: poor combustion, in case of diesel overflows, of an incorrect mixture of fuel with air, engine wear, which is cause of the apparition of diesel molecules in the oil and through the burn of which hydrocarbons are produced.

The nitrogen oxides are pollutants, which come from a burn at very high temperature. This rise in temperature is caused by the following factors: air excess, rough advance adjustments, a pressure at high overpower, a wrong volumetric report.

The carbon monoxide is produced by a flawed burn of the diesel and oil. The smoke and particles represent carbon composite, tars in solid or liquid state, in suspension in the exhaust gases. According to STAS 6926/15-92 the noise level produced by cars is limited at 74-80db in high rotation.

The quantity of harmful (pollutant) substances exhaustions by the car depends on the intensity of traffic, type of vehicles and their speed, number of street lanes.

On a given distance, in a time unit, the average content of exhaustion is calculated with the following formula:

$$N_m = a\rho \sum_{t=1}^{n} C_t Q_t I_t \qquad (1)$$

where Q_i is the per kilometer consumed diesel quantity, I_i - traffic intensity (the numbers of "i" type vehicles passing on a given road length in the given time unit [hr^{-1}], C_i - the correlation coefficient of the harmful exhaustions at consumed diesel, n - the total number of cars of different types, "i" - type vehicle, N_m - represents the average value of the pollutant quantity admitted per time unit.

2. FORMING OF THE FUEL MIXTURE

The cause pollutant formation by the diesel engine are multiple, the most important being determined by the mixture of fuel with air in the burning chamber in the final compression stage. The introduction of the fuel in the burning chamber is realized with the help of injectors. For the burning to be made rapidly and in high proportion, through the injectors must be realized a decomposition of the fuel in drops as small as possible and a very uniform distribution in the whole burning chamber. The pulverization through fuel injection can be appreciated through the following features:

1. The softness of pulverization

Following the pulverization process, its softness is random in nature in most experimental researches, each application leads to results that keep the experience and value of the researcher. This is the reason for which in this paper we use a mathematical procedure based on fuzzy logic, which is known to model good enough random (subjective) phenomenon. One of the characteristics contained in pulverization fineness is the average diameter of drops. In this paper we will present a new method for the calculation of the average diameter of the fuel drops injected in the burning chamber, which we name the FAHP calculation of the average diameter. The general formula for the calculation of the average diameter is:

$$D_m = \sum_{i=1}^{k} \bar{D}_i w_{i,k} \qquad (2)$$

where is the average value of the diameters of the "i" order group of drops which according to Reynolds-Weber, can be calculated (through empirical procedures) with the formula:

$$\bar{D}_i = \frac{8{,}7 d_j}{10^6 (ReWe)^{0.28}}, i = 1 \div k \qquad (3)$$

where dj represents the diameter of the injector [m] orifice, j=1÷s, where s the number of injectors is (in the majority of cases s=1).

$$R_e = \frac{w_{inj} d_j}{\nu_{ci}} \qquad (4)$$

$$W_e = \frac{w_{inj} d_j \rho_c}{\delta_{ci}} \qquad (5)$$

We noted with:

w_{inj} - injection speed [m/s]

ν_{ci} - cinematic viscosity of the fuel [Ns/m^2]

ρ_c - fuel density [kg/m^3]

δ_{ci} - superficial tension of the fuel [N/m]

Note that we assumed the ranking of the drops obtained through injection in the burning chamber, in the time unit, in k groups, because, generally speaking, the cinematic viscosity varies with the temperature of the injected fuel. The weights $w_{i,k}$ must satisfy the conditions:

$$w_{i,k} \in (0{,}1) and \sum_{i=1}^{k} w_{i,k} = 1 \qquad (6)$$

The FAHP algorithm permits us to do the ranking of the drops in groups, according to the viscosity level of the fuel and also to calculate the partial and global weights of best approximation through the eigenvalues and vectors procedure.

We mention that the classic formulas for the calculation of the average diameter D_m, are obtained as particular cases from the formula (2). So, if:

$$w_{i,k} = \frac{n_i}{\sum_{i=1}^{k} n_i} \quad (7)$$

where ni represents the number of drops from the "i" group, than we get the arithmetic average diameter.
If

$$w_{i,k} = \frac{n_i \bar{D}_i^{\,2}}{\sum_{i=1}^{k} n_i \bar{D}_i^{\,2}} \quad (8)$$

then we get the average value D_m, calculated through the Sauter method.

Through this procedure, given by (2), we avoid the calculation of the number of drops from each "i" group, which is not a easy thing to do, furthermore as we mentioned, the weights from (2) are of best approximation. We can observe that the Sauter method can be easily generalized, but this does not assure (from a theoretic point of view) that the obtained weights will be of best approximation.

2.1. Homogeneity of the pulverization

Theoretically the homogeneity of the fuel drops obtained through the pulverization in the burning chamber means that each drop must have the same diameter. In reality this phenomenon is impossible to realize, this being one of the reasons for which we proposed the application of the fuzzy logic.

So, the homogeneity is gets better, when the interval in which Dm varies is restricted. From a statistical point of view, the appreciation of the finesse and homogeneity of the pulverization can be realized through an empirical distribution (empirical probability density), which we name pulverization characteristic. If we apply a Gauss or Weibull type distribution, we can notice that the higher the distribution bell is, the bigger also the homogeneity gets.

2.2. Jet penetration

In the fuel injection process in the burning chamber, the fuel jet covers a rout L, in the direction of the injectors orifice in time τ. The penetration of the jet in the burning chamber must be realized optimally, which means when injected the jet should cross the whole burning chamber so that for the next phase of mixture, no peripheral areas of unused air remain. If the jet penetration is optimally made, then, such a jet is called a free jet. For us to get the average value of L, through a FAHP procedure, attached to a uniform meshing of the time period τ, to use the formula:

$$L_m = \sum_{i=1}^{k} w_{i,k} L_{i,k} \quad (9)$$

Where $\{w_{i,k}\}$ represents the weight rows of best approximation, and can be experimentally determined through one of the formulas: μ_A

$$L_{i,k} = (162,3)\Delta p^{0,25} d_j^{0,515} \sqrt{P_{i,k}} \quad [m] \quad (10)$$

where

$$P_{i,k} = \frac{\tau_{i,k}\rho_a}{\rho_a}\left[1 + 673\left(\frac{\rho_a}{\rho_a}\right)^2\right] \quad (11)$$

In these formulas, beside the already introduced notation, have appeared:
ρ_a - air density
$\tau_{i,k}$ - average value of time in the "i" interval

$$L_{i,k} = \frac{5 d_j^{0,3} \tau_{i,k}^{0,7}}{10^3}\left(\frac{\Delta p}{\rho_{i,k}}\right)^{0,35}\left(\frac{293}{T_{i,k}}\right)^{0,2} \quad (12)$$

where $\rho_{i,k}$ and $T_{i,k}$ are the average density respectively average temperature on the "i" interval from the meshing of the time period τ.

3. THE FAHP ALGORITHM

We will describe the main steps from which this algorithm is composed and we will calculate the weights of best approximation for the determination of the average diameter of the drops from the fuel jet, respectively for the average length of the free jet (optimized jet).
To this purpose we note with CR_i, i=1÷k ,the feature of the group of drops of "i" order, respectively, the feature of the lengths of the average jet for interval "i. so we have the feature vector:

$$CR = (CR_1, CR_2, \dots, CR_n)^T \qquad (13)$$

To each feature from the vector CR we attach a triangular cut fuzzy number, noted with, like in Figure1.

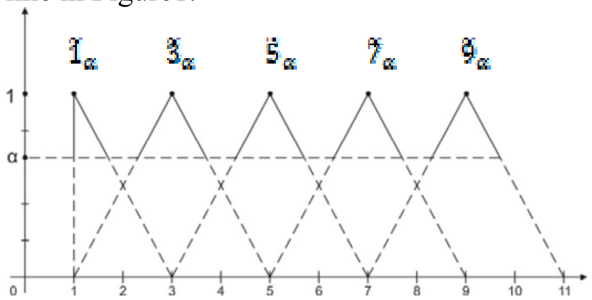

Fig.1. Geometric image of the cut fuzzy numbers

In this case the member function is of form:

$$\mu_A(x) = \begin{cases} 0, x \le a \\ \dfrac{x-a}{b-a}, x \in [a,b] \\ \dfrac{c-x}{c-b}, x \in [b,c] \\ 0, x \ge c \end{cases} \qquad (14)$$

In this paper we will use five fuzzy numbers $\tilde{1}_\alpha, \tilde{3}_\alpha, \tilde{5}_\alpha, \tilde{7}_\alpha, \tilde{9}_\alpha$ and their reverses atached tot he four mixture formation steps, respectively of the lenghts of the optimized fuel jet, and the first step makes reference to the cold start of the motor (maximum 30 seconds), the second step, idling (for the heating of the motor), the third is characterised by the run under total load and the fourth step idlerun (no load). This organisation is actually the hierarchisation on four levels, like in Fig.2. Therefore we have:

$$CR = (CR_1, CR_2, \dots, CR_n)^T$$

For this four features we will use the fuzzy numbers:

$$\begin{aligned} \tilde{1}_\alpha &= [1, 3-2\alpha] \\ \tilde{3}_\alpha &= [1+2\alpha, 5-2\alpha] \\ \tilde{5}_\alpha &= [3+2\alpha, 7-2\alpha] \\ \tilde{7}_\alpha &= [5+2\alpha, 9-2\alpha] \\ \tilde{9}_\alpha &= [7+2\alpha, 11-2\alpha] \end{aligned} \qquad (15)$$

and their reverses:

$$\begin{aligned} \tilde{1}_\alpha^{-1} &= \left[\frac{1}{3-2\alpha}, 1\right] \\ \tilde{3}_\alpha^{-1} &= \left[\frac{1}{5-2\alpha}, \frac{1}{1+2\alpha}\right] \\ \tilde{5}_\alpha^{-1} &= \left[\frac{1}{7-2\alpha}, \frac{1}{3+2\alpha}\right] \\ \tilde{7}_\alpha^{-1} &= \left[\frac{1}{9-2\alpha}, \frac{1}{5+2\alpha}\right] \\ \tilde{9}_\alpha^{-1} &= \left[\frac{1}{11-2\alpha}, \frac{1}{7+2\alpha}\right] \end{aligned} \qquad (16)$$

Using the ordering by arithmetic mean we can observe that $\tilde{1}_\alpha < \tilde{3}_\alpha < \tilde{5}_\alpha < \tilde{7}_\alpha < \tilde{9}_\alpha$.. This result will be used in the formation of the mixture features hierarhisation matrix CR1, CR_2, CR_3, CR_4, which formally are the same fort he average diameter for the fuel drops, as well as for the average length of the jet. The dive in R of the fuzzy numbers will be made by the convex combination of the ends of the interval which define the fuzzy number. So, if

$$\tilde{j}_\alpha = [\tilde{j}_\alpha^{(1)}, \tilde{j}_\alpha^{(2)}] \qquad (17)$$

then $j_\alpha \in \mathbb{R}$, the five of $\tilde{j}_\alpha$ in $\mathbb{R}$ is:

$$j_\alpha = \mu \tilde{j}_\alpha^{(2)} + (1-\mu)\tilde{j}_\alpha^{(1)} \qquad (18)$$

With these preparatory data, the implementation of the FAHP algorithm is realized by follwing steps:

- The hierehisation of the average diamater features, respectively of the jet length (mixture features)
- The description of the matrixes for the partial and global mixture features
- The endowment with fuzzy numbers of the mixture features, of the subcategories and categories
- The load of the matrixes of fuzzy order (MOF)
- The dive in R of the fuzzy order matrixes (the load with real numbers of the oder matrixes)
- Determination of the values an down vectors for the duzzy order matrixes
- Establishing the partial and global weights (taking the highest positive eigenvalue as criteria)

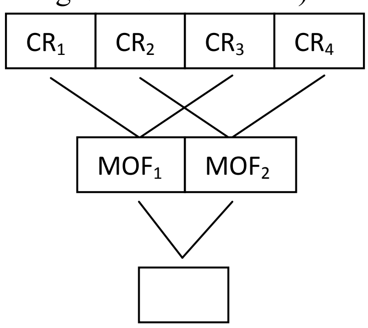

Fig.2. Ranking scheme of the mixture features

The general matrix of the mixture features is given in Figure 3.

CR₁ CR₂ CR₃ CR₄				
C_{11}	C_{12}	C_{13}	C_{14}	CR_1
C_{21}	C_{22}	C_{23}	C_{24}	CR_2
C_{31}	C_{32}	C_{33}	C_{34}	CR_3
C_{41}	C_{42}	C_{43}	C_{44}	CR_4

Fig.3. The matrix of the mixture features

The four mixture features are defined as follows:

CR_1 - the mixture feature for the first period after ignition, under 30 seconds (also known as at cold feature)

CR_2 - the mixture feature for the second period under 3 minutes (also known as at warming feature)

CR_3 - the feature for the third period in which the motor is under full load (also known as roll feature)

CR_4 - the mixture feature for the fourth period (also known as the idle feature)

Taking the importance of each feature in consideration, an attribution of the fuzzy numbers will be made (this attribution has a light subjective character). In this case, taking into account the order of the fuzzy numbers $\tilde{1}_\alpha < \tilde{3}_\alpha < \tilde{5}_\alpha < \tilde{7}_\alpha < \tilde{9}_\alpha$, this means that the most important ist he fuzzy number $\tilde{9}_\alpha$ and the least important ist he fuzzy number $\tilde{1}_\alpha$.

We propose the following attributes:

$$CR_1 \to \tilde{5}_\alpha; CR_2 \to \tilde{3}_\alpha; CR_3 \to \tilde{9}_\alpha; CR_1 \to \tilde{1}_\alpha \quad (19)$$

With this attribution we can build the order matrix FAHP.

	$\tilde{5}_\alpha$	$\tilde{3}_\alpha$	$\tilde{9}_\alpha$	$\tilde{1}_\alpha$
$\tilde{5}_\alpha$	1	$\tilde{5}_\alpha$	$\tilde{9}_\alpha^{-1}$	$\tilde{5}_\alpha$
$\tilde{3}_\alpha$	$\tilde{5}_\alpha^{-1}$	1	$\tilde{9}_\alpha^{-1}$	$\tilde{3}_\alpha$
$\tilde{9}_\alpha$	$\tilde{9}_\alpha$	$\tilde{9}_\alpha$	1	$\tilde{9}_\alpha$
$\tilde{1}_\alpha$	$\tilde{5}_\alpha^{-1}$	$\tilde{3}_\alpha^{-1}$	$\tilde{9}_\alpha^{-1}$	1

Fig.4.Order matrix

The determination of the global weights presumes a calculation of the eigenvalues and vectors and for the subcategories corresponding matrixes. In this case the sub category matrixes are given by the ranking scheme from Figure 2, so we have:

$$MOF1=\begin{pmatrix} 1 & q_\alpha^{-1} \\ q_\alpha & 1 \end{pmatrix} \qquad MOF2=\begin{pmatrix} 1 & \tilde{3}_\alpha \\ \tilde{3}_\alpha^{-1} & 1 \end{pmatrix}$$

Fig.5 .The matrix of the subcategories

where:

$$q_\alpha = \mu(11-2\alpha) + (1-\mu)(7+2\alpha)$$

$$q_\alpha^{-1} = \frac{\mu}{7+2\alpha} + \frac{1-\mu}{11-2\alpha}$$

$$\tilde{3}_\alpha = \mu(5-2\alpha) + (1-\mu)(1+2\alpha)$$

$$\tilde{3}_\alpha^{-1} = \frac{\mu}{1+2\alpha} + \frac{1-\mu}{5-2\alpha}$$

The determination of the global weights we get from using the partial weights. This are realized as follows: Let λ_0 be the biggest positive eigenvalues and $x_0 = (x_1^0, x_2^0, \dots, x_n^0)$ the eigenvector corresponding to λ_0 of a MOF matrix with elements in $\mathbb{R}$ (obtained by sinking in $\mathbb{R}$ with the help of a convex combination).

Then, the partial weights corresponding to MOF (corresponding to the mixture features which define this MOF matrix) are: $w_0 = (w_1^0, w_2^0, \dots, w_n^0)$, where w_k^0 is given by:

$$w_k^0 = \frac{x_k^0}{x_1^0 + x_2^0 + \dots + x_n^0} \quad (20)$$

and n is the dimension of the MOF matrix.

These weights have now the feature asked by the weights theory, which is:

$w_k^0 \in (0,1), k = 1 + n$

$$and \sum_{k=1}^{n} w_k^0 = 1 \qquad (21)$$

The global or final weights are obtained using the T-norm operator, which is applied as follows: If we follow the ranking scheme from Fig.2., we have:

$$T_{w_{CR_i}} = w_i \; and \; w_i = w_{CR_i} \cdot w_{MOF_j} \qquad (22)$$

$i = 1 + 4 \,, j = 1 + 2$

This way we get the global weights sequence:

$$\{w_1, w_2, w_3, w_4\} \qquad (23)$$

In this case:

$$\begin{aligned} w_1 &= w_{CR_1} \cdot w_{MOF_1} \\ w_2 &= w_{CR_2} \cdot w_{MOF_2} \\ w_3 &= w_{CR_3} \cdot w_{MOF_3} \\ w_4 &= w_{CR_4} \cdot w_{MOF_4} \end{aligned} \qquad (24)$$

this procedure given by the T-norm operator is generalized for any ranking scheme with any number of levels.

We can see that the global weights of a mixture feature is composed by more partial weights, it's the result of the contribution of the whole mixture feature system; fact which attenuates the subjective character through which a fuzzy number was attributed to each mixture feature.

The generalization of the feature ranking scheme is necessary if we refer to pollution research, besides her dynamic aspect (the time periods which we divided in four intervals), the intervention of the pollution factors determined by the speed of the auto vehicles which determine a different pollution level. For example [4], the concentration coefficient of the different substances which intervene in (1) depends on the way the car is being used. In this sense we present the next results experimentally obtained [6]:

$$\begin{aligned} &C_1(20) = 0{,}72 \;\; C_2(30) = 0{,}6 \\ &C_3(40) = 0{,}45 \; C_4(50) = 0{,}22 \\ &C_5(80) = 0{,}16 \;\; C_6(120) = 0{,}08 \end{aligned} \qquad (25)$$

where C_i indicates the correlation coefficient of the harmful evacuations of CO in relation to the speed of the car, in this case 20km/h,…,120km/h.

In this study we have to mention that the harmful substances produced by NO_x and C_xH_x don't depend on the speed of the car, they are a constant which has been experimentally approximated by:

$C_{NO_x} = 0{,}04$ and $C_{C_xH_x} = 0{,}1$ (26)

The numeric applications relative to the model proposed in Fig.6., assumes the attribution of values to the α and μ parameters.

In applications, is frequently used, the average fuzzy cut , in the case when α=1/2.

In this case, the MOF matrix with elements in R (Fig.6.), becomes:

$$\begin{pmatrix} 1 & 4+2\mu & \frac{4+\mu}{40} & 4+2\mu \\ \frac{2+\mu}{12} & 1 & \frac{4+\mu}{40} & 2+2\mu \\ 8+2\mu & 8+2\mu & 1 & 8+2\mu \\ \frac{2+\mu}{12} & \frac{1+\mu}{4} & \frac{4+\mu}{40} & 1 \end{pmatrix}$$

Fig.6. The average MOF matrix

For the convex combination parameter we propose a uniform meshing of the [0,1] interval, in four subintervals, as follows:

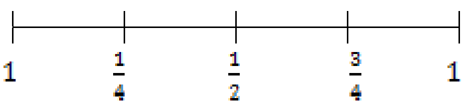

Fig.7. The meshing of the convex combination

For $\mu = \frac{1}{4}$ we get the „optimistic“ case, $\mu = \frac{1}{2}$ we have the „moderate“ case, and for $\mu = \frac{3}{4}$ the „pessimistic“ case (these cases are suggested by the fact that $\mu = \frac{1}{4}$ corresponds to a point from the fuzzy number with slope corresponding to an increasing function, so the line segment between the coordination points $A(2,\frac{1}{2})$ and B(4,1) if we refer to be fuzzy number $\tilde{3}_{\alpha}$, on the BC segment, with $C(6,\frac{1}{2})$ we have a decreasing function, and the maximum of the function in point B, corresponds to be moderate case). For $\mu = \frac{1}{4}$ the matrix in Fig.6. becomes:

1	$\frac{9}{2}$	$\frac{17}{160}$	$\frac{9}{2}$
$\frac{9}{48}$	1	$\frac{17}{160}$	$\frac{5}{2}$
$\frac{17}{2}$	$\frac{17}{2}$	1	$\frac{17}{2}$
$\frac{9}{48}$	$\frac{5}{16}$	$\frac{17}{160}$	1

Fig.8.The MOF matrix in case $\alpha = \frac{1}{2}, \mu = \frac{1}{4}$

We attach to this matrix in Figure 7 according to the ranking scheme from Figure 2, two sub matrixes $MOF_1\left(\frac{1}{2},\frac{1}{4}\right)$ and $MOF_2\left(\frac{1}{2},\frac{1}{4}\right)$:

$MOF_1\left(\frac{1}{2},\frac{1}{4}\right) =$

1	$\frac{17}{169}$
$\frac{17}{2}$	1

respectively

$MOF_2\left(\frac{1}{2},\frac{1}{4}\right) =$

1	$\frac{5}{2}$
$\frac{5}{16}$	1

This practical model is repeted now identically for the other two values of of μ, which is $\mu = \frac{1}{2}$ and $\mu = \frac{3}{4}$.

The positive maximal eigenvalue of the MOF matrix from Figure 8. is $p_1 = 4{,}2224$.

The partial weights corresponding this eigenvalue are:

$$w_{11} = 0{,}2273;\ w_{12} = 0{,}0865$$

$$w_{13} = 0{,}9685;\ w_{14} = 0{,}0534 \qquad (27)$$

For the MOF1 matrix, the positive maximal eigenvalues is p11=1,9492, and the corresponding partial weights are:

$$w_{21} = 0{,}1110\ \ w_{22} = 0{,}9938 \qquad (28)$$

For the MOF_2 matrix, p_{21}=1,8832, and the coresponding partial weights are:

$$w_{31} = 0{,}9429\ \ w_{32} = 0{,}3331 \qquad (29)$$

Finally, the global weights are obtained from the ranking scheme from Fig.2.,so:

$$\begin{aligned} w_1 &= w_{11} \cdot w_{21} \\ w_2 &= w_{12} \cdot w_{31} \\ w_3 &= w_{13} \cdot w_{22} \\ w_4 &= w_{14} \cdot w_{32} \end{aligned} \qquad (30)$$

Consequently, we get:

$$w_1 = 0{,}0252303;\ w_2 = 0{,}08155085$$

$$w_3 = 0{,}9624953;\ w_4 = 0{,}01778754 \qquad (31)$$

If we take into account the complexity of the calculation we can appreciate that the set of numbers from (31), have the feature of weights, because $w_1 + w_2 + w_3 + w_4 = 1{,}0870639 \approx 1$.

This result can be used now in the calculation of the weighted averages for all the mixture features.

In totally analog way is proceeded for the „moderate“ case, $\mu = 2$ respectively for the „pessimistic“ case $\mu = \frac{3}{4}$.

4. CONCLUSIONS

The formulas (30) show us that the subjectivism introduced by the attribution of each mixture feature to a cut fuzzy number, is attenuated by the rule of the ranking scheme. This feature is general, so it remains valid for all the approachable problems through weighted averages of best approximation. As we mentioned, the calculator can (by truncation process) introduce calculation errors. That is why the partial and global weights, calculated by the eigenvalues and vectors method, respectively by the normalization of the components of the eigenvectors, contain those trunks which only give us approximated values of the global weights. However, we finally got the global weights, the sum of which is sufficiently close to 1. This is a sign that the calculation procedure we followed (which is sufficiently laborious, from the point of view of the complexity of the calculation), is correct. The calculation of the sizes relative to the amount of pollutant substances, is of deterministic-stochastic (generated by the fuzzy numbers logic theory), leads to optimal results.

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Studiul poluării motorului DIESEL folosind logica fuzzy şi algoritmul FAHP

Rezumat: Prin această lucrare introducem un procedeu de calcul al cantităților de substanțe nocive (poluante) produse de motoarele DIESEL în procesul de funcționare. Acest nou procedeu presupune utilizarea datelor experimentale (a măsurătorilor în laborator sau standuri de probe) cu ajutorul cărora se formează medii ponderate. Calculul ponderilor se realizează prin metoda FAHP (Fuzzy Analysis Hierarhical Process) folosind numere fuzzy triunghiulare de tăietură.

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