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METHODS FOR DETERMINATION THE MATHEMATICAL MODELS OF VALVES AND ANALYTICAL ESTIMATION OF AGREEMENT BETWEEN THE MODEL AND RESULTS OF RESEARCH

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Abstract. *This paper presents the original methods for the valves mathematical models determination based on the theoretical and experimental results obtained by the valve response time investigation. The methods for defining the estimation of agreement between the model* $T_{zi} = Ar_1^a\gamma_2^b\delta_3^c\varphi_4^d\alpha_5^e p_{f_6}^g$ *and results of research, are also formed, as well as an original plan for theoretical and experimental investigation.*

Key words: *Mathematical modeling, similar valves, investigation plan, characteristic parameters, regression analysis, multi-correlation coefficient, partial correlation coefficient*

1. GOALS AND CONTENT OF RESEARCH

This paper is in continuity with previous ones [1 to 20] made by the same authors. The paper presents the methods for the valves mathematical models determination together with the methods for defining the estimation of agreement between the model and theoretical and experimental results.

The main goal of the research is to define methods for transformation of the valve response time mathematical model into certain analytical expression in the form like $T_{zi} = Ar_1^a\gamma_2^b\delta_3^c\varphi_4^d\alpha_5^e p_{f_6}^g$. Accordingly, the process of analysis could be done much easier.

The next goal is to define the plan of theoretical and experimental research, proper level of investigation and multi-correlation coefficient, all of that in order to establish valuable estimation of agreement between the model and investigation results.

For the functional relationship in the form:

$$T_{zi} = Ar^a\gamma^b\delta^c\varphi^d\alpha^e p_f^{\,g} \tag{1}$$

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coefficients of the best approximation plane in the sense of the least square method, that means, corresponding regression planes, could be obtained by regression analysis, utilizing experimental data for T_{zi}. On the basis of expression (1) it is quite easy to make a choice between the system characteristic parameters (r,γ,δ,φ,α,p_f) which determine the minimum value of the valve response time.

On the basis of the originally developed analytical expressions for multi-correlation coefficients, partial correlation coefficients and plan for theoretical and experimental investigation, couple of algorithms are established. Those algorithms are related to the mathematical models of the similar valves determination, as well as to the characteristic multi and partial correlation coefficients numerical identification, with the final aim to establish the qualitative estimation of the order of harmony between the theoretical model and experimental data for T_{zi}.

2. METHOD FOR MATHEMATICAL MODELS DETERMINATION FOR THE SIMILAR VALVES

The mathematical model of the valve shut-down or response time when the valve is exposed to the air blast pressure impulse, can generally be written in the form as expression looks like. Analytical expression for the valve response time, when the valve is exposed to the shock wave, can be determined by regression analysis, with the least square method, utilizing theoretical and experimental data for T_{zi}.

If we find a logarithm of expression (1) we shall have:

$$1nT_{zi} = 1nA + a1nr + b1n\gamma + c1n\delta + d1n\varphi + e1n\alpha + g1np_f \,.$$

Then, if we introduce the following substitutions:

$$Y_i = 1nT_{zi};\ a_0 = 1nA;\ a_1 = a;\ X_{1i} = 1nr;\ a_2 = b;\ X_{2i} = 1n\gamma;\ a_3 = c;$$
$$X_{3i} = 1n\delta;\ a_4 = d;\ X_{4i} = 1n\varphi;\ a_5 = e;\ X_{5i} = 1n\alpha;\ a_6 = g;\ X_{6i} = 1np_f$$

and take into account the theoretical and experimental data error (ε), we will get a linear regression equation:

$$Y_i = a_0 + a_1X_{1i} + a_2X_{2i} + a_3X_{3i} + a_4X_{4i} + a_5X_{5i} + a_6X_{6i} + \varepsilon \qquad (2)$$

The constants (a_0,a_1,a_2,a_3,a_4,a_5, a_6) determination is made by theoretical and experimental data analyisis, utilizing the least square method [4 to 9, 16, 17 to 26]. The method consists of the minimization of dispersion of theoretical and experimental results form a regression polinomial:

$$\left|\varepsilon\left(Y_i - a_0 - a_1X_{1i} - a_2X_{2i} - a_3X_{3i} - a_4X_{4i} - a_5X_{5i} - a_6X_{6i}\right)\right|_{\min} = (\varepsilon^2)\Big|_{\min} \qquad (3)$$

The minimum dispersion values can be find by differentiation of polinomial (3) with respect to the parameters of interest and by equalizing the first derivative with zero. After some formal rearrangements we shall get the equation set presented in a matrix form:

$$\begin{bmatrix} N & \Sigma X_{1i} & \Sigma X_{2i} & \Sigma X_{3i} & \Sigma X_{4i} & \Sigma X_{5i} & \Sigma X_{6i} \\ \Sigma X_{1i} & \Sigma X_{1i}^2 & \Sigma X_{1i}X_{2i} & \Sigma X_{1i}X_{3i} & \Sigma X_{1i}X_{4i} & \Sigma X_{1i}X_{5i} & \Sigma X_{1i}X_{6i} \\ \Sigma X_{2i} & \Sigma X_{1i}X_{2i} & \Sigma X_{2i}^2 & \Sigma X_{2i}X_{3i} & \Sigma X_{2i}X_{4i} & \Sigma X_{2i}X_{5i} & \Sigma X_{2i}X_{6i} \\ \Sigma X_{3i} & \Sigma X_{1i}X_{3i} & \Sigma X_{2i}X_{3i} & \Sigma X_{3i}^2 & \Sigma X_{3i}X_{4i} & \Sigma X_{3i}X_{5i} & \Sigma X_{3i}X_{6i} \\ \Sigma X_{4i} & \Sigma X_{1i}X_{4i} & \Sigma X_{2i}X_{4i} & \Sigma X_{3i}X_{4i} & \Sigma X_{4i}^2 & \Sigma X_{4i}X_{5i} & \Sigma X_{4i}X_{6i} \\ \Sigma X_{5i} & \Sigma X_{1i}X_{5i} & \Sigma X_{2i}X_{5i} & \Sigma X_{3i}X_{5i} & \Sigma X_{4i}X_{5i} & \Sigma X_{5i}^2 & \Sigma X_{5i}X_{6i} \\ \Sigma X_{6i} & \Sigma X_{1i}X_{6i} & \Sigma X_{2i}X_{6i} & \Sigma X_{3i}X_{6i} & \Sigma X_{4i}X_{6i} & \Sigma X_{5i}X_{6i} & \Sigma X_{6i}^2 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \end{bmatrix} = \begin{bmatrix} \Sigma X_{1i} \\ \Sigma X_{1i}Y_i \\ \Sigma X_{2i}Y_i \\ \Sigma X_{3i}Y_i \\ \Sigma X_{4i}Y_i \\ \Sigma X_{5i}Y_i \\ \Sigma X_{6i}Y_i \end{bmatrix} = \begin{bmatrix} B(0) \\ B(1) \\ B(2) \\ B(3) \\ B(4) \\ B(5) \\ B(6) \end{bmatrix} \quad (4)$$

The mathematical model of valve (1) could be obtained by the regression analysis, exploiting the least square method and utilizing theoretical and experimental data for T_{zi}.

To establish the qualitative estimation of the order of agreement between analyitical expression for T_{zi} and investigation results obtained for T_{zi}, it is necessary to define analytical expressions for the multi-correlation coefficients and characteristic partial correlation coefficients related to the functional relationship (1).

For that purposes, in order to make the presentation as simplest as possible, the following indexes are intoduced: index »1« correspond to the vlave fin semiradius (r), index »2« corresponds to the valve fin material density (γ), index »3« corresponds to the valve fin thickness (δ), index »4« corresponds to the valve fin rotation angle (φ), index »5« corresponds to the fin rotational axis inclincation angle with respect to vertical plane (α), and index »6« corresponds to the pressure in the direct shock wave front (p_f), [16, 17]. So, the functional relationship (1) can be expressed in the following form, considering the indexes mentioned above:

$$T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g \quad (5)$$

3. MULTI-CORRELATION COEFFICIENT $R_{i\cdot 123456}$ FOR FUNCTIONAL RELATIONSHIP $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g$

The multi-correlation coefficient $R_{i\cdot 123456}$ for functional relationship (5) defines the order of agreement between the established valve mathematical model and the obtained investigation results for T_{zi}. That coefficient can be defined by the following analytical expression, [17]:

$$R_{i\cdot 123456} = \sqrt{1-[(1-r_{i1}^2)(1-r_{i2\cdot 1}^2)(1-r_{i3\cdot 12}^2)(1-r_{i4\cdot 123}^2)(1-r_{i5\cdot 1234}^2)(1-r_{i6\cdot 12345}^2)]} \quad (6)$$

3.1. Partial correlation coefficient $r_{i2\cdot 1}$

The partial correlation coefficient $r_{i2\cdot 1}$, existing in expression (6) can be defined by the following analytical expression, [16,17]:

$$r_{i2\cdot 1} = \frac{r_{i2} - r_{i1}r_{21}}{\sqrt{(1-r_{i1}^2)(1-r_{21}^2)}} \quad (7)$$

3.2. Partial correlation coefficient $r_{i3\cdot12}$

The partial correlation coefficient $r_{i3\cdot12}$, existing in expression (6) can be defined by the following analytical expression:

$$r_{i3\cdot12} = \frac{r_{i3\cdot2} - r_{i1\cdot2} r_{31\cdot2}}{\sqrt{(1 - r_{i1\cdot2}^2)(1 - r_{31\cdot2}^2)}} \tag{8}$$

The partial correlation coefficients, $r_{i3\cdot2}$, $r_{i1\cdot2}$ and $r_{31\cdot2}$ existing in expression (8) can be defined by the following analytical expressions, [16,17]:

$$r_{i3\cdot2} = \frac{r_{i3} - r_{i2} r_{32}}{\sqrt{(1 - r_{i2}^2)(1 - r_{32}^2)}} \tag{9}$$

$$r_{i1\cdot2} = \frac{r_{i1} - r_{i2} r_{12}}{\sqrt{(1 - r_{i2}^2)(1 - r_{12}^2)}} \tag{10}$$

$$r_{31\cdot2} = \frac{r_{31} - r_{32} r_{12}}{\sqrt{(1 - r_{32}^2)(1 - r_{12}^2)}} \tag{11}$$

3.3. Partial correlation coefficient $r_{i4\cdot123}$

The partial correlation coefficient $r_{i4\cdot123}$, existing in expression (6) can be defined by the following analytical expression, [17]:

$$r_{i4\cdot123} = \frac{r_{i4\cdot23} - r_{i1\cdot23} r_{41\cdot23}}{\sqrt{(1 - r_{i1\cdot23}^2)(1 - r_{41\cdot23}^2)}} \tag{12}$$

The partial correlation coefficients $r_{i4\cdot23}$, $r_{i1\cdot23}$ and $r_{41\cdot23}$ existing in expression (12) can be defined by the following analytical expressions:

$$r_{i4\cdot23} = \frac{r_{i4\cdot3} - r_{i2\cdot3} r_{42\cdot3}}{\sqrt{(1 - r_{i2\cdot3}^2)(1 - r_{42\cdot3}^2)}} \tag{13}$$

$$r_{i1\cdot23} = \frac{r_{i1\cdot3} - r_{i2\cdot3} r_{12\cdot3}}{\sqrt{(1 - r_{i2\cdot3}^2)(1 - r_{12\cdot3}^2)}} \tag{14}$$

$$r_{41\cdot23} = \frac{r_{41\cdot3} - r_{42\cdot3} r_{12\cdot3}}{\sqrt{(1 - r_{42\cdot3}^2)(1 - r_{12\cdot3}^2)}} \tag{15}$$

The partial correlation coefficients $r_{i4\cdot3}$, $r_{i2\cdot3}$ and $r_{42\cdot3}$, existing in expressions (13) and (14) can be defined by the following analytical expressions:

$$r_{i4\cdot3} = \frac{r_{i4} - r_{i3} r_{43}}{\sqrt{(1 - r_{i3}^2)(1 - r_{43}^2)}} \tag{16}$$

$$r_{i2\cdot3} = \frac{r_{i2} - r_{i3} r_{23}}{\sqrt{(1 - r_{i3}^2)(1 - r_{23}^2)}} \tag{17}$$

$$r_{42\cdot 3} = \frac{r_{42} - r_{43}r_{23}}{\sqrt{(1-r_{43}^2)(1-r_{23}^2)}} \tag{18}$$

The partial correlation coefficients $r_{i1\cdot 3}$ and $r_{12\cdot 3}$, existing in expressions (14) and (15) can be defined by the following analytical expressions:

$$r_{i1\cdot 3} = \frac{r_{i1} - r_{i3}r_{13}}{\sqrt{(1-r_{i3}^2)(1-r_{13}^2)}} \tag{19}$$

$$r_{12\cdot 3} = \frac{r_{12} - r_{13}r_{23}}{\sqrt{(1-r_{13}^2)(1-r_{23}^2)}} \tag{20}$$

The partial correlation coefficient $r_{41\cdot 3}$, existing in expression (15) can be defined by the following analytical expression:

$$r_{41\cdot 3} = \frac{r_{41} - r_{43}r_{13}}{\sqrt{(1-r_{43}^2)(1-r_{13}^2)}} \tag{21}$$

3.4. Partial correlation coefficient $r_{i5\cdot 1234}$

The partial correlation coefficient $r_{i5\cdot 1234}$, existing in expression (6) can be defined by the following analytical expression, [17]:

$$r_{i5\cdot 1234} = \frac{r_{i5\cdot 234} - r_{i1\cdot 234}r_{51\cdot 234}}{\sqrt{(1-r_{i1\cdot 234}^2)(1-r_{51\cdot 234}^2)}} \tag{22}$$

The partial correlation coefficients $r_{i5\cdot 1234}$, $r_{i1\cdot 234}$ and $r_{51\cdot 234}$, existing in expression (22) can be defined by the following analytical expressions:

$$r_{i5\cdot 234} = \frac{r_{i5\cdot 34} - r_{i2\cdot 34}r_{52\cdot 34}}{\sqrt{(1-r_{i2\cdot 34}^2)(1-r_{52\cdot 34}^2)}} \tag{23}$$

$$r_{i1\cdot 234} = \frac{r_{i1\cdot 34} - r_{i2\cdot 34}r_{12\cdot 34}}{\sqrt{(1-r_{i2\cdot 34}^2)(1-r_{12\cdot 34}^2)}} \tag{24}$$

$$r_{51\cdot 234} = \frac{r_{51\cdot 34} - r_{52\cdot 34}r_{12\cdot 34}}{\sqrt{(1-r_{52\cdot 34}^2)(1-r_{12\cdot 34}^2)}} \tag{25}$$

The partial correlation coefficients $r_{i5\cdot 34}$, $r_{i2\cdot 34}$ and $r_{52\cdot 34}$, existing in expression (23) can be defined by the following analytical expressions:

$$r_{i5\cdot 34} = \frac{r_{i5\cdot 4} - r_{i3\cdot 4}r_{53\cdot 4}}{\sqrt{(1-r_{i3\cdot 4}^2)(1-r_{53\cdot 4}^2)}} \tag{26}$$

$$r_{i2\cdot 34} = \frac{r_{i2\cdot 4} - r_{i3\cdot 4}r_{23\cdot 4}}{\sqrt{(1-r_{i3\cdot 4}^2)(1-r_{23\cdot 4}^2)}} \tag{27}$$

$$r_{52\cdot 34} = \frac{r_{52\cdot 4} - r_{53\cdot 4}r_{23\cdot 4}}{\sqrt{(1-r_{53\cdot 4}^2)(1-r_{23\cdot 4}^2)}} \tag{28}$$

The partial correlation coefficients $r_{i1\cdot34}$ and $r_{12\cdot34}$, existing in expression (24) can be defined by the following analytical expressions:

$$r_{i1\cdot34}=\frac{r_{i1\cdot4}-r_{i3\cdot4}r_{13\cdot4}}{\sqrt{(1-r_{i3\cdot4}^2)(1-r_{13\cdot4}^2)}} \tag{29}$$

$$r_{12\cdot34}=\frac{r_{12\cdot4}-r_{13\cdot4}r_{23\cdot4}}{\sqrt{(1-r_{13\cdot4}^2)(1-r_{23\cdot4}^2)}} \tag{30}$$

The partial correlation coefficients $r_{51\cdot34}$, existing in expression (25) can be defined by the following analytical expression:

$$r_{51\cdot34}=\frac{r_{51\cdot4}-r_{53\cdot4}r_{13\cdot4}}{\sqrt{(1-r_{53\cdot4}^2)(1-r_{13\cdot4}^2)}} \tag{31}$$

The partial correlation coefficients $r_{i5\cdot4}$, $r_{i3\cdot4}$ and $r_{53\cdot4}$, existing in expression (26) can be defined by the following analytical expressions:

$$r_{i5\cdot4}=\frac{r_{i5}-r_{i4}r_{54}}{\sqrt{(1-r_{i4}^2)(1-r_{54}^2)}} \tag{32}$$

$$r_{i3\cdot4}=\frac{r_{i3}-r_{i4}r_{34}}{\sqrt{(1-r_{i4}^2)(1-r_{34}^2)}} \tag{33}$$

$$r_{53\cdot4}=\frac{r_{53}-r_{54}r_{34}}{\sqrt{(1-r_{54}^2)(1-r_{34}^2)}} \tag{34}$$

The partial correlation coefficients $r_{i2\cdot4}$ and $r_{23\cdot4}$, existing in expression (27) can be defined by the following analytical expressions:

$$r_{i2\cdot4}=\frac{r_{i2}-r_{i4}r_{24}}{\sqrt{(1-r_{i4}^2)(1-r_{24}^2)}} \tag{35}$$

$$r_{23\cdot4}=\frac{r_{23}-r_{24}r_{34}}{\sqrt{(1-r_{24}^2)(1-r_{34}^2)}} \tag{36}$$

The partial correlation coefficient $r_{52\cdot4}$, existing in expression (28) can be defined by the following analytical expression:

$$r_{52\cdot4}=\frac{r_{52}-r_{54}r_{24}}{\sqrt{(1-r_{54}^2)(1-r_{24}^2)}} \tag{37}$$

The partial correlation coefficients $r_{i1\cdot4}$ and $r_{13\cdot4}$, existing in expression (29) can be defined by the following analytical expressions:

$$r_{i1\cdot4}=\frac{r_{i1}-r_{i4}r_{14}}{\sqrt{(1-r_{i4}^2)(1-r_{14}^2)}} \tag{38}$$

$$r_{13\cdot4}=\frac{r_{13}-r_{14}r_{34}}{\sqrt{(1-r_{14}^2)(1-r_{34}^2)}} \tag{39}$$

The partial correlation coefficient $r_{12\cdot4}$, existing in expression (30) can be defined by the following analytical expression:

$$r_{12\cdot4} = \frac{r_{12} - r_{14}r_{24}}{\sqrt{(1-r_{14}^2)(1-r_{24}^2)}} \tag{40}$$

The partial correlation coefficient r_{51}, existing in expression (31) can be defined by the following analytical expression:

$$r_{51\cdot4} = \frac{r_{51} - r_{54}r_{14}}{\sqrt{(1-r_{54}^2)(1-r_{14}^2)}} \tag{41}$$

The partial correlation coefficients r_{i1}, r_{i2}, r_{i3}, r_{i4} and r_{i5}, can be defined by the following analytical expressions:

$$r_{i1} = \frac{\Sigma X_{1i}Y_i}{\sqrt{(\Sigma X_{1i}^2)(\Sigma Y_1^2)}} = \frac{B(1)}{\sqrt{X(1,1)C(0)}} \tag{42}$$

$$r_{i2} = \frac{\Sigma X_{2i}Y_i}{\sqrt{(\Sigma X_{2i}^2)(\Sigma Y_1^2)}} = \frac{B(2)}{\sqrt{X(2,2)C(0)}} \tag{43}$$

$$r_{i3} = \frac{\Sigma X_{33i}Y_i}{\sqrt{(\Sigma X_{3i}^2)(\Sigma Y_i^2)}} = \frac{B(3)}{\sqrt{X(3,3)C(0)}} \tag{44}$$

$$r_{i4} = \frac{\Sigma X_{4i}Y_i}{\sqrt{(\Sigma X_{4i}^2)(\Sigma Y_i^2)}} = \frac{B(4)}{\sqrt{X(4,4)C(0)}} \tag{45}$$

$$r_{i5} = \frac{\Sigma X_{5i}Y_i}{\sqrt{(\Sigma X_{5i}^2)(\Sigma Y_i^2)}} = \frac{B(5)}{\sqrt{X(5,5)C(0)}} \tag{46}$$

The partial correlation coefficients r_{12}, r_{13} and r_{14}, can be defined by the following analytical expressions:

$$r_{12} = \frac{\Sigma X_{1i}X_{2i}}{\sqrt{(\Sigma X_{1i}^2)(\Sigma X_{2i}^2)}} = \frac{X(1,2)}{\sqrt{X(1,1)X(2,2)}} \tag{47}$$

$$r_{13} = \frac{\Sigma X_{1i}X_{3i}}{\sqrt{(\Sigma X_{1i}^2)(\Sigma X_{3i}^2)}} = \frac{X(1,3)}{\sqrt{X(1,1)X(3,3)}} \tag{48}$$

$$r_{14} = \frac{\Sigma X_{1i}X_{4i}}{\sqrt{(\Sigma X_{1i}^2)(\Sigma X_{4i}^2)}} = \frac{X(1,4)}{\sqrt{X(1,1)X(4,4)}} \tag{49}$$

The partial correlation coefficients r_{23}, r_{24} and r_{34}, can be defined by the following analytical expressions:

$$r_{23} = \frac{\Sigma X_{2i}X_{3i}}{\sqrt{(\Sigma X_{2i}^2)(\Sigma X_{3i}^2)}} = \frac{X(2,3)}{\sqrt{X(2,2)X(3,3)}} \tag{50}$$

$$r_{24} = \frac{\Sigma X_{2i}X_{4i}}{\sqrt{(\Sigma X_{2i}^2)(\Sigma X_{4i}^2)}} = \frac{X(2,4)}{\sqrt{X(2,2)X(4,4)}} \tag{51}$$

$$r_{34} = \frac{\Sigma X_{3i} X_{4i}}{\sqrt{(\Sigma X_{3i}^2)(\Sigma X_{4i}^2)}} = \frac{X(3,4)}{\sqrt{X(3,3)X(4,4)}} \tag{52}$$

where: $r_{23} \equiv r_{32}$, $r_{24} \equiv r_{42}$ and $r_{34} \equiv r_{43}$.

The partial correlation coefficients r_{52}, r_{53} and r_{54}, can be defined by the following analytical expressions:

$$r_{52} \equiv r_{25} = \frac{\Sigma X_{2i} X_{5i}}{\sqrt{(\Sigma X_{2i}^2)(\Sigma X_{5i}^2)}} = \frac{X(2,5)}{\sqrt{X(2,2)X(5,5)}} \tag{53}$$

$$r_{53} \equiv r_{35} = \frac{\Sigma X_{3i} X_{5i}}{\sqrt{(\Sigma X_{3i}^2)(\Sigma X_{5i}^2)}} = \frac{X(3,5)}{\sqrt{X(3,3)X(5,5)}} \tag{54}$$

$$r_{54} \equiv r_{45} = \frac{\Sigma X_{4i} X_{5i}}{\sqrt{(\Sigma X_{4i}^2)(\Sigma X_{5i}^2)}} = \frac{X(4,5)}{\sqrt{X(4,4)X(5,5)}} \tag{55}$$

3.5. Partial correlation coefficient $r_{i6\cdot 12345}$

The partial correlation coefficient $r_{i6\cdot 12345}$ for functional relationship (5) defines the order of agreement between dependent variable T_{zi} and independent parameter p_f, in the case when the other independent parameters (r,γ,δ,φ,α) are presumed to be constant. This coefficient can be defined by the following analytical expression, [17]:

$$r_{i6\cdot 12345} = \frac{r_{i6\cdot 2345} - r_{i1\cdot 2345} r_{61\cdot 2345}}{\sqrt{(1 - r_{i1\cdot 2345}^2)(1 - r_{61\cdot 2345}^2)}} \tag{56}$$

4. Plan for theoretical and expreimental investigation of functional relationship $T_{zi} = A r_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g$

The plan for theoretical and experimental investigation of the functional relationship $T_{zi} = A r_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g$ is given in Table 1. The total number of experimental units is:

$$N = n_r n_\gamma n_\delta n_\varphi n_\alpha n_{p_f} \tag{57}$$

where: n_r - level number of characteristic parameter r,
n_γ - level number of characteristic parameter γ,
n_δ - level number of characteristic parameter δ,
n_φ - level number of characteristic parameter φ,
n_α - level number of characteristic parameter α and
n_{p_f} - level number of characteristic parameter p_f

Table 1

Valve fin semiradius r[m]	Valve fin material density γ[kg/m^3]	Valve fin thickness δ[mm]	Valve fin rotation angle φ[^{o}]	Valve fin rotational axis inclination angle α[^{o}]	Direct shock wave front pressure p_f[kPa]			
					p_{f_1}	p_{f_2}	...	$p_{f_{npf}}$
					Valve shut – down or response time T_{zi}[s]			
				α_1				
			φ_1	...				
				α_{n_α}				
		δ_1	...					
				α_1				
			φ_{n_φ}	...				
				α_{n_α}				
	γ_1	...						
				α_1				
			φ_1	...				
				α_{n_α}				
		δ_{n_δ}	...					
				α_1				
			φ_{n_φ}	...				
r_{n_r}				α_{n_α}				
				α_1				
			φ_1	...				
				α_{n_α}				
		δ_1	...					
				α_1				
			φ_{n_φ}	...				
				α_{n_α}				
	γ_{n_γ}	...						
				α_1				
			φ_1	...				
				α_{n_α}				
		δ_{n_δ}	...					
				α_1				
			φ_{n_φ}	...				
				α_{n_α}				

5. CONCLUSION

The original method for determination of the valves mathematical models were presented here, as well as the methods for estimation of the agreement between the model $T_{zi} = A r_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g$ and practical results of investigation. The methods are based upon the theoretical and experimental research.

More precisely, here we defined the methods for transformation of analytical expressions of the similar valves shut-down time (obtained in exact way, utilizing the laws of Physics) into analytical expressions in form $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g$. It was done in order to make the analysis of the system characteristic parameters ($r,\gamma,\delta,\varphi,\alpha,p_f$) as easier as possible. The analysis has to show which parameters determine the minimum valve response times. An original plan for theoretical and experimental investigation of suitable level of research was made. Also, the analytical expressions for characteristic partial correlation coefficients and multi-correlation coefficient were developed in order to establish qualitative estimation of the agreement between the model and practical data.

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METODE ZA ODREĐIVANJE MATEMATIČKIH MODELA VENTILA I ANALITIČKA OCENA SLAGANJA MODELA I ISTRAŽIVANJA

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Ovaj rad prezentira originalne metode za određivanje matematičkih modela ventila bazirane na teorijskim i eksperimentalnim rezultatima dobijenim pomoću istraživanja vremenskog odziva ventila. Formirane su metode za određivanje ocene slaganja između modela $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f_6}^g$ *i rezultata istraživanja kao i originalni plan teorijskog i eksperimentalnog istraživanja.*