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ANALYTICAL DEFINITION OF INFLUENCE OF THE SYSTEM $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f6}^g$ CHARACTERISTIC PARAMETERS (r,γ,α,p_f) UPON THE VALVE RESPONSE TIME

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Abstract. *This paper presents a method for analytical definition of influence of the system $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f6}^g$ characteristic parameters (r,γ,α,p_f) upon the valve response times (T_{zi}). The method is formed to identify the system characteristic parameters which determine the valve response time minimum value. Mathematical model of the response times of the valve being under the action of shock wave, is made utilizing the regression analysis, by the least square method and exploiting the experimental data for T_{zi}.*

Key words: *Pneumatic valve, mathematical model, response times, characteristic parameters, model quantitative estimation.*

INTRODUCTION

The paper is in continuity with previous papers [1 to 5] by the same authors and deals with the method for analytical definition of influence of the system $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f6}^g$ characteristic parameters (r,γ,α,p_f) upon the valve response time. The method serves to identify the system characteristic parameters which determine the valve response time minimum value, when the valve is exposed to the nuclear explosion air-blast wave. The purpose of research is to define the analytical expressions for the characteristic parameters influence upon the response times of the similarly designed valves being under the action of shock wave.

On the basis of analytical expressions for the system characteristic parameters influence upon the valve response times, the quantitative analysis of that influence is done.

The qualitative analysis of the system characteristic parameters (r,γ,α,p_f) influence upon the valve response times is made on the basis of numerical values of the characteristic partial correlation coefficients $r_{i1\cdot23456}$, $r_{i2\cdot13456}$, $r_{i5\cdot12346}$ and $r_{i6\cdot12345}$ for the

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functional relationship $T_{zi} = Ar_1^{\,a}\gamma_2^{\,b}\delta_3^{\,c}\varphi_4^{\,d}\alpha_5^{\,e}p_{f6}^{\,g}$.

Symbols:

T_{zi} - response time of the valve being under the direct shock wave action,
r - valve vane semiradius,
γ - valve vane material density,
δ - valve vane thickness,
p_f - pressure in front of the nuclear explosion direct air-blast wave,
α - valve vane rotation axis inclination angle with respect to the vertical plane,
A,a,b,c,d,e,g - constants,
α_n, p_{fn} - system characteristic parameters nominal values,
$r_{\min}$, $\gamma_{\min}$ - system characteristic parameters minimum values,
$r_{i1\cdot 23456}$, $r_{i2\cdot 13456}$, $r_{i5\cdot 12346}$, $r_{i6\cdot 12345}$ - characteristic partial correlation coefficients for the system $T_{zi} = Ar_1^{\,a}\gamma_2^{\,b}\delta_3^{\,c}\varphi_4^{\,d}\alpha_5^{\,e}p_{f6}^{\,g}$,
A_r,a_r - valve response time ratio coefficient and characteristic parameter r_i influence, with respect to the minimal value $r_{\min}$, for the case when other characteristic parameters ($\gamma,\delta,\varphi,\alpha, p_f$) are constant,
A_γ,a_γ - valve response time ratio coefficient and characteristic parameter γ_i influence, with respect to the minimal value $\gamma_{\min}$, for the case when other characteristic parameters ($r,\delta,\varphi,\alpha, p_f$) are constant,
A_α,a_α - valve response time ratio coefficient and characteristic parameter α_{ii} influence, with respect to the nominal value α_n, for the case when other characteristic parameters ($r,\gamma,\delta,\varphi, p_f$) are constant,
A_{p_f},a_{p_f} - valve response time ratio coefficient and characteristic parameter p_{fi} influence, with respect to the nominal value p_{fn}, for the case when other characteristic parameters ($r,\gamma,\delta,\varphi, \alpha$) are constant,
a_r[%], a_γ[%], a_α[%], a_{p_f}[%]- percentage values of the characteristic parameters (r,γ,α, p_f) influence, with respect to the extreme values of the characteristic parameters (r,γ,α,p_f), for the cases when other characteristic parameters ($\gamma,\delta,\varphi,\alpha, p_f$), ($r,\delta,\varphi,\alpha, p_f$), ($r,\gamma,\delta,\varphi,p_f$) and ($r,\gamma,\delta,\varphi,\alpha$) are constant, respectively.

ANALYTICAL EXPRESSIONS FOR THE SYSTEM $T_{zi} = Ar_1^{\,a}\gamma_2^{\,b}\delta_3^{\,c}\varphi_4^{\,d}\alpha_5^{\,e}p_{f6}^{\,g}$ CHARACTERISTIC PARAMETERS INFLUENCE UPON THE SIMILAR VALVES RESPONSE TIMES

Analytical expressions for the system $T_{zi} = Ar_1^{\,a}\gamma_2^{\,b}\delta_3^{\,c}\varphi_4^{\,d}\alpha_5^{\,e}p_{f6}^{\,g}$ characteristic parameters (r,γ,α,p_f) upon the valves response times, with respect to the extreme values of those characteristic parameters, for the cases when the other characteristic parameters ($\gamma,\delta,\varphi,\alpha, p_f$), ($r,\delta,\varphi,\alpha, p_f$), ($r,\gamma,\delta,\varphi,p_f$) and ($r,\gamma,\delta,\varphi,\alpha$), respectively, are constant, can be defined by exploiting the analytical expressions for the valves response times. Generally, analytical expression for the similar valves response time, when the valves are directly exposed to the shock wave, can be written in the following form, [4,5]:

$$T_{zi} = Ar_1^{a}\gamma_2^{b}\delta_3^{c}\varphi_4^{d}\alpha_5^{e}p_{f6}^{g} \tag{1}$$

Analyzing the influence of the system characteristic parameters ($r,\gamma,\delta,\varphi,\alpha,p_f$) upon the valve response time T_{zi}, one can transform expression (1) into:

$$T_{zi} = A\frac{r_1^a\gamma_2^b\delta_3^c\varphi_4^d}{\alpha_5^e p_{f6}^g} \tag{2}$$

The expression above is pretty convenient for quantitative analysis of the system characteristic parameters influence upon the valves response times.

2.1 Characteristic parameter *r* influence upon the valves response times T_{zi}

The valve response time ratio coefficient and characteristic parameter r_i influence, with respect to the minimal value $r_{\min}$, for the case when other characteristic parameters ($\gamma,\delta,\varphi,\alpha,p_f$) are constant, could be analytically defined, utilizing expression (2), as follows:

$$A_r = \frac{T_{zi} \mid r_{\min}}{T_{zi} \mid r_i} = \left(\frac{r_{\min}}{r_i}\right)^a \tag{3}$$

$$a_r = \left[1 - \left(\frac{r_{\min}}{r_i}\right)^a\right] \tag{4}$$

2.2 Characteristic parameter γ influence upon the valves response times T_{zi}

The valves response time ratio coefficient and characteristic parameter γ_i influence, with respect to the minimal value $\gamma_{\min}$, for the case when other characteristic parameters ($r,\delta,\varphi,\alpha,p_f$) are constant, could be analytically defined, utilizing expression (2) as follows:

$$A_\gamma = \frac{T_{zi} \mid \gamma_{\min}}{T_{zi} \mid \gamma_i} = \left(\frac{\gamma_{\min}}{\gamma_i}\right)^b \tag{5}$$

$$a_\gamma = \left[1 - \left(\frac{\gamma_{\min}}{\gamma_i}\right)^b\right] \tag{6}$$

2.3 Characteristic parameter α influence upon the valves response times T_{zi}

The valve response time ratio coefficient and characteristic parameter α_i influence, with respect to the nominal value α_n, for the case when other characteristic parameters ($r,\gamma,\delta,\varphi,p_f$) are constant, could be analytically defined, utilizing expression (2), as follows:

$$A_\alpha = \frac{T_{zi} \mid \alpha_n}{T_{zi} \mid \alpha_i} = \left(\frac{\alpha_i}{\alpha_n}\right)^e \tag{7}$$

$$a_\alpha = \left[1 - \left(\frac{\alpha_i}{\alpha_n}\right)^e\right] \tag{8}$$

2.4 Characteristic parameter p_f influence upon the valves response times T_{zi}

The valves response time ratio coefficient and characteristic parameter p_{f_i} influence, with respect to the nominal value p_{f_n}, for the case when other characteristic parameters (r,γ,δ,φ,α) are constant, could be analytically defined, utilizing expression (2), as follows:

$$A_{p_f} = \frac{T_{zi} \mid p_{f_n}}{T_{zi} \mid p_{f_i}} = \left(\frac{p_{f_n}}{p_{f_i}} \right)^g \tag{9}$$

$$a_{p_f} = \left[1 - \left(\frac{p_{f_i}}{p_{f_n}} \right)^g \right] \tag{10}$$

2.5 Percentage values of the characteristic parameters (r,γ,α,p_f) influence upon the valves response times T_{zi}

Percentage values of the system (1) characteristic parameters (r,γ,α,p_f) influence upon the similarly designed valves response times (T_{zi}), with respect to the extreme values of those characteristic parameters, for the cases when other characteristic parameters (γ,δ,φ,α,p_f), (r,δ,φ,α,p_f), (r,γ,δ,φ,p_f) and (r,γ,δ,φ,α) are constant respectively, could be defined on the basis of (1) and (2), utilizing expressions (4), (6), (8) and (10), as follows:

$$a_r = \left[1 - \left(\frac{r_{\min}}{r_i} \right)^a \right] 100\,[\%] \tag{11}$$

$$a_\gamma = \left[1 - \left(\frac{\gamma_{\min}}{\gamma_i} \right)^b \right] 100\,[\%] \tag{12}$$

$$a_\alpha = \left[1 - \left(\frac{\alpha_i}{\alpha_n} \right)^e \right] 100\,[\%] \tag{13}$$

$$a_{p_f} = \left[1 - \left(\frac{p_{fi}}{p_{fn}} \right)^g \right] 100\,[\%] \tag{14}$$

CONCLUSION

Analytical expressions for the system $T_{zi} = A r_1^{\,a} \gamma_2^{\,b} \delta_3^{\,c} \varphi_4^{\,d} \alpha_5^{\,e} p_{f6}^{\,g}$ characteristic parameters (r,γ,α,p_f) influence upon the similarly designed valves response times (T_{zi}) are defined in order to enable the identification of the system characteristic parameters which determine the minimal values of the valves response times.

On the basis of the analytical expressions mentioned above, the quantitative analysis of the system characteristic parameter influence upon the valves response times has been

conducted.

The analytical expression for the valves response times when they are directly exposed to shock wave, is determined utilizing the regression analysis, by the least square method, [5 to 12] and exploiting the experimental data for T_{zi}.

The qualitative analysis of the system (1) characteristic parameters (r,γ,α,p_f) influence upon the valves response times is made on the basis of numerical values of the partial correlation characteristic coefficients $r_{i1\cdot 23456}$, $r_{i2\cdot 13456}$, $r_{i5\cdot 12346}$ and $r_{i6\cdot 12345}$, of the functional relationship $T_{zi} = Ar_1^a \gamma_2^b \delta_3^c \varphi_4^d \alpha_5^e p_{f6}^g$. The coefficients mentioned have to be analytically defined.

For the qualitative analysis of the system characteristic parameter p_f influence upon the valve response time, the partial correlation characteristic coefficient $r_{i6\cdot 12345}$ has been defined, [4].

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ANALITIČKA DEFINICIJA UTICAJA KARAKTERISTIČNIH PARAMETARA SISTEMA $T_{zi} = Ar_1^{\ a}\gamma_2^{\ b}\delta_3^{\ c}\varphi_4^{\ d}\alpha_5^{\ e}p_{f6}^{\ g}$ NA VREME ODZIVA VENTILA

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Ovaj rad prikazuje metodu za analitičko definisanje uticaja karakterističnih parametara (r,γ,α,p_f) *sistema* $T_{zi} = Ar_1^{\ a}\gamma_2^{\ b}\delta_3^{\ c}\varphi_4^{\ d}\alpha_5^{\ e}p_{f6}^{\ g}$ *na vreme odziva ventila* T_{zi}. *Ova metoda je formirana u cilju identifikacije karakterističnih parametara sistema koji određuju minimalno vreme odziva ventila. Matematički model vremena odziva ventila na koji dejstvuje pobudni talas dobijen je korišćenjem analize regresije, metodom najmanjih kvadrata i korišćenjem eksperimentalnih podataka za* T_{zi}.