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THE MOMENT OF INERTIA OF THE JET OF EXTINGUISHING AGENT

The expression for the moment of inertia of the jet of extinguishing agent with respect to the vertical axis at its maximum range is obtained.

Keywords: jet, extinguishing agent, moment of inertia.

Problem formulation. The appearance of serially produced fire fighter robots caused a significant expansion of the scope of automatic fire extinguishing systems. In particular, it concerns the protection of production facilities with large square, wide-span building and structures (hangars for aircraft, sport and exhibition complexes, tunnels, storages, etc), outdoor facilities with high fire risk and other. Effectiveness of these systems depends on technical characteristics of fire fighter robots. One of the problems is effective delivery of fire extinguishing agent to the combustion zone.

Analysis of recent researches and publications. The solution of the problem of effective delivering the extinguishing agent to combustion zone corresponds to solving the problem of external ballistics of these agents [1]. These problems have a fairly correct solution [1, 2], but the solutions are obtained for stationary conditions of the fire fighting nozzle position. Practically three are cases when it needs to implement for example cyclic motion of fire fighting nozzle [3].In that cases it needs to develop the special electric drives which implement preset law of nozzle motion. The moment of inertia of the nozzle and then jet of fire fighting agent is one of initial parameter for designing the electric drives. There is no information about determining the parameter for the solving the problem of designing the automatic extinguishing system, which implements changing the position of fire fighting nozzle.

Statement of the problem and its solution. The main goal of the work is obtaining the moment of inertia of the jet of extinguishing agent with respect to the vertical axis.

For obtaining the moment of inertia of the jet of extinguishing agent let us suppose that extinguishing agent moves along the trajectory with negligible resistance force. In this case the equation of moving trajectory (jet equation) takes the form [1] (fig. 1)

$$y = h + x\,\mathrm{tg}\alpha - \frac{g}{2V_0^2 \cos^2 \alpha} x^2, \qquad (1)$$

where h is the height of fire fighting nozzle above ground level; α is the inclination angle; V_0 is velocity of extinguishing agent flow from fire fighting nozzle; g is acceleration of gravity.

The moment of inertia of elementary mass dm of extinguishing agent jet with respect to axis y is

$$dI = x^2 dm, \tag{2}$$

where $dm = \pi\rho r^2 dl$; ρ is the density of extinguishing agent; r is the jet radius (fig. 1); dl is the length of elementary section of the jet of extinguishing agent along its trajectory.

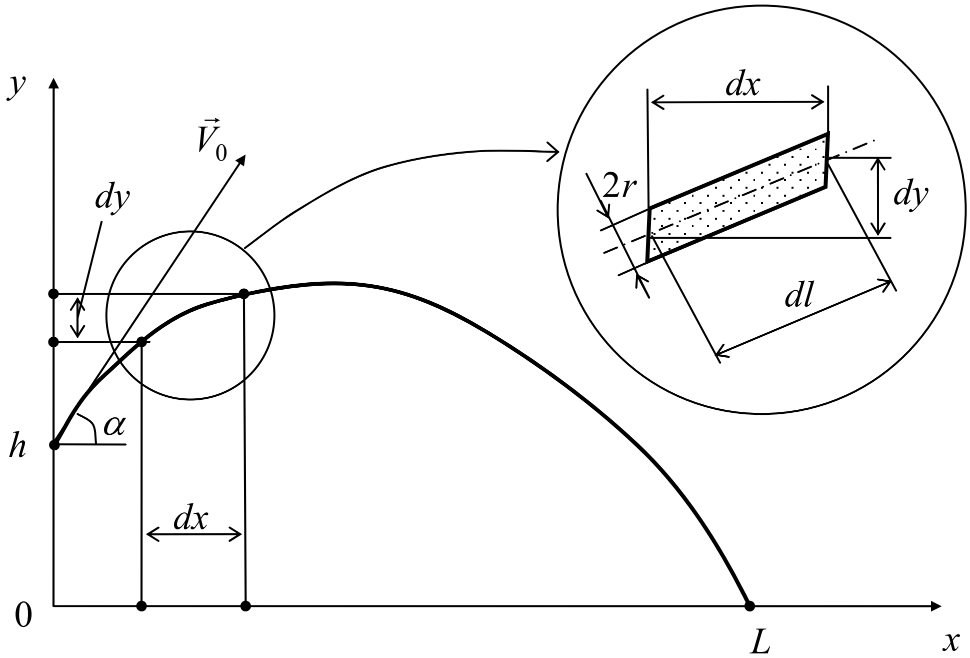

Fig. 1. Obtaining the moment of inertia of extinguishing agent along its trajectory

It follows (fig. 1) that

$$dl = dx\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{0.5}. \tag{3}$$

Then the elementary moment dm of inertia (2) is

$$dI = \pi\rho r^2 \left[1 + \left[tg\alpha - \frac{g}{V_0^2 \cos^2\alpha} x\right]^2\right]^{0.5} x^2 dx. \tag{4}$$

Expression for the moment of inertia I of extinguishing agent jet takes the form

$$I = \int_L dI = \frac{\pi\rho r^2}{\cos\alpha} \int_0^L x^2 \left(1 - Cx + Dx^2\right)^{0.5} dx, \qquad (5)$$

where $C = \frac{2g}{V_0^2} tg\alpha$; $D = \frac{g^2}{V_0^4 \cos^2\alpha}$; $L = \frac{V_0^2}{g} \sin 2\alpha$.

Values of parameters C, D, L for different initial data α and V_0 are shown in the tables 1, 2.

Tabl. 1. Values of parameters C, D

V_0, $m \cdot s^{-1}$		8.0	12.0	16.0
$\alpha = 35^o$	C	0.21	0.10	0.05
	D	0.03	0.007	0.001
$\alpha = 40^o$	C	0.26	0.12	0.006
	D	0.04	0.008	0.002
$\alpha = 45^o$	C	0.30	0.14	0.08
	D	0.05	0.01	0.003

Tabl. 2. Value of parameter L

V_0, $m \cdot s^{-1}$	8.0	12.0	16.0
$\alpha = 35^o$	6.1	13.8	24.5
$\alpha = 40^o$	6.3	14.4	15.6
$\alpha = 45^o$	6.5	14.7	26.1

The values of parameters shown in tables 1, 2 allow to obtain numerical values for integral (5) which is describing the moment of inertia of extinguishing agent jet. It can be done using Maple. The results are shown in the table 3. This table contains values for $\left(10^3 r^2\right)^{-1} I$.

Tabl. 3. Values of reduced moment of inertia of extinguishing agent jet

V_0, $m \cdot s^{-1}$	8.0	12.0	16.0
$\alpha = 35^o$	243.8	2928.5	12422.3
$\alpha = 40^o$	288.5	3383.9	15703.3
$\alpha = 45^o$	360.5	4030.6	21140.9

Example. Consider the nozzle characteristics are $2r = 2.8 \cdot 10^{-2}$ m; $V_0 = 12.0$ $m \cdot s^{-1}$; $\alpha = 35^o$. In this case the moment of inertia of extinguishing agent jet with the maximum distance $L = 13.8$ m is equal to 574 $kg \cdot m^2$ (the extinguishing agent is water).

Conclusions. Expression for moment of inertia of the jet of extinguishing agent with respect to vertical axis is obtained. The value of the moment of inertia of the jet is estimated for maximum range of jet. The results are obtained for the case when the resistance force is negligible. It is shown that changing the initial velocity of extinguishing agent jet in the range between $8.0\ \text{m}\cdot\text{s}^{-1}$ and $16.0\ \text{m}\cdot\text{s}^{-1}$ leads to changing the value of the jet moment respect to vertical axis by two orders.

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Момент інерції струменя вогнегасної речовини

Стосовно струменя вогнегасної речовини отримано вираз для моменту інерції відносно вертикальної вісі при його максимальній дальності подачі.

Ключові слова: струмінь, вогнегасна речовина, момент інерції.

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Момент инерции струи огнетушащего вещества

Применительно к струе огнетушащего вещества получено выражение для момента инерции относительно вертикальной оси при ее максимальной дальности подачи.

Ключевые слова: струя, огнетушащее вещество, момент инерции.