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LIGHT ANTITANK WEAPON WITH DOUBLE REGIME PROPULSION SYSTEM

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A b s t r a c t :

The paper deals with the solution of light antitank weapon when its principle is deduced from the principle of the "dual regime" rocket motor with solid propellant charge. The chosen principle of light antitank weapon has some advantages and also some disadvantages. The paper is oriented mainly on positive features of this solution.

The paper by its content logically follows the paper having the title "Light Antitank Weapons".

1. Introduction

The principle of light antitank weapons function, mainly the propulsion unit principle can be solved by a variety of possibilities. Each of them represents positives, as well as negatives of the solution accepted. One of all these possibilities is the propulsion system solution, based on a *double regime* solid propellant rocket motor.

The double regime **s***olid* **p***ropellant* **r***ocket* **m***otor – (SPRM)* as a propulsion unit solution of a light antitank weapon by its construction principle integrate the function of an *ejecting motor* together with a *sustainer motor* in one construction complex.

Individual functional phases are mutually separated by a convenient type of *separating mechanism*. The mentioned separating mechanism can be of two types:

- *Membrane separating mechanism;*
- *Valve separating mechanism.*

The separating mechanism fulfils two functions, i.e.:

- *It separates in time the ejecting phase from the sustainer phase and simultaneously fulfils the sustainer part sealing from the ejecting part of the propulsion unit;*
- *After the finishing of ejecting phase function secures the sustainer phase of the propulsion unit regarding the required missile flight velocity.*

2. General solution of a double regime propulsion unit

A general theoretical double regime propulsion unit solution can be carried out when there are fulfilled the following assumptions:

- *Initial gas flow parameters are known (regarding the type of used kind of solid propellant, i.e.* p_{CCE}, p_{CCS}, T_{CCE}, T_{CCS}*);*
- *Gas flow is considered to be ideal(without thermal exchange with ambient);*
- *Mass flow rate of gases through the propulsion unit is constant, one;*
- *Gas flow in each cross-section assumed is isentropic;*
- *Flow areas are selected so that the total pressure and velocities are equal to each other.*

A double regime SPRM scheme is introduced in Fig. 2. 1.

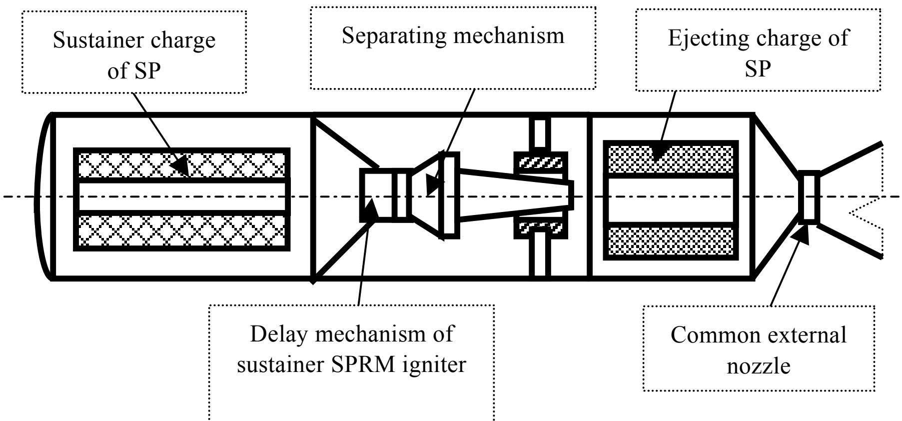

Fig. 2. 1. A double regime propulsion unit scheme for a light antitank weapon

A principle scheme of a double regime propulsion unit is introduced in Fig. 2. 2 (there are main dimensions of important cross-sections introduced).

Gas flow parameters in individual cross-sections are given by equations [1]

$$A_S\lambda_S\left(1-\frac{\kappa-1}{\kappa+1}\lambda_S^2\right)^{\frac{1}{\kappa-1}}=\varepsilon_R A_R\lambda_R\left(1-\frac{\kappa-1}{\kappa+1}\lambda_R^2\right)^{\frac{1}{\kappa-1}};$$

$$A_E\lambda_W\left(1-\frac{\kappa-1}{\kappa+1}\lambda_E^2\right)^{\frac{1}{\kappa-1}}=\varepsilon_{CR} A_{CR}\lambda_{CR}\left(1-\frac{\kappa-1}{\kappa+1}\lambda_{CR}^2\right)^{\frac{1}{\kappa-1}}, \tag{2.1}$$

where ε_R, ε_{CR} are coefficients of the gas flow contraction in given cross-sections. Their magnitudes in case of input edges convenient rounding are ε_R = ε_{KR} = *1.0* and in case of sharp input edges are $\varepsilon_R \neq \varepsilon_{KR} \neq 1.0$.

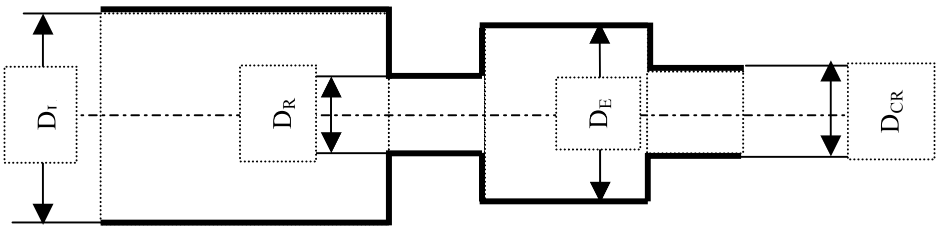

Fig. 2. 2. A double regime propulsion unit principle scheme

If the gas flow impulse conservation holds, then the following equation will be correct, i.e.

$$(\dot{m}w + Ap) = Apf(\lambda)\ , \tag{2.2}$$

where $f(\lambda)=\left(1+\lambda^2\right)\left(1-\frac{\kappa-1}{\kappa+1}\lambda^2\right)^{\frac{1}{\kappa-1}}$ is the gas dynamics function.

In case when holds ε_R = ε_{KR} = *1.0*, i.e. the input edges are rounded then the equation (2.2) can be rewritten as follows

$$A_S z(\lambda_R) = A_R z(\lambda_S)\ ;$$

$$A_E z(\lambda_{CR}) = A_{CR} z(\lambda_E)\ , \tag{2.3}$$

where $z(\lambda) = 0{,}5\left(\lambda + \dfrac{1}{\lambda}\right)$ is another gas dynamics function.

The dependencies which determine the values λ_R, λ_E can be deduced from equations which hold for acting forces, i.e.

$$F_E = F_R + (A_E - A_R)p_R \, . \tag{2.4}$$

The forces F_E, F_R can be determined when knowing the total reactive force F_C. Then holds [2]

$$F_E = k_E F_C \; ;$$

$$F_R = k_R F_C \; , \tag{2.5}$$

where F_C is as follows

$$F_C = (\dot{m}w + Ap) = \dot{m}c_{CR}\left(\frac{\kappa + 1}{\kappa}\right)z(\lambda) \, . \tag{2.6}$$

Let $\lambda = 1.0$ (critical flow), then F_C is as follows

$$F_C = \dot{m}c_{CR}\left(\frac{\kappa + 1}{\kappa}\right) . \tag{2.7}$$

Substituting the equation (2.7) into equation (2.5) and (2.4) then there will hold

$$k_E = k_R + \frac{A_R p_R \kappa}{\dot{m}c_{CR}(\kappa + 1)}\left(\frac{A_E}{A_R} - 1\right) . \tag{2.8}$$

The pressure in position of regulating cross-section (see Fig. 2. 2 – diameter D_R) is as follows

$$p_R = \left(\frac{\kappa + 1}{2\kappa}\right)\frac{\dot{m}c_{CR}}{A_R}\frac{\left(1 - \frac{\kappa - 1}{\kappa + 1}\lambda_R^2\right)}{\lambda_R} \; , \tag{2.9}$$

wherefrom

$$\frac{A_R p_R}{F_C} = \frac{\left(1 - \frac{\kappa - 1}{\kappa + 1}\lambda_R^2\right)}{2\lambda_R} \; . \tag{2.10}$$

Then the equation (2.8) when using the equation (2.10) will be

$$k_V = k_R + \left(\frac{A_V}{A_R} - 1\right)\frac{\left(1 - \frac{\kappa - 1}{\kappa + 1}\lambda_R^2\right)}{2\lambda_R} \ ,$$

or also

$$z(\lambda_E) = z(\lambda_R) + \left(\frac{A_V}{A_R} - 1\right)\frac{\left(1 - \frac{\kappa - 1}{\kappa + 1}\lambda_R^2\right)}{2\lambda_R} \ . \qquad (2.11)$$

Dimensionless velocity $\lambda_R = w_R/c_{CR}$ will reach the value $\lambda_R = 1.0$, if there holds the relationship $(A_E/A_R - 1) = (A_E/A_R - 1)_{CR}$.

The critical value of this relationship can be obtained from the equation (2.11), i.e.

$$z(\lambda_E) = 1 + \left(\frac{A_V}{A_R} - 1\right)_{CR}\frac{1}{(\kappa + 1)} \ ,$$

where from

$$\left(\frac{A_E}{A_R}\right)_{CR} = z(\lambda_E)(\kappa + 1) - \kappa \ . \qquad (2.12)$$

When $(A_E/A_R) \le (A_E/A_R)_{CR}$, then $\lambda_R < 1.0$.

The value λ_E from the equation (2.11) for $\lambda_R = 1.0$ after arrangement will be [1], [2]

$$\lambda_E = \frac{A_E}{A_R} - \sqrt{\left(\frac{A_E}{A_R}\right)^2 - 1} \ . \qquad (2.13)$$

The value λ_R is as follows

$$\lambda_R = \frac{z(\lambda_E)}{a_E} \pm \sqrt{\left[\frac{z(\lambda_E)}{a_E}\right]^2 - \frac{1}{a_E}\frac{A_E}{A_R}} \ , \qquad (2.14)$$

where $a_E = 1 - (\kappa - 1).(A_E/A_R - 1)/(\kappa + 1)$.

The value λ_S from the first equation (2.3) will then be

$$\lambda_S = \frac{A_S}{A_R} z(\lambda_R) - \sqrt{\left[\frac{A_S}{A_R} z(\lambda_R)\right]^2 - 1} \ . \qquad (2.15)$$

The solution is possible in all the cases when $p_{CCE} > p_A.[(\kappa + 1)/2]^{\kappa/(\kappa - 1)}$.

The pressure ratio is then as follows

$$\frac{p_{ES}}{p_{CC}} = \frac{A_R}{A_{CR\,\Sigma}}\left(\frac{\kappa+1}{2}\right)^{\frac{1}{\kappa-1}}\lambda_R\left(1-\frac{\kappa-1}{\kappa+1}\lambda_R^2\right)^{\frac{1}{\kappa-1}} . \tag{2.16}$$

The mass flow rate in case of double regime propulsion unit is as follows

$$\dot{m}_{SP} = \left(\frac{2\kappa}{\kappa+1}\right)\frac{p_{CCE}}{c_{CR}}A_E\lambda_E\left(1-\frac{\kappa-1}{\kappa+1}\lambda_E^2\right)^{\frac{1}{\kappa-1}} . \tag{2.17}$$

The equation (2.17) expresses the mass flow rate during the function of sustainer SPRM.

The amount of gases being defined by the equation (2.17) has simultaneously flow out through the common external nozzle, i.e. [1]

$$\dot{m}_N = \frac{\varphi(\kappa)A_{CR\,\Sigma}}{\sqrt{rT_{CCS}}} = A_{CR\,\Sigma}\sqrt{\frac{\kappa M_{mE}}{R_0 T_{CCL}}\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{\kappa-1}}} . \tag{2.18}$$

The double regime propulsion unit thrust is then as follows

$$F_E = c_{F\,\Sigma}p_{CCE}A_{CR\,\Sigma}\ ;\ \text{(Ejecting phase)}$$

$$F_S = c_{F\,\Sigma}p_{ES}A_{CR\,\Sigma}\ .\ \text{(Sustainer phase)} \tag{2.19}$$

For the given magnitude of sustainer SP charge burning surface – S_{0S} the working pressure p_{CCS} from continuity equation is given by equation

$$p_{CCS} = \left\{\frac{S_{0S}u_{0S}f(t_{SPS})\rho_{SPS}}{A_{CR\,\Sigma}\left[\frac{\kappa M_{mS}}{R_0 T_{CCS}}\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa+1}{\kappa-1}}\right]^{0,5}\left(\frac{p_{ES}}{p_{CCS}}\right)}\right\}^{\frac{1}{(1-\alpha_S)}} . \tag{2.20}$$

Then the pressure ratio p_{ES}/p_{CCS} determines the value p_{ES} which for $\varepsilon_R = \varepsilon_{CR} = 1.0$ is given by equation

$$p_{ES} = p_{CCS}\left(\frac{p_{ES}}{p_{CCS}}\right) . \qquad (2.21)$$

The specific impulse of the double regime SPRM during sustainer phase function is as follows [1]

$$i_{sS} = \sqrt{\frac{2\kappa}{\kappa-1}\frac{R_0}{M_{mS}}T_{CCS}\left[1-\left(\frac{p_e}{p_{CCE}}\right)^{\frac{\kappa-1}{\kappa}}\right]} + \left(\frac{A_e}{A_{CR\,\Sigma}}\right)c_S^*\left[\left(\frac{p_e}{p_{CCE}}\right)-\frac{p_A}{p_{ES}}\right] , \qquad (2.22)$$

where p_e/p_{ES} is the same value *as* p_e/p_{CCE} due to the given geometry of the common external nozzle.

2.1. Solution of an ejecting propulsion unit

Ejecting SPRM operates at the base of an *impulse* rocket motor (also ***i**mpulse* ***e**xciting* **p**ropulsion **u**nit) – *(IEPU)* and serves for a very short time of operation. Assuming that the *IEPU* operates at the initial temperature of solid propellant charge – $t_{SPE} = -40^0C$ during the time $t_{eE} \approx 0.02\ s$. Initial (muzzle) velocity is assumed to be $v_M \approx (90 \div 100)\ ms^{-1}$. Selected SP has the specific impulse $i_{sE}\ (Nskg^{-1})$. Then the mass of ejecting SP charge will be $m_{SPE} = F_E t_{EE}/i_{sE}\ (kg)$.

A solution of ejecting IEPU has to be carried out regarding the SP charge geometric shape (main parameter will be the initial burning thickness $e_{0E} = u_{0E}f(t_{SPE})p^{\alpha E}_{CCE}t_{eE}$).

For the solution of ejecting propulsion unit can be accepted the following:

- *n – tube solid propellant charge;*
- *Strip solid propellant charge of spiral shape.*

For the solution selected the following values p_{CCE}, p_e, ρ_{SPE}, K_{TE} have to be as well as the other needed values.

2.2. Solution of a sustainer propulsion unit

A sustainer propulsion unit of a double regime SPRM has to secure the required flight velocity of the missile having the total missile mass $m_{0m}\ (kg)$. Such velocity should reach the following values $v_S = (3 \div 3.2)v_m\ (ms^{-1})$. The magnitude of specific impulse is $i_{sS}\ (Nskg^{-1})$.

The missile propulsion unit is a double regime SPRM so that the sustainer propulsion unit and therefore there is also given the geometry of the common external nozzle.

From theoretical missile velocity will be [3]

$$v_S = v_m + i_{sS} \ln\left(1 + \frac{m_{SPS}}{m_m - m_{SPE} - m_{SPS}}\right) , \tag{2.23}$$

where v_m is the muzzle velocity of the rocket, then the mass of sustainer SP charge will be [1]

$$m_{SPS} = \left(m_m - m_{SPE}\right)\frac{\left[\exp\frac{\left(v_S - v_m\right)}{i_{sL}} - 1\right]}{\exp\frac{\left(v_S - v_m\right)}{i_{sS}}} . \tag{2.24}$$

The solution also requires selection of the working pressure p_{CCS} and diameters D_E, D_S. Further on let us presuppose the rounded inlet edges, i.e. $\varepsilon_R = \varepsilon_{CR} = 1.0$.

Remark: *- for the solution is further on used the same SP in both the propulsion units and $D_E = D_S$ (inner diameters of both the combustion chambers are the same).*

The solution of a sustainer propulsion unit is carried out according to the following set of equations [1]:

$$1.\ \lambda_E^{(\kappa+1)} - \left(\frac{\kappa+1}{\kappa-1}\right)\lambda_E^{(\kappa-1)} + \left(\frac{A_{CR\,\Sigma}}{A_E}\right)^{(\kappa-1)}\frac{2}{(\kappa-1)} = 0 \ ;$$

$$a_{Ei} = 1 - \left(\frac{\kappa-1}{\kappa+1}\right)\left(\frac{A_E}{A_{Ri}} - 1\right) \ ;$$

$$2.\ z(\lambda_E) = 0.5\left(\lambda_E + \frac{1}{\lambda_E}\right) \ ;$$

$$3.\ \lambda_{Ri} = \frac{z(\lambda_V)}{a_{Ei}} \pm \sqrt{\left[\frac{z(\lambda_E)}{a_{Ei}}\right]^2 - \frac{A_E}{a_{Ei}A_{Ri}}} ; \tag{2.25}$$

$$4.\ z(\lambda_{Ri}) = 0.5\left(\lambda_{Ri} + \frac{1}{\lambda_{Ri}}\right) \ ;$$

$$5.\ \lambda_{Si} = z(\lambda_{Ri})\frac{A_S}{A_{Ri}} - \sqrt{\left[z(\lambda_{Ri})\frac{A_S}{A_{Ri}}\right]^2 - 1} \ ;$$

$$6.\ \left(\frac{p_{ES}}{p_{CCS}}\right) = \frac{A_{Ri}}{A_{CR\,\Sigma}}\left(\frac{\kappa+1}{2}\right)^{\frac{1}{\kappa-1}}\lambda_{Ri}\left(1-\frac{\kappa-1}{\kappa+1}\lambda_{Ri}^{2}\right)^{\frac{1}{\kappa-1}}\ ;$$

$$7.\ \left(p_{ESi}\right) = p_{CCS}\left(\frac{p_{ES}}{p_{CCSL}}\right)_{i}\ ; \qquad (2.25)$$

$$8.\ F_{Si} = c_{F\,\Sigma}p_{ESi}A_{CR\,\Sigma}\ ;$$

$$9.\ \dot{m}_{SPSi} = A_{CR\,\Sigma}p_{VLi}\sqrt{\frac{\kappa}{rT_{CCS}}\left(\frac{2}{\kappa+1}\right)^{\frac{\kappa-1}{\kappa}}}\ ;$$

$$10.\ i_{sSi} = \sqrt{\frac{2\kappa}{\kappa-1}\frac{R_0T_{CCS}}{M_{mS}}\left[1-\left(\frac{p_e}{p_{CCE}}\right)^{\frac{\kappa-1}{\kappa}}\right]} + \left(\frac{A_e}{A_{CR}}\right)_{\Sigma}c_S^{*}\left[\left(\frac{p_e}{p_{CCE}}-\frac{p_A}{p_{ESi}}\right)\right]\ .$$

The solution of a sustainer propulsion unit should be carried out for $D_{Ri} \in \langle D_{RMIN} \div D_{RMAX}\rangle$.

2.3. Solution of a separating mechanism

A double regime propulsion unit is a special type of SPRM having two stages of thrust. Its function depends on so called separating mechanism, which can be either of a *membrane* or *valve* type.

The membrane separating mechanism is simpler from the point of view of construction but on the other hand it has some more serious disadvantages. The membrane rupture needs relatively high pressures (especially in sustainer combustion chamber). The membrane opening can’t happen at the same time. This phenomenon can affect the gas flow character; more over the separated parts of the membrane can cause significant failures of the propulsion unit.

Therefore a more convenient type of separating mechanism is the *valve* type.

Its principle is evident from Fig. 2. 3 [1].

The function of the valve separating mechanism can be divided practically into three phases, i.e.:

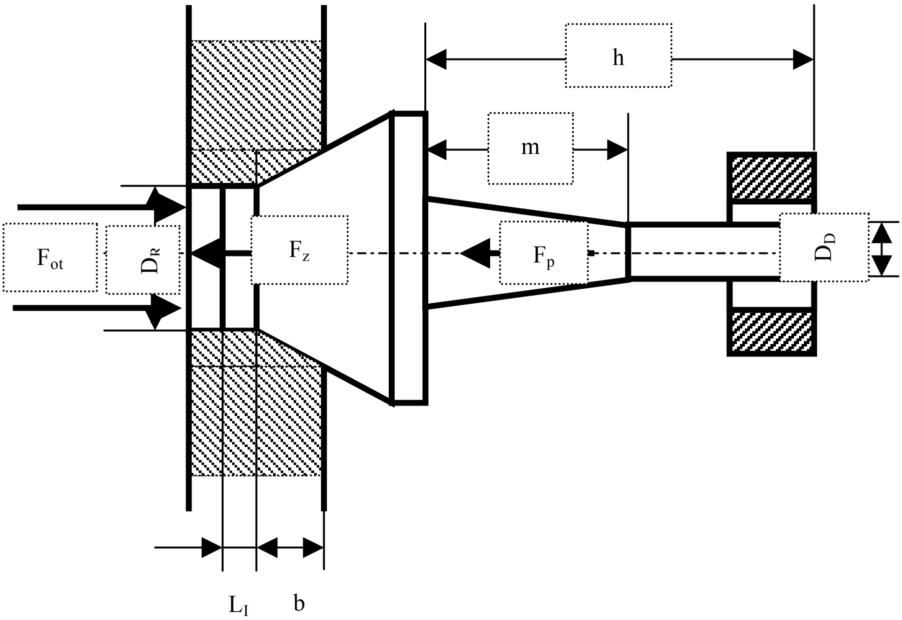

Fig. 2. 3. Scheme of the valve type separating mechanism

- *Drawing out of pressed part of the valve having the length L_1 (see Fig. 2.3) to the position of its opening – lift – h_1.*
- *Opening of the valve to the lift value $h_2 = h - m$;*
- *Opening of the valve to the maximum valve lift h.*

In the first phase of the valve opening acts on the valve the force, which is equals to

$$F_{op} = \frac{\pi}{4} D_R^2 p_{op} \ . \tag{2.26}$$

Thrust force F_{th} being the result of gas pressure in the ejecting combustion chamber of the dual regime propulsion unit is as follows

$$F_{th} = \frac{\pi}{4} D_E^2 p_A \ . \tag{2.27}$$

Suppression force being created by the cylindrical pressed part of the valve into the valve seat is as follows

$$F_{ret} = \pi D_R L_1 f p_{ret} \ . \tag{2.28}$$

Afterwards the basic equation of motion of the separating mechanism of the valve type will have the following form

$$m_v \frac{d^2x}{dt^2} = F_{op} - F_{ret} - F_{th} \ , \tag{2.29}$$

or after substitution of individual forces we shall get

$$m_v \frac{d^2x}{dt^2} = \frac{\pi}{4}\left(D_R^2 p_{op} - D_E^2 p_A\right) - \pi D_R L_1 f p_{ret} \ . \tag{2.30}$$

Let us arrange the equation (2.30) to the shape

$$\frac{d^2x}{dt^2} = \frac{\pi}{4m_v}\left[D_R^2 p_{op} - D_E^2 p_A - 4D_R L_1 f p_{ret}\right] . \tag{2.31}$$

Integrating the equation (2.31) will be determined the valve motion velocity and its path in the first phase of its motion, i.e. v_{v1}; $x_{v\ 1}$.

The valve mass m_v should be determined according to the real valve construction proposal.

The valve separating mechanism during action of gases in time of the sustainer propulsion unit ($p_{op} = 0$) for the required valve lift h will take place by the velocity v_{v1}, which from equation of the valve motion is as follows

$$\frac{dv_v}{dt} = \frac{1}{m_v}\left[\dot{m} c_{CR}\left(\lambda_R - \lambda_{Ee}\cos\alpha\right) + \frac{\pi}{4}\left(D_R^2 p_{op} - D_E^2 p_A - 4D_R L_1 f p_{ret}\right)\right] , \tag{2.32}$$

The valve path will then be

$$\frac{dx}{dt} = \frac{t}{m_v}\left[\dot{m} c_{CR}\left(\lambda_R - \lambda_{Ee}\right) + \frac{\pi}{4}\left(D_R^2 p_{op} - D_V^2 p_A - 4D_R L_1 f p_{ret}\right)\right] , \tag{2.33}$$

where λ_R (see equation 2.5, $\dot{m}$ equation 2.5).

The value $\lambda_{Ee} = \frac{z(\lambda_E)}{a_E} \pm \sqrt{\left[\frac{z(\lambda_E)}{a_E}\right]^2 - \frac{A_{Ee}}{A_R a_E}}$. Angle α is the angle of the nozzle enlargement.

The valve braking secures the braking ring (see Fig. 2. 4) being placed in the separating mechanism holder and by conical surface of the valve shaft (see Fig. 2. 5).

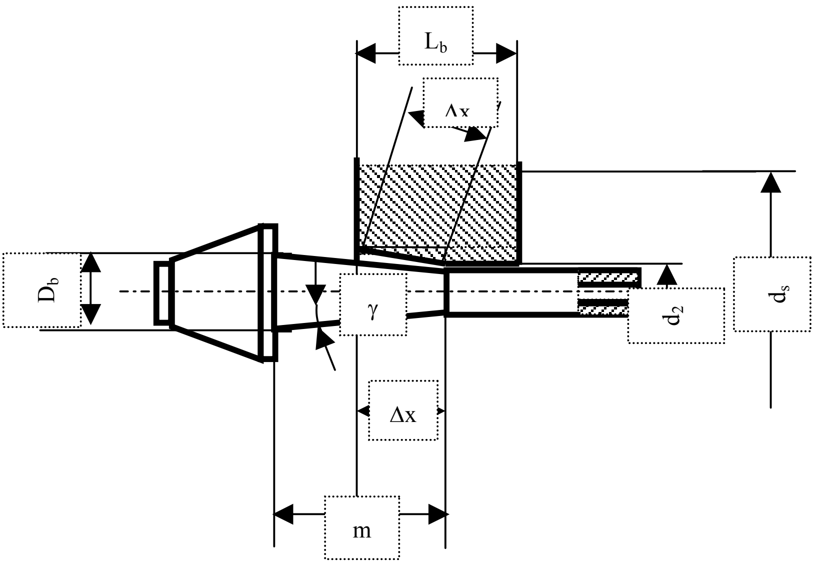

Fig. 2. 4. Breaking principle of the valve separating mechanism

Against the valve motion acts the force F_R, which is as follows

$$F_R = p_R A_{\Delta x} (\sin\gamma + f_{DF}\cos\gamma) \ , \qquad (2.34)$$

where p_R is the pressure acting in contact area, $A_{\Delta x}$ is the area where the breaking takes place, γ is the angle of the shaft cone, f_{DF} is the coefficient of dynamic friction.

The valve velocity being gained for a certain lift h is during braking lowered and complete valve stop happens when the valve velocity reaches the value $v_s = 0$.

From Fig. 2. 5 holds the following

$r_2 = r_D + \delta + \Delta r_2$; $tg\gamma = \dfrac{2\Delta r_2}{\Delta x}$; $\delta = r_{0R} - r_D$, then the friction area $A_{\Delta x}$ will bee

$$A_{\Delta x} = 2\pi r_2 \Delta x = 4\pi \frac{\Delta r_2}{tan\,\gamma}(r_{0B} - e_D) \ .$$

Friction force is given by equation (2.34), and then the equation of motion is as follows

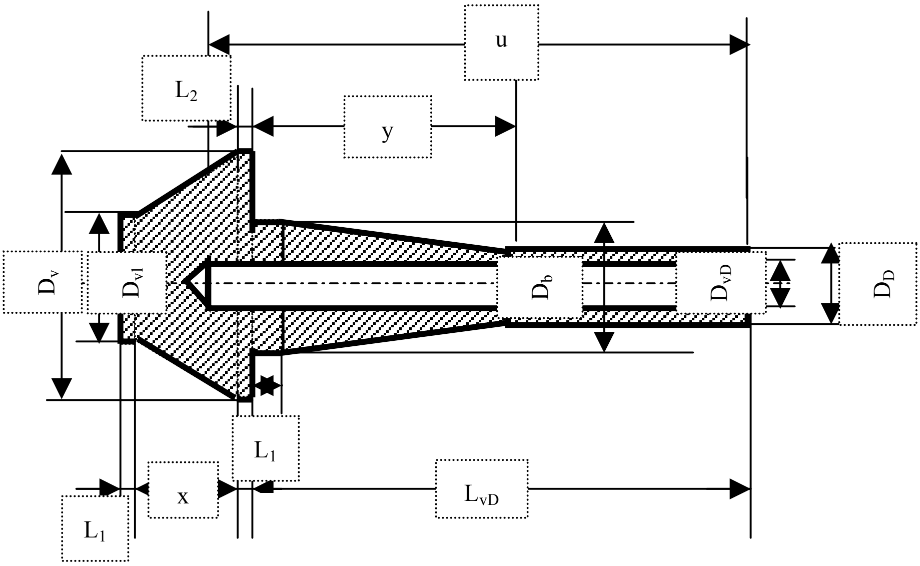

Fig. 2. 5. Shape and main dimensions of separating mechanism valve

$$\frac{d^2x}{dt^2} = v_v - \frac{1}{m_v} p_B A_{\Delta x} \left(\sin\gamma + f_{DF} \cos\gamma \right) . \tag{2.35}$$

For its solution it is necessary to know the angle γ, the value of dynamic friction coefficient f_{DF}, and the pressure of the valve braking p_b (its value is as a rule chosen).

The breaking process is analogical to the process to the solution of barrels design. Therefore an absolute value of deformation $/\Delta r'_2/$ is given by equation

$$\left| \Delta r_2^I \right| = \frac{r_2}{E_1} \left[\frac{p_1 r_{Dv}^2 - p_2 r_2^2}{r_2^2 - r_{Dv}^2} + \frac{r_{0Bv}^2 (p_1 - p_2)}{r_2^2 - r_{Dv}^2} - \mu_1 p_2 \right]. \tag{2.36}$$

An absolute value of deformation $/\Delta r''_2/$ is as follows

$$\left| \Delta r_2^{II} \right| = \frac{r_2}{E_2} \left[\frac{p_2 r_2^2 - p_1 r_{0Bv}^2}{r_{0Bv}^2 - r_1^2} + \frac{r_{0Bv}^2 (p_2 - p_1)}{r_{0Bv}^2 - r_2^2} + \mu_2 p_2 \right], \tag{2.37}$$

then the value Δr_2 will be

$$\Delta r_2 = \left| \Delta r_2^I \right| + \left| \Delta r_2^{II} \right| . \tag{2.38}$$

Let us assume for the solution that the valve is made of convenient steel ($E_1 \approx 2.1.10^5$ *MPa*; $\mu_1 = 0.03$), the braking ring is made from duralumin ($E = 0.686.10^5$ *MPa*; $\mu_2 = 0.33$). Pressure p_1 is the pressure inside the ejecting propulsion unit combustion chamber (for completely opened separating mechanism valve).

Shape and dimensions are evident from Fig. 2. 5.

The valve mass (see Fig. 2. 5, needed value for the solution of separating mechanism valve equations of motion) is given by equation

$$m_v = \frac{\pi}{4} D_{v1}^2 L_1 \rho_m + \frac{\pi}{4} D_v^2 L_1 \rho_m + \frac{\pi}{4} D_b^2 L_2 \rho_m + \frac{\pi}{4} D_D^2 (L_D - y) \rho_m +$$
$$+ \frac{\pi}{12} x \left(D_v^2 + D_v D_{v1} + D_{v1}^2 \right) \rho_m + \frac{\pi}{12} (y - L_2) \left(D_b^2 + D_b D_D + D_D^2 \right) \rho_m -$$
$$- \frac{\pi}{4} D_{vD}^2 u \rho_m$$

and after some arrangement

$$m_v = \rho_m \frac{\pi}{4} \left\{ \begin{array}{l} \left[\left(D_{v1}^2 + D_v^2 \right) L_1 + D_b^2 L_2 + D_D^2 (L_D - y) \right] + \\ \dfrac{1}{3} \left[\begin{array}{l} x \left(D_v^2 + D_v D_{v1} + D_{v1}^2 \right) + \\ + (y - L_2) \left(D_b^2 + D_b D_D + D_D^2 \right) \end{array} \right] - D_{vD}^2 u \end{array} \right\} . \qquad (2.39)$$

Remark: *When carrying out the valve separating mechanism it is necessary to take into consideration the gas flow character through the regulating opening after the valve opening. Supercritical flow leads to the valve dimensions decrease and also the decrease of the separating mechanism mass. On the other hand it deteriorates the value of specific impulse of the double regime propulsion unit. Therefore for the separating mechanism solution it is better that the gas flow through the regulating opening will be subsonic (character of the gas flow influences the diameter* $D_{v1} = D_R$*). Such solution will increase the mentioned diameter a little and in this way also the valve mass, but regarding the construction mass there will be only a very small change of the overall mass.*

3. Conclusion

The matter of a light antitank propulsion unit discussion is the reactive principle, i.e. the principle of "*double regime*" of SPRM. Such solution is convenient from the point of view that the propulsion unit is more compact construction when compared with the other types of propulsion units. A certain disadvantage is a little higher propulsion unit mass. In this case there isn't the danger of missile vibration motion due to the non-uniform separation of the booster (ejecting) SPRM from the missile.

This as a rule leads to worst dispersion characteristics or drops the total weapon accuracy.

In all cases of light antitank propulsion systems the presence of convenient delay system which secures the function of sustainer propulsion unit (SPRM) is necessary. Therefore this necessity also exists in case of the double regime propulsion unit (prevention of the gunner against hot combustion products flowing out from the sustainer propulsion unit).

Booster (ejecting) SPRM (in case of double regime SPRM from the point of view of function secures the same as booster SPRM or barrel accelerator of the other cases) has to finish the function inside the launching tube. Therefore bigger attention has to be paid to a respective choice of SP, i.e. regarding its chemical composition as well as its burning rate. A little lower criteria hold for sustainer SPRM (i.e. choice of convenient SP etc.). The main advantage of the above mentioned propulsion unit is the fact that the working pressure in booster and the sustainer phase is relatively small value, resulting in convenient over all mass of a light antitank weapon.

Above mentioned findings related to the light antitank weapon propulsion unit give evidence that the modern (sophisticated) solution is in practice possible and contributes to progressive development of these means.

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