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METHOD FOR PROJECTING A TRUNCATED TIGHT RING FOR MORTAR SYSTEMS WITH A SMOOTH BODI

V. T. Ivanov

The report presents a method for projecting a truncated congestion ring with a rectangular section. A particular attention has been paid to the restriction conditions regarding its geometry. There are defined requirements when choosing the materials. The necessary strength checks for the machine corpus are pointed out. The dominating construction change of the central thickening of the mortar and the increasing pressure when shooting must be taken into consideration as well.

The usage of congestion rings at current smooth-walled mortar systems is a dominating tendency towards improving tactical and technical characteristics of the shooting system. The mortar congestion and stabilizing effect at the rings is better than the effect at the traditionally maze congestion. As a result the shooting improves and the grouping when shooting. The accessible literature does not show any methods for projecting congestion ring at smooth-walled mortar. This fact is a motif for the proposed method. Its aim is a possibility for developing a congestion element to the mine corpus under restriction conditions that guarantee: the process of charging, the conservation of the characteristics of the body and the ammunitions, the usage of the state mines without a significant change in the corpus.

The process of projecting also proposes the following procedure: restriction conditions; determining construction characteristics; determining the nominal and actual area of the congestion element; determining the area of the play, a choice of the material for the congestion; determining the minimum necessary area and length of the truncated section, strength checks of the mortar and mine corpuses.

1. Restriction Conditions:

These conditions guarantee the attained quick-firing, the process of charging and the possibility for using existing mines with an insignificant change in corpus. The creation of a channel for the ring in the centralizing thickening at the mine leads to a decrease in the transverse section and is a good reason to view it as a critical factor for its strength. On the other hand it is necessary to keep the conditions when charging the mortar.

Because of this the following restrictions are enforced:

1.1. Strength - It guarantees the preservation of the minimum assumed external radius of the mine corpus along the centralizing thickening with respect to the pressure in the channel of the body. The following formula determines the pressure [1]:

$$(1)\ p_{pac} = (1 + 0{,}0036\Delta t)p_m$$

To determine the minimum radius of the mine along the centralizing thickening (internal diameter of the ditch of the ring) the third strength theory must be used. It gives closest results with respect to the experimnentally established values [6]:

$$(2)\ r_0 \geq \sqrt{\frac{0{,}5\sigma_{02} r_n^{\ 2}}{0{,}5\sigma_{02} - p_{pac}}}$$

where: r_n – internal radius of the mine corpus, m; p_m – maximum pressure in the mortar body, P_a; σ_{02} – border of elasticity for the materials used for the corpus of the mine, P_a.

1.2. Constructive:

The requirement for preserving the radial play between the body and the mine says:

$$(3)\ D_p^{\,,} \leq D_m$$

where: $D_p^{\,,}$– external diameter of the ring in a free condition, mm; D_m – diameter of the mine along the centralized thickening, mm.

The maximum possible height along the transverse section at the ring can be attained by the following inequality:

$$(4)\ h \leq \frac{D_m - 2r_0}{2}$$

Choosing a suitable profile of the section at the congestion element is a question of a compromise with respect to the conditions of the working area, the requirements for exploitation duration and the effectiveness of the congestion.

Considering the gas-dynamic nature of the process, the duration of the shoot and the only usage of the ring as criteria for choosing a suitable profile enforce the presence of: a good technology in manufacturing, compactivity, easy installation, and a low prime cost.

A suitable decision is for example a square profile of the section with a width:

$(5)\, b = h$

2. Constriuctive characteristics:

The following algorithm must be followed:

$(6)\, D_p' = D_m$

$(7)\, D_p'' = D_p' - 2h$

$$(8)\, H = \frac{D_m - D_p''}{2} + 0{,}5$$

$(9)\, B = b + 2$

$$(10)\, r_p = \frac{D_p'}{2}$$

$(11)\, D_0 = D_p' - 2H$

$$(12)\, \varphi_1 = 2\arcsin\frac{\frac{s}{2}}{r_p}$$

$$(13)\, \delta_{p_1} = \frac{\varphi_1^{\,0}\pi r_p}{180}$$

$(14)\, l_{p_1} = z\pi D_p' - s_0$

$(15)\, l_{p_2} = z\pi D_p'' - s_0$

$(16)\, C = \pi D_p' - \delta_{p_1}$

$$(17)\, \alpha = arctg\frac{b}{C}$$

$(18)\, l_s = \sqrt{b^2 + C^2}$

$(19)\, l_k = \pi D_k$

$(20)\, \delta_{p_2} = l_k - C$

$(21)\, \delta_p = \delta_{p_2} - \delta_{p_1}$

$$(22)\, r_k'' = \frac{D_k''}{2}$$

$$(23)\, \varphi_2 = \frac{\delta_{p_2} 180^0}{\pi r_k''}$$

$(24)\, D_k' = D_k - 2h$

$$(25)\, r_k' = \frac{D_k'}{2}$$

$$(26)\, r_{cp} = \frac{r_k' + r_k''}{2}$$

$(27)\, D_{cp} = 2r_{cp}$

$(28)\, l_{cp} = z\pi D_{cp}$

where: D_p' - external diameter of the ring in a free condition, mm; D_p'' - internal diameter of the ring in a free condition, mm; H – height of the channel of the ring , mm; B – width of the channel of the ring, mm; r_p – external radius of the ring in a free condition, mm; D_0 – internal diameter of the ditch, mm; φ_1 – central angle between the ends of the ring in a free condition, degre; δ_{p1} – length of the semicircle of the truncated section along the external diameter of the ring in a free condition, mm; l_{p1} – length of the ring along the external diameter, mm; l_{p2} – length of the ring along the internal diameter, mm; C – length of one winding from the ring to the external diameter in a free condition, mm; α – angle of the slope of the section, degre; l_s – length of the section дължина на среза, mm; l_k – length of the channel of the body along the internal diameter, mm; δ_{p2} - length of the semicircle between the ends of the ring along the internal diameter of the body, mm; δ_p - displacement of the ends until a contact with the body is established, mm;

r_k'' - radius of the deformed ring along the external diameter, mm; φ_2 - central angle between the ends of the ring in a deformed condition, degre; D_k' - internal diameter of the deformed ring, mm; r_k' - radius of the deformed ring along the internal diameter, mm; r_{cp} – middle radius of the deformed ring, mm; D_{cp} – middle diameter of the deformed ring, mm; l_{cp} – length of the deformed ring along the middle diameter, mm; D_m – diameter of the mine along the centralized thickening; D_k – internal diameter of the channel of the body, mm.

3. Areas

The determination of the nominal, actual and contact areas is a major event of the projecting when considering the optimum relation between the constructive parameters and of the ring and the attainment of a desired congestion effect and a suitable choice of a material for it. It is obligatory to have two surfaces in contact – "ring-body" and "ring-mine".

The following formulas are used to determine these contact surfaces:

(29) $F_1 = bl_{p_1}$

(30) $F_2 = \frac{\pi}{4}\left(D_m^2 - D_k'^2\right)$

(31) $F_3 = bl_{p_2}$

(32) $F_4 = 2l_s h$

(33) $F_5 = hC$

(34) $F_6 = F_5$

(35) $A_N = F_1 + F_3 + F_4 + F_5 + F_6$

(36) $A_F = F_1 + F_4$

where: F_1 – area along the external diameter / contact with the body/, m^2; F_2 – minimum area with the face of the ditch, m^2; F_3 – area along the internal diameter /to the bottom of the ditch/, m^2; F_4 – area length of the section, m^2; F_5 - area to the charging camera, m^2; F_6 - area to the muzzle section, m^2; A_N – nominal area, m^2; A_F - actual /contact/ area, m^2.

4. Plays

The magnitude of the radial play has a significant meaning for the expense of ineffectively used powder gas usage. The area of the section is a determining factor.

Having in mind the pressumption that the congestion effect in the contact surfaces takes place within the borders of the class of roughness for the material of the ring, there are several formulas to use [3]:

$$(37)\ H_{\max} = \frac{R_z}{2}$$

$$(38)\ \delta_t = \delta_m = \frac{t_v H_{\max}}{u}$$

where : R_z – distance between the highest and the lowest part of the roughnesses, m; H_{max} – maximum height of the roughnesses, m; t_v – a probability mistake; u – normal digression; δ_t ,δ_m –plays with respect to the body and the mine, m.

The following formulas calculate the areas in the respective radial plays:

$$(39)\ s_s = \frac{\varphi_2 \pi \left(r_k^{"2} - r_m^{\ 2} \right)}{360^0}$$

$$(40)\ s_t = \delta_t l_{p_1}$$

$$(41)\ s_m = \delta_m l_{p_2}$$

$$(42)\ s_y = s_s + s_t + s_m$$

where : s_s - radial area of the section at the deformed ring, m^2; s_t - radial area of the play "ring-body", m^2; s_m - radial area of the play at the "ring-mine", m^2; s_y – total area of the play at the ring, m^2.

5. Choosing materials for the congestion

Having in mind the gas-dynamic conditions for work of the ring and the neccessity of attaining congestion and stabilizing effect at the mine, a major requirement with respect to the physics and machanics properties of the material is its hardness.

To determine the minimum value of the flow border, the following algorithm must be used [4,5]:

$$(43)\ p_{cp} = \frac{\frac{2}{3}\left(p^3 - p_a^{\ 3} \right)}{p^2 - p_a^{\ 2}}$$

$$(44)\ W = pA_N - p_{cp}\left(A_N - A_F \right)$$

$$(45)\ p^{,} = \frac{W}{A_F}$$

$$(46)\ c = c_1 c_2 c_3$$

$$(47)\ \sigma_s = \frac{p^{,}}{c}$$

where: p, p_a – pressure before and after the congestion, P$_a$; W – resultant pressure on the ring, N; $p^{,}$ - contact pressure контактно налягане, P$_a$; c – coefficient of security; c_1 – coefficient calculating the inaccuracies as a result of the pressure; c_2 – coefficient calculating the heterogenity of the material; c_3 – coefficient calculating the importance of the detail in the construction.

Rubber-like materials are suitable in this case.

6. Minimum necessary area */F4/* **and length of the section** */l_s/*

From the condition for deformation of the ring until a contact with the body is established:

(48) $p_{cp}\left(F_3 + F_4\right) \geq p_{cp}F_1$

Therefore:

(49) $F_4 = \dfrac{p_{cp}F_1 - p_{cp}F_3}{p_{cp}}$

(50) $l_s = \dfrac{F_4}{2h}$

where: l_s – length of the section, m.

7. Strength Checks

Having in mind the restriction conditions that the proposed method obeys, it is highly recommended to accomplish strength checks concerning the mine and mortar corpuses.

7.1.Determining the pressures in the mine and ditch corpuses

The familiar relations are used in order to determine the tense condition in the critical section [1].

Axial pressure:

(51) $\sigma_z = -\dfrac{p_{pac} r_m^{2} q_{mn}}{\left(r_0^{2} - r_n^{2}\right)q}$

Radial pressures along the external surface of the corpus:

(52) $\sigma_{r_1} = -p_{pac}$

along the internal surface of the corpus:

(53) $\sigma_{r_2} = -p_c$

Tangential pressures:

- along the external surface of the corpus;

(54) $\sigma_{t_1} = \dfrac{p_c r_n^{2} - p_{pac} r_0^{2}}{r_0^{2} - r_n^{2}} - \dfrac{r_n^{2}\left(p_{pac} - p_c\right)}{r_0^{2} - r_n^{2}}$

- along the internal surface of the corpus.

(55) $\sigma_{t_2} = -\dfrac{2p_{pac} r_0^{2}}{r_0^{2} - r_n^{2}} + \dfrac{p_c\left(r_0^{2} + r_n^{2}\right)}{r_0^{2} - r_n^{2}}$

where : p_c – pressure from the elastic deformation of the disruption charge, P_a; r_n – internal radius of the mine corpus at the cylindrical part, m; r_m – maximum radius of the mine at the cylindrical part, m; q_{mn} – mass of the parts of the mine corpus placed above the critical section

7.2. Checking the tense condition in the critical section of the corpus

The experimental investigations have proven that the energy morphology theory is most suitable. According to it the cited pressures are as follows [1]:

- Along the external surface of the corpus;

$$(56)\ \sigma_{i_1} = \frac{\sqrt{2}}{2}\sqrt{\left(\sigma_z - \sigma_{r_1}\right)^2 + \left(\sigma_{r_1} - \sigma_{t_1}\right)^2 + \left(\sigma_{t_1} - \sigma_z\right)^2} \le \sigma_{02}$$

- Along the internal surface of the corpus.

$$(57)\ \sigma_{i_2} = \frac{\sqrt{2}}{2}\sqrt{\left(\sigma_z - \sigma_{r_2}\right)^2 + \left(\sigma_{r_2} - \sigma_{t_2}\right)^2 + \left(\sigma_{t_2} - \sigma_z\right)^2} \le \sigma_{02}$$

where: σ_{02} – border of elasticity of the material used for building the mine corpus, P_a;

7.3. Checking the mortar body for an increased pressure

A second strength theory is highly recommended for checking the border of elascticity at the material. The theory's results are very close to the experimentally established values [6]:

$$(58)\ \sigma_e = \frac{2p_{pac}\left(2R^2 + r_{k_{\max}}{}^2\right)}{3\left(R^2 - r_{k_{\max}}{}^2\right)} \le \sigma_s$$

where : r_k – internal radius of the body, m; R – external radius in the middle of the body, m; σ_s – flow border of the material used for the body, P_a.

8. Conclusions

8.1. The proposed method gives a possibility for projecting the congestion rings for smooth-walled mortars when preserving the mortars' corpuses of the existing mines.

8.2. Its application is possible regardless of the calibre of the system.

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Author:
PhD Valentin Totev Ivanov
"IPIO" Military Academy "G.S.Rakovski"
tel : 02/747894
E-mail: vivanof@abv.bg