Operational and physical characteristics of self-drilling rock bolt

A A Zubkov1,2, I M Kutlubaev2,3 V A Samigullin2 and V A Buzmakov2
1 JSC UralEnergoResurs, room 12, 12 Metallurg street, Magnitogorsk 455000, Russia
2 Nosov Magnitogorsk State Technical University, 38 Lenin street, Magnitogorsk 455000, Russia
3 E-mail: ptmr74@mail.ru

Abstract. The key factor in the operation safety for the shaft mining is stabilization of the working surface [1]. The time required to install support element is crucial [2, 3]. Surface stabilization can be done three ways: using frame support or rock bolt or their combination [4]. The rock stabilizing method is realized using significant number of design options of rock stabilizer systems [5, 6]. Friction rock bolts with tubular profile have become widespread recently [7 -9]. Its fixation in borehole is based on generation of friction force at contact surface. There are two methods realized: Swellex and Split Set. According to the first method the closed tubular profile (after being freely inserted into borehole) that has working liquid inside forced under the high pressure is used. Under the pressure outside dimension of profile is increased and its forcing against the borehole surface is provided [10]. The second method is based on use of spindle with unclosed tubular profile and outside diameter that exceeds the spindle diameter [11]. When spindle is inserted into borehole it elastically deforms at cross section. By means of that the distributed pressure is provided on contact surface. This operating principle of spindle and borehole interaction determined name of the support as self-installing rock bolt (SARB). Usage of SARB is preferable for building temporary support because of smaller time expenditure on installation.

1. Introduction

The combined rock bolt manufactured on the basis of SARB is represented in figure 1. Apart from a spindle it also includes a bearing plate that provides distributed support to the working surface. The interaction between the spindle and the bearing plate is realized by a bearing ring 1 connected with a weld 3.

![Figure 1](image.png)

**Figure 1.** The combined rock bolt: a) bearing ring, b) spindle, c) weld, d) bearing plate, e) sectors, f) technologic slot.
Normal operation of combined rock bolt is determined by holding power provided with its operational and physical characteristics. The main characteristics are load capability of the spindle, bearing plate, limit stop performed on a rock stabilizer spindle, stability of the spindle when it is installed into the borehole.

The works performed during the fixation of the working surface in a shaft are specified by standardized documents. In particular, GOST 31559-2012 'Rock bolt. The general specifications' determines the minimal holding power of usage of support with frictional way of fixation of 50 kN. In respect to combined support the working efficiency is determined by strength parameters of a support unit and bearing plate. In this regard the certificate for the manufactured combined rock bolt must include the noted operational and physical characteristics determined by a calculation method or experimentally.

2. Assessment of the impact of SARB parameters on operational characteristics of combined rock bolt

In the process of drawing up a datasheet of fixation of an underground working the value of the holding power of support determined by geometric parameters of structural components and steel characteristics should be taken as a basis.

The holding power of a combined rock bolt with SARB \(P_{HR}\) is the minimal of two values

\[ P_{HR} = \min (F_{RS}, P_{SC}) \]  \hspace{1cm} (1)

\(F_{RS}\) – resistance of shearing of a rock stabilizer along the borehole, kN;

\(P_{SC}\) – the ability of structural components to react the load, kN.

The minimal value of the rock stabilizer resistance to shearing along the borehole equals the friction force on the contact surface

\[ F_{RS} = F_F \] \hspace{1cm} (2)

The friction force is a parameter mainly determined by the condition of a borehole surface. Therewith, the correlation (2) is fulfilled at the initial stage of the support loading. Henceforth in case of transverse displacement of the rock towards the borehole axis the value of \(F_{RS}\) may increase to \(P_{SR}\) – the holding power of the rock stabilizer spindle.

The load capability of structural components is determined as minimal from three elements

\[ P_{HR} = \min (P_{BP}, P_{SR}, P_{LS}) \] \hspace{1cm} (3)

\(P_{BP}\) – load capability of bearing plate, N;

\(P_{SR}\) – load capability of spindle of rock stabilizer, N;

\(P_{LS}\) – load capability of limit stop, N.

The factor of stability during installation a spindle into a borehole is determined by the observance of terms

\[ F_{RC} \leq F_{EC} \] \hspace{1cm} (4)

\(F_{RC}\) – the current value of resistance to insertion a spindle into a borehole \(F_{EC}\);

\(F_{EC}\) – critical force determined by Euler formula.

2.1. Bearing plate

GOST 31559-2012 specifies the bearing plate thickness as no less than 4 mm. The experimental research is performed for assessment of loading capability of the bearing plate depending on geometric parameters. The dimensions of supporting surface and height of spherical part were varying with 4 mm of constant value of thickness. It is found that changing of dimensions of plane part from 150×150 till 200×200 does not depend on load capability. Along with the constant radius of spherical part equals 133 mm and diameter of a hole for a spindle equals 41,5 mm the influence on its height above
the bearing plate equals 24 mm, 28 mm, 34 mm was researched. The stress leading to the loss of shape made up correspondingly 41 kN, 86 kN, 102 kN.

In respect to the combined rock bolt $P_{br}$ should be considered as equal to the force corresponding to the initial stage of the loss of the shape of a spherical surface. When $H = 34$ mm the limitary load capability of the bearing plate composes $P_{br} = 102$ kN. The increasing of the height $H$ on more than 34 mm is not reasonable since it is connected with distortion of geometry of the bearing plate conditioned by deep drawing.

2.2. The spindle of a rock stabilizer
In the contex of holding power of the rock stabilizer spindle $P_{sr}$ it is necessary to distinguish allowable stress $[P_{sr}]$ and force that leads to its destruction $P^*_{sr}$. By reference to providing the required safety level $P_{sr} = [P_{sr}]$ should be accepted.

Value $[P_{sr}]$ is determined by the formula

$$[P_{sr}] = [\sigma] \times S_{CSA}$$

(5)

$[\sigma]$ – allowable stress of the spindle material, MPa, $[\sigma] = \sigma_t / n$;

$\sigma_t$ – yield limit of the spindle material, MPa;

$n$ – safety coefficient, $n = 1.1 - 1.2$;

$S_{CSA}$ – cross sectional area of the rock stabilizer spindle, $m^2$.

The value $S_{CSA}$ is determined by the wall thickness $t$ and the length of the broach of the spindle $L$.

The correspondence (5) is true for the sections of the spindle placed at a distance from a limit stop. Its value decreases by means of changing of a metal structure conditioned by weld in a zone bordering on the limit stop. The calculated value of the allowable stress for the rock stabilizer made from Steel 20 with $d_{sr} = 46$ mm, $t = 3$ mm, and the slot width $b = 12$ mm makes up $[P_{sr}] = 96.2$ kN.

2.2. Limit stop on the rock stabilizer
The holding power of the limit stop $P_{ls}$ depends on the structure of the support unit. In the process of connection of the limit stop with a spindle by means of only a weld the calculation is performed for a cut along the section getting through the right angle bisector and having a leg of a joint $k$.

According to the strength condition $[P_{ls}] / (k \times l) \leq R_{w}$

$$[P_{ls}] = R_{w} \times k \times l$$

(6)

$R_{w}$ – the calculated metal resistance of the joints of welded seams with corner joints;

$l$ – the length of a weld;

$R_{w} = 180$ MPa, and $k = 1.2 \times t$ [12].

The weld is performed along the outside surface of the spindle in the existent rock bolt. The limit value of the length of the weld is determined by diameter of the spindle and decreased by a width of slot

$$l = \pi \times d_{sr} - b$$

After the appropriate substitutions the allowable stress of the limit stop is determined by the correspondence

$$[P_{ls}] = 216 \times t \times (\pi d_{sr} - b)$$

3. Conclusions
The combined rock bolts of a friction type are the advanced version of fixation of workings surface. Its proper functioning is provided by accomplishment of set of requirements to strength of elements. The holding power of a combined rock bolt is determined by operating characteristics such as load capability of structural components that are spindle, limit stop and bearing plate. In this case the load capability of the limit stop is limitative.
The assessment of workability of combined rock bolt according to the holding power characteristic should be performed according to the holding power of limit stop.

References

[1] Masaev Yu A, Masaev V Yu and Filina L D 2015 New developments in the field of fastening and increasing the stability of rock outcrops in mine workings Bulletin of the Kuzbass State Technical University 1 pp 41-44

[2] Kalmykov V N, Grigoryev V V, Volkov P V 2010 Research of variants of systems of working out for dredging at the onboard stocks at the combined geotechnology Vestnik Nosov Magnitogorsk State Technical University 1(29) pp 17-21

[3] Song G, Li W, Wang B and Ho S C M 2017 A Review of Rock Bolt Monitoring Using Smart Sensors Sensors 17 p 776

[4] Yeremenko V A, Inbinder I I, Marysuk V P and Nagovitsin Yu N 2018 The development of instruction for choosing the type and parameters of fixation of support of Talanha mine workings based on quantitative assessment of the rock mass conditions Mining magazine 10 pp 101-106

[5] Li C C 2015 Analysis of inflatable rock bolts Rock Mech Rock Eng 49 (1) pp 273-289

[6] Duzgun H S B 2005 Analysis of roof fall hazards and risk assessment for Zonguldak coal basin underground mines Int J Coal Geol 64 pp 104-115

[7] Kalmykov V N, Latkin V V, Zubkov A A , Neugomonov S S and Volkov P V 2015 Technological peculiarities of building of intensive support at underground mining Mining information-analytical bulletin 3 Conditions of stable functioning of Russian mineral resources sector. Special issue 15 pp 63-69

[8] Zubkov A A, Latkin V V, Neugomonov S S, Volkov P V 2014 Perspective ways of fastening of mine workings on underground mines Mining information-analytical bulletin. Conditions of stable functioning of Russian mineral resources sector. Mining book 1 pp 106-117

[9] Neugomonov S S, Volkov P V, Zhynov A A 2018 Fixation of semi-stable solid by intensive combined support based on friction rock stabilizers of SARB type Mining magazine 2 pp 31-34 DOI: 10.17580/gzh.2018.02.04

[10] Chen J, Qiao X, Wang M 2011 Stress and action mechanism of rock bolt in Loess Tunnel Chin. J. Rock Mech. Eng. 30 pp 1690-1697

[11] Zubkov A A, Zubkov A V, Kutlubaev I M, Latkin V V 2016 Improvement of the construction and technology of installation of supports with frictional fastening Mining magazine 5 pp 48-52

[12] SP 16.13330.2011 Steel structures. Revised edition SNiP II-23-81* (as modified N 1)