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Development and Research of a New Reinforced Design of the Mounting Block

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Abstract. In connection with the modernization of coal mine equipment in the Karaganda coal basin, the customer faced the problem of installing large units: the existing installation blocks have a low load-bearing capacity. This article discusses the development of an experimental model of a reinforced installation block according to the customer's technical specifications. In accordance with the customer's requirements for dimensions, weight and load-bearing capacity, design and technological documentation for a new reinforced installation block design was developed. Mathematical calculations for the strength of the design units were verified by the APM FEM program in the KOMPAS-3D system. Steel grade 30XGSA is the optimal material for the main parts of this product under the specified loads. The nominal diameter of the rod for the "axis" and "earring" parts is 48 mm. The weight of the structure meets the requirements and does not exceed 15 kg. The minimum permissible cross-sectional area of the eye of the "earring" part is 329 mm². Two installation blocks were manufactured according to the developed drawings, which successfully passed the tensile strength tests. This design has been found to be operational and is to be tested in coal mine conditions.

Keywords: mounting block, bracket, steel rope, lifting device, rigging.

Introduction

The assembly block is widely used in assembly and disassembly work on equipping coal mine long walls with equipment and serves to transport and install the units of the complex at the work site [1, 2].

The assembly block must meet strict safety, reliability, and efficiency requirements [3].

The main requirements for the assembly block are [4-6]:

- strength and reliability of the structure;
- the quality of the material from which it is made;
- ensuring its lifting capacity with a safety margin;
- the safety of load fixation.

The block must be made of materials resistant to high loads, corrosion, abrasive wear and exposure to aggressive mine environments (dust, humidity, gases) [7, 8].

The block must be designed to lift and move loads corresponding to its lifting capacity with a safety margin [9]. Reliable grips, slings, and other fastening elements must ensure the safe fixation of the load during transportation and installation [10].

The assembly block is a structure consisting of three main elements: a bracket, an axis, and a block (Figure 1). Before carrying out work, the assembly block is fixed by the bracket with fastening elements (chain, rope, etc.) to the metal arch support of the mine workings or to the metal structures of the installed mechanized support, a branch of the rope Ø22.5 ... 27 mm is passed through the block and the block is fixed with an axis. The assembled assembly block is used both to change the direction of movement of the ropes and to lift and move loads.

Fig. 1. - General view of the operating mounting block

In modern realities, new and modernized equipment is heavier and less divided into component units, which complicates the production of installation work with operation at maximum loads of installation blocks [11]. The brackets of the installation block often fail during the work. Also, in case of critical deformation of the bracket, the released rope can cause injury to workers.

In this regard, in the mines of Karaganda, there was a need to use a new reinforced design of the installation block that meets the following requirements:

1) type of design - collapsible;

2) breaking load - not less than 320 kN;

3) weight - no more than 15 kg (maximum weight of the load lifted by the worker, permitted by safety requirements);

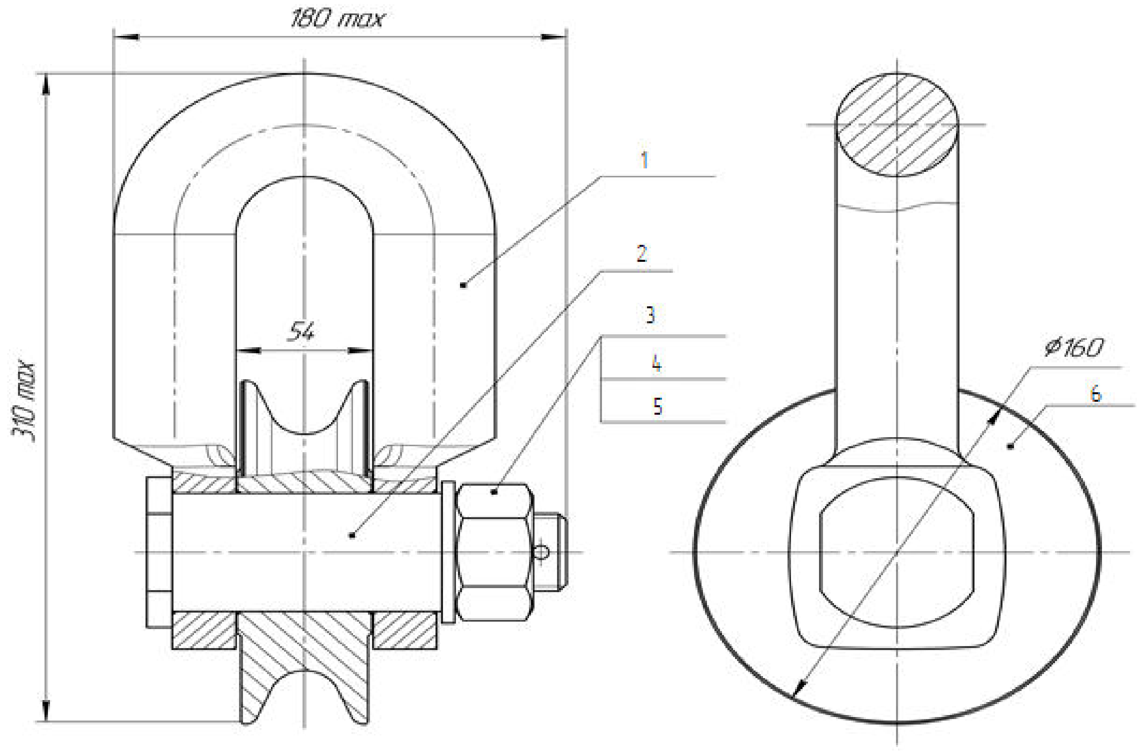
4) overall dimensions - 160 × 180 × 310 mm.

When monitoring the market of lifting devices, the required blocks were not identified. Most of the assembly blocks either exceed the declared dimensions and weight, or do not have the required load-bearing capacity.

The aim of the study is to develop a new reinforced design of the mounting block for assembly and dismantling works in coal mine long walls, ensuring the above requirements.

1. Research methodology

The main load-bearing elements of the assembly block structure are the “axle”, “block” and “earring” parts (Figure 2).



1 – earring; 2 – axis; 3 – washer; 4 – nut; 5 – cotter pin; 6 – block

Fig. 2. – Scheme of the design of the reinforced mounting block

In accordance with the stated requirements, the design of the assembly block must have dimensions of 160 × 180 × 310 mm. The "axis" was previously made of 30KhGSA steel and to increase the lifting capacity it will be enough to calculate and change the working diameter upwards.

The design of the "block" Ø160 mm for ropes Ø22.5 ... 27 mm did not change except for the diameter of the hole for the "axis". The design of the "earring" was selected for the required dimensions and the loads on the eyes were calculated using various grades of steel, since previously the "earring". At “Kurylysmet” LLC it was made of steel 20.

For comparison with steel 20, the most commonly used structural carbon high-quality and structural alloyed round steels were selected, namely: 35, 45, 30XGSA and 40C. The main criterion for optimizing the choice of material for the construction of the assembly block is the strength criterion. To assess the strength criterion of the structure, it is necessary to know the yield strength of the selected material. The yield strengths of the steel grades used are presented in Table 1.

Table 1. Yield strength of steel grades

Steel grade	Yield strength, MPa
20	250
35	320
45	360
30XGSA	850
40X	330

The safety factor of the structure is determined by the formula [12]:

$$n = \frac{\sigma_s}{\sigma_{max}}, \tag{1}$$

where σ_s – yield strength of material, MPa;

σ_{max} – maximum stresses in the structure, MPa.

2. Calculation of the geometrical dimensions of the mounting block structure

To determine the diameter of the “axle” and “earring”, the formula for calculating the rod on shear was used [13]:

$$d = \sqrt{\frac{4 \times S}{\pi \times \tau_{sh} \times 0,3}}, \tag{2}$$

where d – axle diameter, mm;

S - нагрузка на срез, Н;

0,21 - allowable voltage coefficient;

τ_{sh} - allowable shear stress (yield strength of the rod material), MPa.

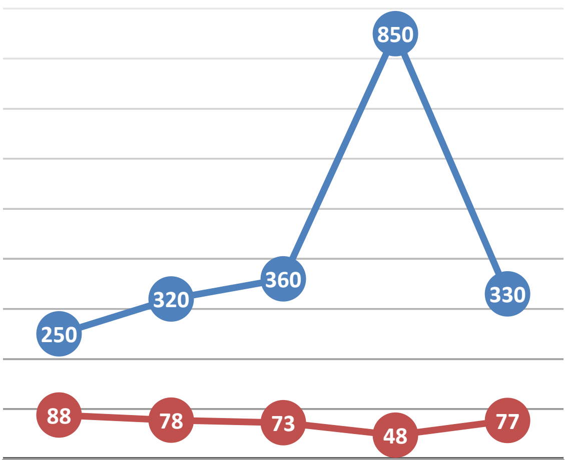
Substituting into the formula the values for steel 30XGSA and the required breaking load, the following result was obtained:

$$\sqrt{\frac{4 \times 320000}{3,14 \times 850 \times 0,21}} \approx 48\ mm$$

According to calculations, the diameter of the rod of the “axle” and “earring” was taken as 48 mm.

At the pin diameter of 48 mm, the weight of the structure is minimal.

For comparison, we made similar calculations with the previously mentioned steel grades (Figure 3).



	20	35	45	30XGSA	40X
Yield strength, MPa	250	320	360	850	330
Rod diameter, mm	88	78	73	48	77

Fig. 3. - Diameter of the axis of the mounting block structure when using different steel grades

According to this table, we were convinced of the correctness of the choice of material - steel 30XGSA, which with the highest characteristics of yield strength provides the smallest diameter of the rod, necessary for the design of the structure in the given overall dimensions.

The following calculations were made for the “earring” lugs.

The permissible normal stress at break is determined by the formula [14]:

$$[\sigma_{\text{n}}] = \frac{\sigma_{\text{t}}}{n}, \tag{3}$$

where $\sigma_{в}$ - tensile strength, MPa;

n – safety factor.

Permissible normal stress at rupture by formula (3):

$$[\sigma_{\text{n}}] = \frac{1220}{3} = 406 \text{ MPa}$$

The permissible shear stress at shear is determined by the formula [15]:

$$[\tau_{ps}] = 0{,}6 \times [\sigma_n] = 0{,}6 \times 406 = 243 \text{ MPa} \tag{4}$$

The tangential stress in the vertical section at given parameters depends on the cross-sectional area of the eye S and is determined by the formula [16]:

$$\tau_{ts} = \frac{Q}{4 \times S} < [\tau_{\text{ps}}], \tag{5}$$

where Q - breaking load, N;

S – cross-sectional area, mm^2.

Accordingly, the area of the eyelet must be no less than [17]:

$$S = \frac{Q}{4 \times \tau_{ps}} = \frac{320000}{4 \times 243} = 329\ mm^2 \tag{6}$$

The cross-sectional area of the eye is determined by the formula [18]:

$$S = \frac{D-d}{2} \times B, \tag{7}$$

where D = 85 – eye outer diameter, mm;

d = 49 – diameter of the eyelet hole, mm;

B = 25 – eye thickness, mm.

Cross-sectional area of the eye by formula (7):

$$S = \frac{85 - 49}{2} \times 25 = 450\ mm^2$$

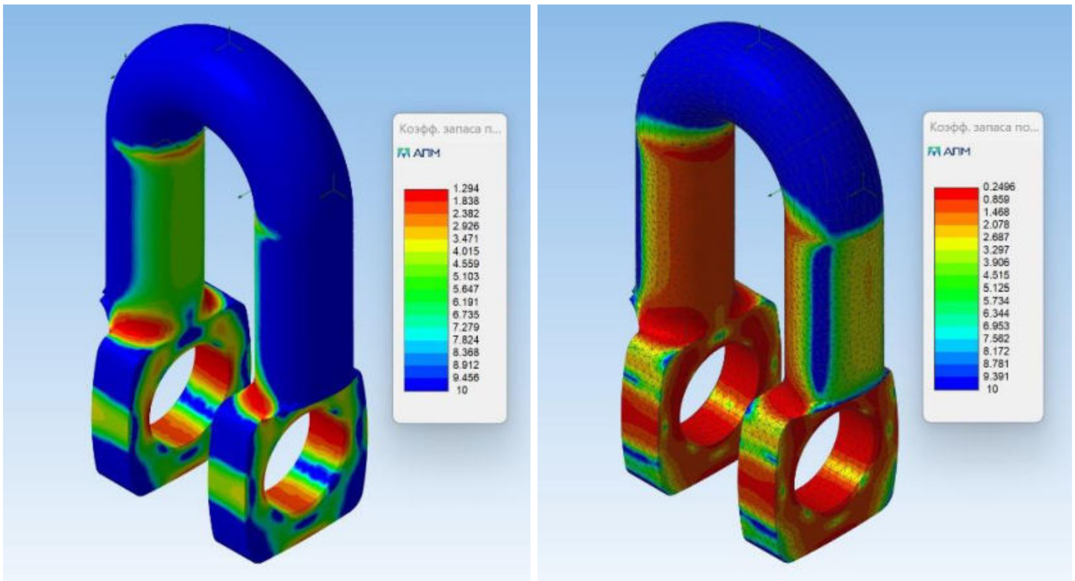
The total tangential stresses in the vertical section are equal to:

$$\tau_{ts} = \frac{Q}{4 \times S} = \frac{320000}{4 \times 450} = 178 \text{ M}Pa < 243 \text{ MPa}$$

In the final version, the strength condition is fulfilled: the result of the calculation of the tangential stress in the vertical section of the “ear” lugs was lower than the permissible one, which corresponded to the stated requirements.

3. Engineering analysis of the mounting block design

Verification of mathematical calculations of the part “bracket” was performed in the APM FEM program in the KOMPAS-3D system of ASKON LLC. The functional set of the program allowed to simulate a solid object and comprehensively analyze the behavior of the calculation model under various influences on it [19, 20]. The results of calculation of the applied loads on the lugs of the solid three-dimensional model at the fixed arc-shaped part were visually reflected in it. In addition, as a comparison for steel 30XGSA and steel 20, calculations for safety factor (Figure 4) and total deformations (Figure 5) were carried out.

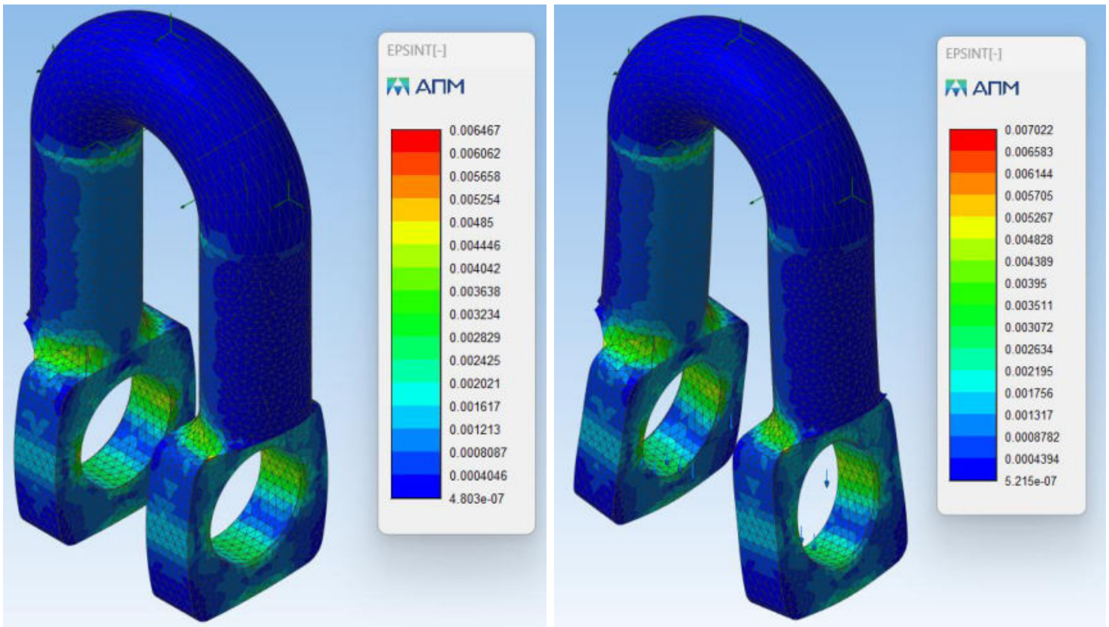


a) b)

a) steel 30XGSA; b) steel 20

Fig. 4. - Result of calculation of safety factor of the part "earring" in APM FEM application

The safety factor of the earring made of 30 XGSA steel ranges from 1.8 to 10 mm, the total deformation of the earring structure made of 20 steel ranges from 0.8 to 10. The most vulnerable parts of the earring are the inner diameter of the eyelet and the eyelet flanges.



a) b)

a) steel 30XGSA; b) steel 20

Fig. 5. - Result of calculation of total deformations of the part "earring" in APM FEM application

The total deformations in the cross-section of the eyelet of the earring from steel 30 XGSA range from 0.004 to 4.8 mm, the total deformations of the earring structure from steel 20 - 0.005÷5.2.

All the results obtained by the program confirmed the mathematical calculations and on this basis it was decided to proceed to the manufacture of prototypes for experimental testing in laboratory conditions. This analysis allowed to avoid labor and material costs for manufacturing of physical experimental samples in case of undetected errors in calculations.

Based on the results of mathematical calculations and engineering analysis, a working set of drawings of the mounting block was developed for the manufacture of prototypes.

4. Experimental studies

Two prototypes of mounting blocks were manufactured for the experimental breaking force test. The parts “earring” were made by free forging with subsequent machining, the other parts, except for standard products for axis fixation, were made on lathes. The parts “earring” and “axis” have undergone the necessary heat treatment. All parts individually and the complete assembly have been quality controlled. During the inspection, the main dimensions of the assemblies of the blocks planned for control measurements during the tests were documented, namely:

- diameter of the “axis”;
- diameter of the holes of the lugs of the “shackle”;
- width, height and thickness of the holes of the “earring”.

For the experiment was prepared universal machine with ultimate load of 100 tons type UMM-100 (hereinafter: breaking machine), which has a certificate of periodic verification. The part “block” was excluded from the test, as its strength was not questioned and separate calculations for it were not carried out. Instead of the “block” part, a fixture in the form of a rod with an eye and a threaded rod for fixing the block in the movable and fixed frames of the tensile machine was developed (Figure 6).

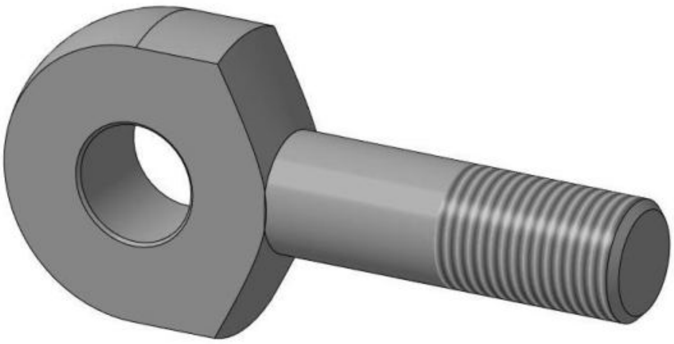


Fig. 6. - Fixture for installation of mounting blocks

It was decided to install two blocks simultaneously on the tensile machine; this allowed to save testing time and to exclude the development of an additional fixture for fixing the “earring” part in the frames of the tensile machine. For this purpose, firstly, the “earring” parts were provided with joint contact of the inner surfaces of the bending radii. Then the fixtures in the form of a rod were installed with lugs instead of parts “block” and fixed in “earrings” with “axes” and standard products, then the rods with threaded rods were installed and fixed in the frames of the rupture machine (Figure 7).

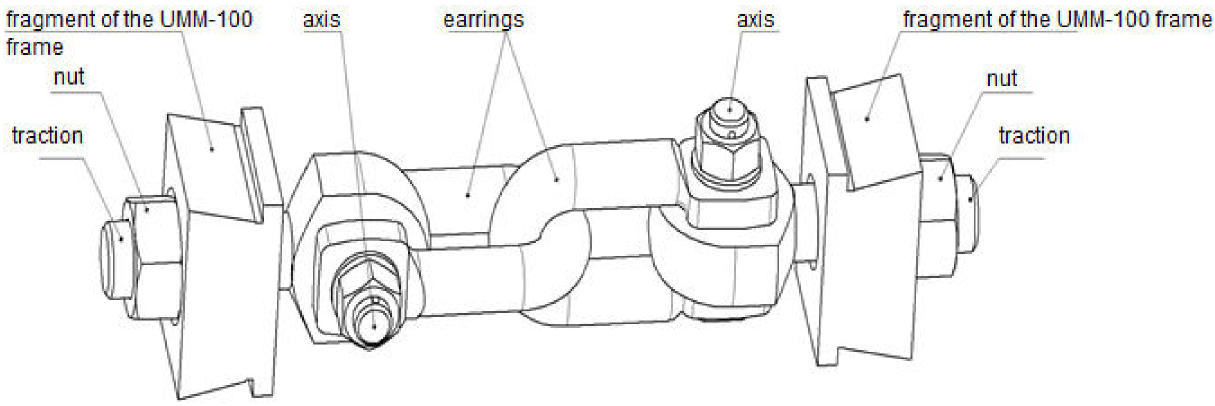


Fig. 7. - Project of mounting blocks installation on the UMM-100 machine

The tests were carried out in four stages with a gradual increase in load. After placing the prototype mounting blocks on the tensile machine (Figure 8), they were subjected to a load of 26000 kgf for 5 minutes. After that, the assembly blocks were dismantled from the tensile machine, visually inspected for deformations and disassembled into assemblies, over which a control measurement of the main dimensions was carried out.

Рис. 8. – Installed mounting blocks on the UMM-100 machine

The mounting blocks were then reinstalled and tested under loads of 32000 kgf, 40000 kgf and 48000 kgf. Each load was applied to the mounting blocks for 5 minutes. After each test, disassembly and measurements of the main dimensions were taken.

During the whole experiment, none of the dimensions of the mounting blocks were changed, which means that they were fully tested by the tensile testing machine and the experiment can be considered a success.

In the future, based on the conducted experiment, each newly manufactured mounting block before acceptance by the department of technical control of "Kurylysmet" LLP will be subjected to load testing in laboratory conditions on the breaking machine UMM-100 in 40000 kgf for 5 minutes with recording the test results in the product passport.

Conclusions

The results of mathematical calculations, engineering analysis and experimental tests proved the performance of the design. As a result of the conducted researches the following was established:

1) Steel grade of the main parts, taking into account the loads acting on them - 30XGSA;

2) The diameter of the rod of the parts "axle" and "earring" - 48 mm;

3) The minimum permissible cross-section of the eye of the part "earring" - 329 mm^2;

4) The developed design did not exceed the required weight limit of 15 kg;

5) The conducted experiment proved that actually the assembly block is able to withstand a short-term load of ≈470 kN.

This design is made in strict accordance with the stated requirements for the mines of Karaganda coal basin.

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