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USE OF COMPUTER SIMULATION TO ESTABLISH PARAMETERS OF STEEL STRUCTURE STRENGTHENING ELEMENTS

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The article presents the results of computer simulation related to establishing the parameters of mine hoisting machine steel structure strengthening elements. The simulation was performed using the ANSYS computer program. The basis of this program is the finite element method therefore, selecting the type and the size of the finite element affects the calculation accuracy. There have been studied 11 computer models. The results obtained make it possible to establish the strengthening element optimal shape, size and thickness. The most optimal shape of the pad is a disc; this has a positive effect on reducing the level of mechanical stresses in the fracture zone of the beam. The strengthening element «disc pad» is used to combat fatigue failure of the brake beam structures of a mine hoisting machine. The article presents practical experience in the fight against fatigue failure of f mine hoisting machine steel structures.

Keywords: mine hoisting machines, fatigue strength, stress-strain state, structure, computer simulation

INTRODUCTION

The operation of mine hoisting machines (MHMs) is fraught with a number of difficulties and problems. One of the problems of the MHM operation is fatigue failure of its metal structures. The metallurgical company ArcelorMittal uses MHMs to transport coking coal from the mine to the surface.

Then, coke is produced using this coal at the ArcelorMittal metallurgical plant.

In [1, 2], there are presented statistics of damages and methods of dealing with fatigue destruction with the use of strengthening elements. Metal structures are susceptible to fatigue failure. The appearance of fatigue cracks reduces the strength of the braking device metal structures. Computer simulation of the stress-strain state of structures will help solve this problem. There is positive experience of using strengthening elements in practice [1, 2]. As the experience of practical observations has shown, over time, "hazardous destruction zones" are formed in the metal structure of the beam. They must be eliminated since they can lead to complete destruction of the structure, and this can in turn lead to a serious accident and provide an emergency [1, 2]. The danger of the situation consists in the fact that the MHM lifts coking coal from the several hundred meters depth, and sudden damage to the braking device due to fatigue failure can lead to serious consequences and endanger human lives. This article is a continuation of previously published research materials, which are detailed in [1, 2]. It has been mentioned earlier that there is positive experience in dealing with fatigue cracks with the use of strengthening elements. Within 6 years, scientific work has been carried out to find methods of restoring steel structure strength of MHMs [1, 2]. This article highlights those issues that were not included in the previously published material [1, 2], namely, the methods that were used to establish the parameters of the strengthening elements of steel structures.

The basis of this article is the experience in developing methods of combating fatigue fracture with the use of strengthening elements. The process of fatigue crack development in metal structures was analyzed [3]. To understand the material of scientific research published earlier in [1, 2], it is necessary to study the mechanism of fatigue failure of structural steel [4], as well as to understand the use of the basic laws of fracture mechanics in calculating metal structures strength and reliability [5]. It is important to assess reaching the limiting state of structures in the event of an emergency [6].

Since the MHM elements are subject to high-cycle fatigue, the results were analyzed and the features of this process were taken into account [7]. The mechanism of ultra-long fatigue fracture of steels is considered in detail [8]. Similar cases of fatigue failure were found in [9, 10]. An important point is non-destructive testing as the main method of searching for cracks in

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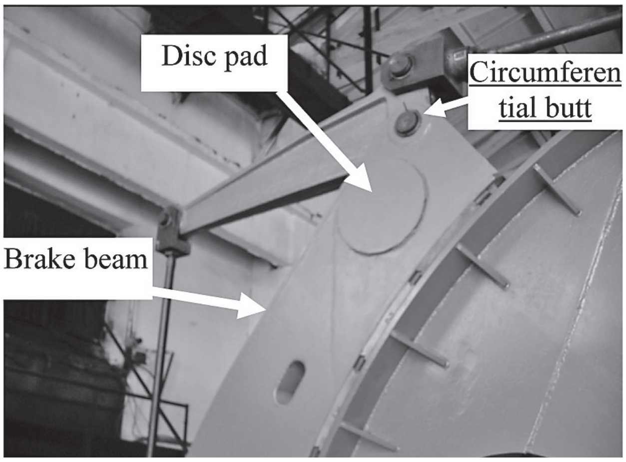

Figure 1 Practical use of structural strengthening elements of the ArcelorMittal MHM design

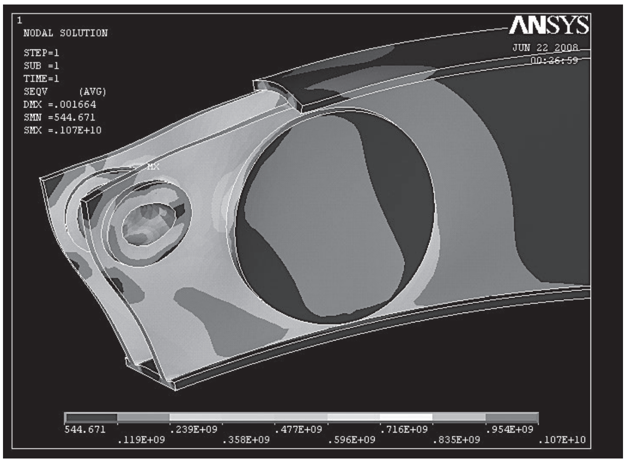

Figure 2 Imitation of different diameters of the disc pad and coordinates of its location

steel structures [11]. Since the basis of this article is the stress-strain state (SSS) modeling of the MHM brake device beam, the information of the fatigue cracks behavior and the formation of mechanical stresses in the beams was obtained from [12, 13]. The experience of assessing the performance of metal structures with cracks presented in [14] was studied. All of the above sources have helped developing methods of strengthening steel structures to restore structural strength.

In [1, 2], a description of the method of establishing the optimal parameters of the strengthening elements, which were used in the repair of steel beams of MHMs, has already been given.

Figure 1 shows the practical use of strengthening elements to increase the metal structure strength of the braking device steel beam.

The strengthening element can be a disc pad or a ring pad of the sleeve. There also can be used the rib strengthening element, but this element was not used in the case described. In this article, the results of computer simulation are presented to determine the strengthening elements parameters of steel structures using the ANSYS program. This program is based on the finite element method, so selecting the type and the size of the finite element affects the accuracy of calculations [1, 2]. In [1, 2], all the stages of simulating the stress-strain state of the braking device beam of a MHM are considered, except for the establishment of the strengthening elements parameters of steel structures, namely, their size, shape, thickness.

COMPUTER SIMULATION OF THE STRESS-STRAIN STATE OF MINE HOISTING MACHINE BRAKE MECHANISM BEAM STEEL STRUCTURE

To find the optimal size, shape, and thickness of the “disc pad” there were studied 11 different computer models of the brake beam with different diameters of disc pads and different coordinates of their location on the side faces (Figure 2).

These studies made it possible to determine the most optimal rational diameter of the disc pad and the coordinates of its location relative to the center of the axis of the hoisting machine drum. During the study, the pad is moved along the OX and OY axes, but the coordinates along the OZ axis did not change. Thirty experiments were carried out with the use of disc pads; their diameters varied from 0,2 to 0,5 meters. On the basis of the experiments carried out, the model of the brake beam with the best diameters of the “disc pad” and the coordinates of its location, at which the minimum values of mechanical stresses were reached under loading from 1 to 10 MPa, were determined. Figure 3 shows a graph of the mechanical stresses developing in the section of the beam, when it is loaded, dependence on the diameter of the “disc pad”.

The best result is obtained by the computer model with the disc pad diameter equal to 500 mm. When studying the stress-strain state of 11 computer models, with the same load equal to 10 MPa lower stress values were formed, they were reduced by more than 20 % (14 MPa). So, increasing the diameter of the disc pad has a positive effect on reducing the level of mechanical stresses in the fracture zone of the beam.

Modeling the shape of the pad showed that among the 11 models, the best performance was achieved by using a disc, while a square and a hexagon were less effective in reducing stress.

The most optimal shape of the pad is a disc, this has a positive effect on reducing the level of mechanical stresses in the fracture zone of the beam. The stress values for each pad shape are shown in Figure 4.

Figure 5 shows visualization of the stress-strain state of the beam strengthened with a square pad.

It is obvious that a ring-shaped pad performs slightly better than a disc, but practical experience has shown that this difference is not significant.

The use of pads with corners is not desirable, since they create additional stress concentrations in the zone of fatigue failure of the beam. The values of stresses inside the sleeve and the seam of the upper face in-

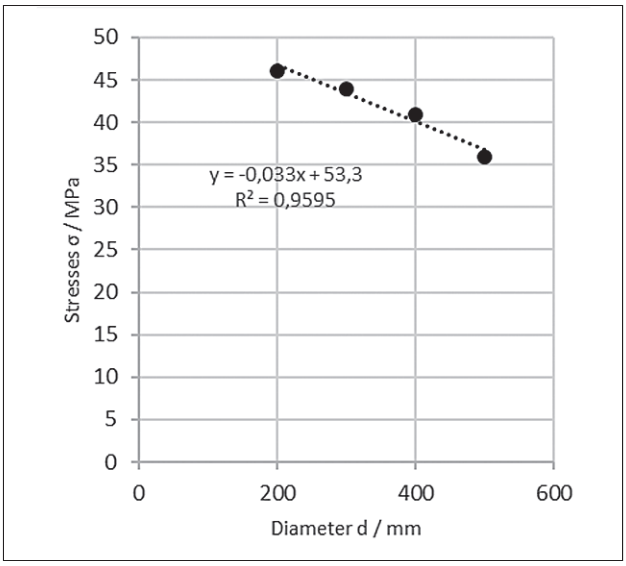

Figure 3 Results of studying imitation models with different diameters of the disc pad

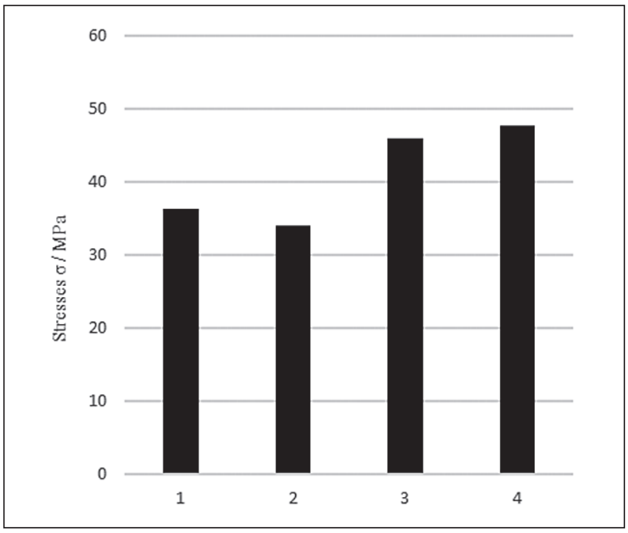

Figure 4 Stress values for the pad of different shapes: 1 – disc, 2 – ring, 3 – hexagon, 4 – square

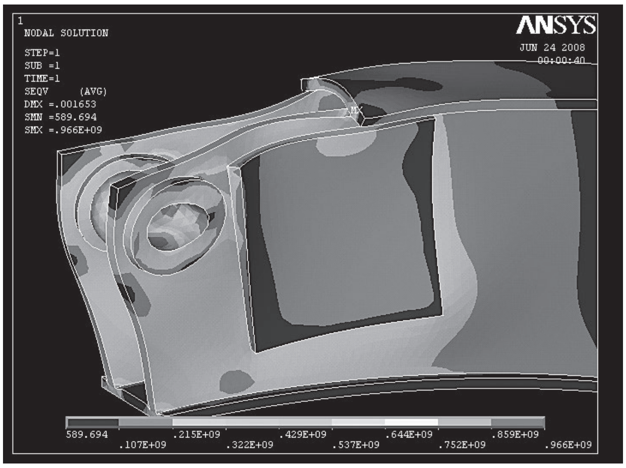

Figure 5 Visualization of the stress-strain state of the beam strengthened with a square pad

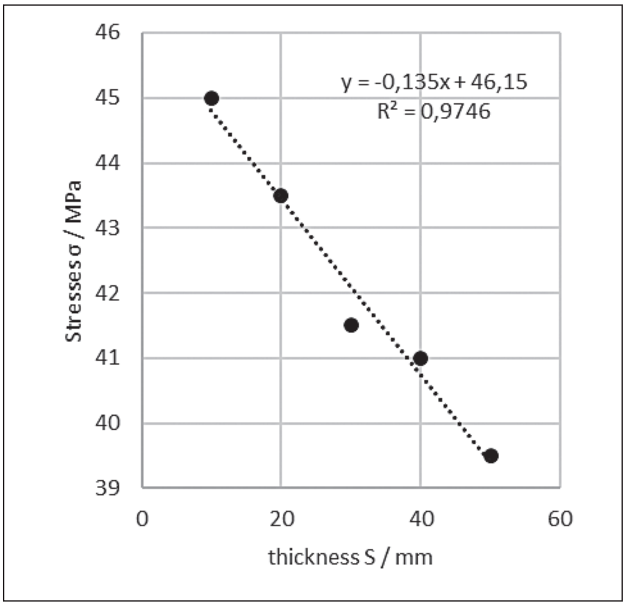

Figure 6 Graph of the mechanical stress reduction dependence on increasing the disc pad thickness

crease, this leads to the formation of cracks in the area of the lugs.

The use of a ring is technologically complicated since to fix it, it is required to make two circular welds located on the inside and outside of the ring. For this reason, in practice a disc is used instead of a ring. The final examination is to determine the thickness of the “disc pad”.

Figure 6 shows a graph of the mechanical stresses reduction dependence with increasing the thickness of the “disc pad.

Analyzing the graph shown in Figure 6, it can be concluded that increasing the thickness of the disc pad leads to decreasing mechanical stresses in the fracture zone of the beam. The thickness of the real wall of the brake beam of the MHM is 20 mm.

Computer simulation has shown that increasing the thickness of the “disc pad” from 20 mm to 40 mm will double the weight of the pad and reduce stress at the point of damage to the beam by only 5 %. The response time of the main brake can increase, which is not permissible according to safety rules. Further increasing the thickness of the “disc pad” by 40 mm will cause difficulties in welding during its mounting.

DISCUSSION AND CONCLUSIONS

The optimum form of strengthening elements for the brake beam is the “disc pad” with the wall thickness of 20 mm and the diameter of 500 mm. Increasing its thickness to 40 mm leads to significant increasing the inertial mass of the beam, due to which the dynamic loads on the drive of the MHM brake device increase.

The considered method is universal and suitable for any metal structure subject to fatigue failure, for example, made of channel, I-beam and box-shaped steel profiles. Computer simulation of the stress-strain state of metal structures will help solve the problem of fatigue failure. Using the computer simulation allows you to establish parameters of the steel structures strengthening elements.

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Note: Translated from Russian into English by N. Drak, translator of Karaganda Tech-nical University