Using of science technologies for mining machinery constructions' strength improvement

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Abstract. Recommendations for strengthening the brake construction in accident dangerous areas of fatigue destruction were developed. Computer modeling was made using the ANSYS program that helps to visualize stained condition of the construction for further practical testing of the strength and reliability improving technology of mining elevating machines' constructions, which are being in a long-term use, with a help of the strengthening elements. A way of construction strengthening, which eliminates the possibility of further fatigue destruction of the brake system elements, because of the load cycle in exploitation process.

1. Introduction

The trend of modern development of production technology of mining equipment is that the main task should not be placed on maintaining technology to achieve a high level, but the need for prompt changes. The most significant changes are not on the path of modernization, but due to a fundamental transformation of existing technologies in high-tech.

Improving the reliability of the mining elevating machine's (MEM) brake system (BS) requires, including scientific research of a construction's rational variant which can withstand long-term fatigue and continue to remain MEM operational for a long service life.

The ANSYS program, allows you to simulate the stress-strain state of the BS elements specifications and replace bulky full-scale tests of experimental samples by modelling find the best option reinforced construction, with higher strength parameters and reliability, also to develop practical recommendations to restore strength through the BS MEM repair works. With the gain elements it is possible to locate and stop the growth of fatigue cracks in the BS elements and to prolong its service life.

Ensuring the reliability of the Karaganda basin-ray's mining elevating machines' brake system is becoming increasingly important, as the load sharply increases due to increased mining in recent years. The load increasing directly affects the wear and the brake element failures. In the process of raising or

lowering the load must be considered rapidly changing nature of the load on the brake system. Significant peak loads on the brakes occur during sudden stops of the body coiling rope in time of emergencies. Equally important is the number of cycles of the brake system’s working during the day, which is from 500 to 1500 "ascending and descending" [1]. These factors contribute to the development of fatigue cracks in BS which can develop during operation and lead to structural failure. It is hard to predict the development and forming of such damages, only the most affordable and reliable method is destructive testing. According to the data presented in [2], fatigue cracks are formed in place of the lugs which fasten the brake linkage sleeve. After identifying the damages in the brake beam elements it is necessary to make its repair or replacement. The beam replacing associated with considerable economic and labour costs, as it requires disassembly of indigenous parts of hoisting machine, which in turn causes a length-tive simple lifting machine. Repair usually boils down to cutting and welding-arc welding cracks. However, this method does not provide a reliable operation of the construction, since the operation may continue to develop cracks cracks formed.
Considering these circumstances, it is appropriate to increase the strength of brake beams by strengthening its structure in the presence of stress concentrators places where eventually formed fatigue cracks. Strengthening MEM BS can significantly improve their durability.

2. The studying of stress-strain state of the mining elevating machine’s brake beam construction

Based on the requirements of the studying object, is formed the ultimate goal of research, outlined the rational way to achieve it and formed a research program [1]. The last one should be regarded pre-loading process optimization and modes of operation of mining elevating machine’s brake system, implementing this knowledge-based technology, which should provide the best technical and economic parameters of the studying object. An important component of this technology is to obtain an adequate model, which can be used to identify "critical points of failure" and "accident-prone zones of deformation." It is known that the details of the brake system are carry-out its functions only in the initial period of operation [1]. They often can be destroyed by fatigue reasons related to exposure to repeated cyclic loads. Mechanical stresses concentrators reduce stress durability during cyclic loading, and form the "accident-prone zones of deformation" in the BS constructions. Figure 1 shows a graphical representation of a mechanical stresses modeled in the ANSYS program. Marked decrease in fatigue strength of the beam structure in accident-prone zones 1 and 2, where the greatest concentration of stress in the process of using the pro-beam fatigue cracks is formed. Zone 1 and 2 are located in an area-weld the top and the side face of the beam (Figure 1). This is also related to metal structural changes around the suture zone and the concentration of residual stresses after welding.

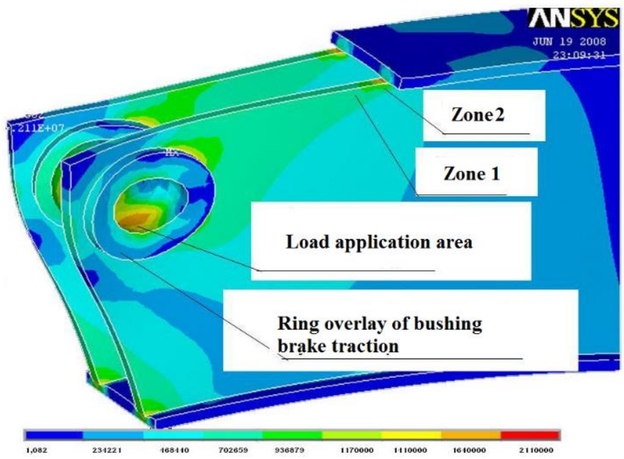


Figure 1. Graphical display of typical brake beam model with the "accident-prone zones" fatigue fracture 1 and 2.

Analysis of the fatigue fracture of metal brake beam with the cyclic load factor showed that the main factors in the development of fatigue cracks is:
- The amplitude of the stresses and deformations;
- Duration and number of cycles.

A transition from a hidden (fine) to ext-term (broad) fracture is observed in the process of destruction due to metal fatigue which accompanied by the accumulation of damages in the grain boundaries of the metal from cycle to cycle. Results modeling of structure cracks development using the ANSYS presented on Figure 2. The computer model allows you to visualize the development of fatigue cracks in the accident-prone zones 1 and 2, that will set the parameters of structural elements in the future [2].

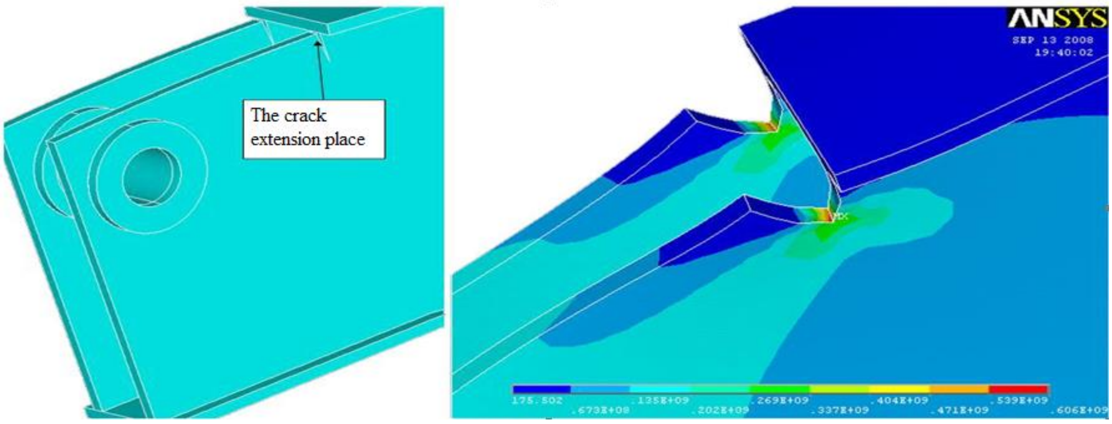


Figure 2. Graphical representation of a fatigue crack development process in the "accident-prone area."

A method of the construction enhancing based on the use of overhead elements, which can eliminate the possibility of further fatigue failure associated with multiple cyclic loads application BS elements during its operation. Overlay gain can be disc pad, edge, ring pad or combined options. Overhead elements mount on the side faces of the BS beam using a welded or adhesive bondings. These methods have been practically tested on existing MEM. The disc pad attaching by welding method requires measures for liquidation of the con-effects of welding deformation. The perspective direction is complement-installation work on the establishment of the use of adhesive pad. The present level of adhesive joints provide mechanical properties equal to connections made using arc welding. The advantage of adhesive joints is the lack of stress and deformations, also the formation of hardening structures of metal in the weld seam area because of the heat-affected influences occurring during welding process. The last are more efficient, related to the localization of "emergency - danger zones" and fatigue crack growth resistance. The technology of manufacture and installation of overhead components is simple and does not require sophisticated welding and mounting hardware. Figure 3 shows the elements of the proposed options for reinforcement of BS type "disk pad" and "edge" that are able to influence the nature of the development of cracks, significantly reducing stress concentrations and thus increase the durability and reliability. ANSYS software opportunities allow you to simulate the load on the beam elements associated with cyclical load and the asymmetry of the cycle.

During the simulation was able to establish the nature of changes in the rate of fatigue crack growth, which depends on the cycle asymmetry coefficient of stress intensity. Using the structural reinforcement of BS reduce the scope of cycle asymmetry coefficient of stress intensity, and therefore significantly reduce the fracture closure predisposition to change state on the verge of exhaustion and stress cycle asymmetry, which ultimately reduces the probability of the fatigue crack growth.

Terms and conditions of the process of formation and growth of fatigue cracks are directly depend on the cycle stress parameters (amplitude, asymmetry, frequency) and environmental impact (its reactivity, humidity, temperature), as well as the nature of the stress-strain state near the crack tip in the structural element which is defined by their geometry and dimensions.

The task of increasing the work durability and reliability of the top beam of brake system reduces to the definition of "dangerous places" in the design and measures for decreasing the stress and deformation. This can be done using the method of simulation of the development of cracks in the structure using the ANSYS program [3].

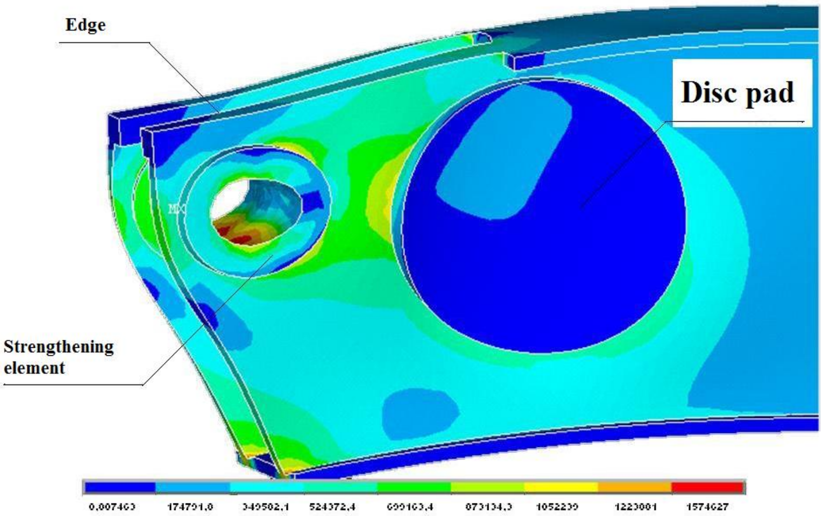
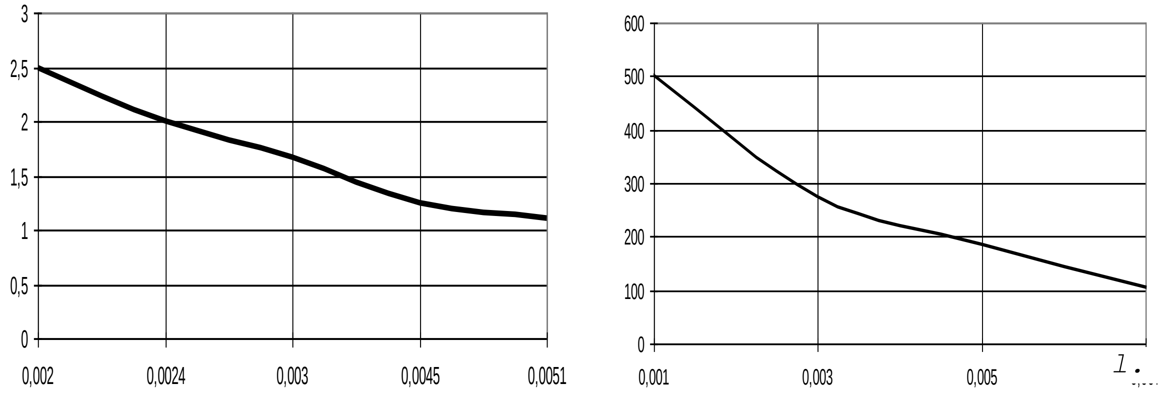


Figure 3. The design of beam elements with structural reinforcements.

The results of studies on the establishment of dependence reduction factor for the pass-β structural strength of the length of the growing crack in it; and reducing the dependence of values permissible for the construction of mechanical stress on the σk stresses growing crack in it, leading to the destruction of the structure presented in Figure 4*a* and Figure 4*b* respectively.

Computer modelling confirmed that the use of strengthening elements provide values reduction of mechanical stress and deformation at the crack tip, and significantly weaken the influence of stress concentrators (Figure 5).

The basis for calculation of the fatigue life (endurance) determining the ability of a material to resist the design cycle fatigue, which leads to the destruction of life and reduce the braking device. Calculation of endurance runs using three methods: calculation of the deformation, stresses calculation and fracture mechanics. All the listed methods are available in the module calculation of durable, available in ANSYS Fatigue Module. Computer simulation in the ANSYS Fatigue Module environment allowed to determine the geometric parameters of the overhead elements and rational coordinates of their location on the side faces of the beam structure [4].



a) b)

Figure 4. The nature of the development of cracks in the MEM BS structure: a) the dependence of reducing the construction safety of the length of the growing crack in it; b) the dependence of reducing allowable stress values, leading to the destruction of the structure, increasing the length of the crack in it.

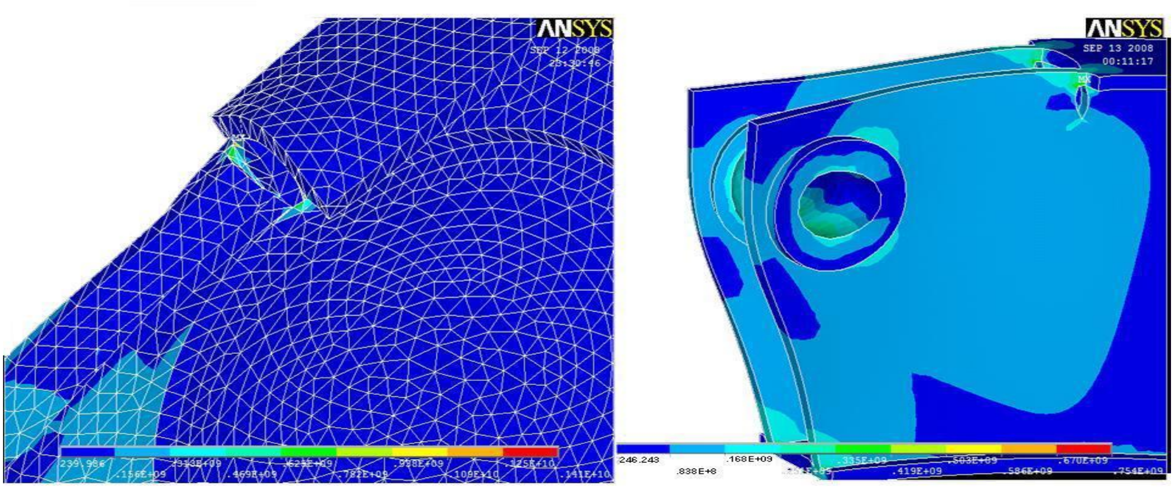


Figure 5. Graphic display of the localization of the cracks development in the MEM BS structure using reinforcements.

3. Practical implementation of knowledge-based technology to enhance emergency and hazardous areas of fatigue failure

Advantages of the practical implementation of knowledge-based technology is the use of ultrasonic destructive testing, which allows detecting at an early stage fatigue cracks and modeling. The modeling allows determining the design parameters of the gain elements to restore the parameters of reliability and durability of steel structures, without a considerable amount of field experiments. It will significantly reduce material costs for repairs and losses from downtime and to create high-optimal shape design with low metal content, without the use of expensive high alloys in the future.

Three-dimensional models, developed an automated way of solving the problem of the finite element method, are created based on the data of field surveys, analysis, technical documentation and design study of the stress-strain state of typical beams brake system the results are presented in the form of numerical values, graphs. The developed mathematical schemes have flexible program code and can be used as templates for algorithmization of solving such problems. During the operational load, analyzed the stress-strain state of the model and the major factors that lead to premature-time violations of brake system beams. As a result, a BS beam lifting machine's simulation-model developed, which allows you to set the static and cyclic loads in this construction depending on the type of use the momentum and technical conditions [5]. The use of simulation techniques makes it possible to eliminate the full-scale tests completely, to optimize the shape and construction parameters of the structural reinforcement elements, to reduce the values of maximum stress and achieve a leveling effect on the harmful effects of stress concentrators in the "critical points" at the operational design loads. Mounting technology is unique in its simplicity and does not require expensive equipment [6].

A number of field experiments conducted at existing MEM (diagram in Figure 6), showed that the brake system beam having a wall thickness of 20 mm without power in the "critical points" (model 14) and construction with a wall thickness of 20 mm, but with the combined option amplification "disk-pad edge" (Model 26) are capable to operate at the exploitation loads and retain its strength as construction with a wall thickness of 40 mm (Model 44).

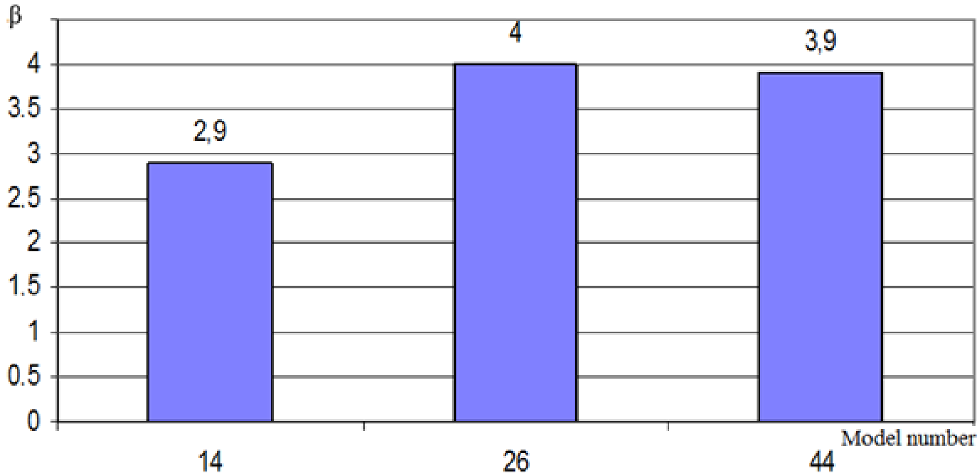


Figure 6. The safety coefficient for the brake system beam construction.

The installing disc pad allows to eliminate the hotbed of fatigue cracks occurrence, and the edge works to increase the structural strength of the beam. The technique was pro-operational testing in making repairs on existing MEM BS (Figure 7).

Figure 7. Disc pads' practical application for Novokramatorsky Engineering Factory mining elevating machine's brake system repair

4. Conclusions.

The results of computer modeling using ANSYS program allowed us to develop techniques for strength structural parts of mining machines improving that are using elements of the gain in continuous operation. It is established that at the top of the crack formed during loading the relative concentration of stress occurs, and then there is a redistribution of the latter, which causes further cracks development. It is necessary to have the distribution of stresses and deformations near the crack tip for quantitative characteristics of a material's ability to resist brake system beam construction violations.

BS construction's reinforcement elements allow eliminating the formation and growth of cracks in the field of bushings' mount; providing the necessary strength and durability; increase the service life of the brake system; significantly reduce the impact of stress concentrators, lower values of stress and deformation in the construction. Disc pad installing allows to eliminate the hotbed of fatigue cracks occurrence and the edge works to increase the structural strength of the beam and eliminates the possibility of construction's further deterioration associated with multiple cycles of load application during operation.

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