

Setting up excavators with growing cracks in their metal structures for repairs

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Abstract. When determining the loads that arise on the working bodies of excavators, it is assumed that the developed soils and blown rock are homogeneous and are cut by a bucket in the form of shavings of a certain thickness. At the same time, it is considered that in metal structures of excavators there are no stress jumps from the bucket collision with individual pieces of rock, and cyclic loads are related only to the loading and unloading cycle of the bucket.

Studies have shown that in cyclic loading of metal structures, the bucket collides with each piece of rock. The magnitude of voltage jump depends on the size of rock piece.

Presently, theoretical calculation of stresses in metal structures of excavators is carried out without taking into account the concentration of stresses in zones of welding defects and this gives underestimated stresses. Studies have also shown that in zones with defects, the stresses can differ several times from nominal stresses.

1. Purpose of study

The purpose of this study was to determine the zones with the most frequent occurrence of cracks in the metal structures of excavators when operating them on blown rocks, and to establish the relationship between the middle-sized piece in rock debris and the level of forces in the elements of excavator designs.

2. Carrying out research

Reduction in emergency downtime and repair works of excavators increases productivity of excavators, volume of day-lighting and mining of minerals in quarries. A significant part of repairs is associated with failure of metal structures due to crack formation [1-3]. Due to fatigue failure plastic collapse and even brittle fracture, cracks begin to develop in the metal structures of machines long before accidents. The duration of crack growth until complete destruction takes a significant part of the "life" of the component, reaching 90% or more [4-6] and the process of crack formation is continuous. Repair of excavators should be carried out immediately after the detection of a crack since the presence of cracks in metal structures according to existing standards is not allowed. However, immediate elimination after their detection is economically and technologically impossible. In practical conditions, the welding of cracks is carried out during planned repairs or by the decision of the management. Such a deviation from the rules is associated with certain risks and may lead to an excavator failure. Taking into account the above-mentioned facts, it



can be considered that receipt of the criterion for setting up for an excavator with cracks for repair and extension of its operation time has not yet been developed sufficiently and this is very relevant [7, 8].

Over a long period, the state of the structures was observed, and the stressed state of typical parts of EKG-12.5, EKG-15 (18), ESH-13/50 and ESH-10/70 excavators on the Kuzbass open-cast was investigated. The work was carried out to determine the influence of operating conditions on the formation of cracks, the rate of crack growth in metal structures and the increase in their durability.

When mining excavators are used in hard pit faces to excavate rocks with average-sized piece of diameter 0.35 - 0.45 m, a large number of cracks appear in their metal structures. The conducted studies showed that the greatest number of cracks in the EKG-12.5 and EKG-15 (18) excavators occurs in the trolleys (where the axes of the rollers are adjacent) and the struts of the superstructure. However, cracks are formed in booms and handles less often. The need to eliminate cracks calls for regular emergency repairs of excavators, reducing normal operation periods; in addition, they create a permanent threat of catastrophic destruction to the excavator. Studies showed that EKG-12.5 and EKG-15 had common design solutions but different running carriages: early models - four-tracked, and the latter having two-tracked.

For walking ESH-13/50 and ESH-10/70 excavators, cracks were most often formed in the elements of boom and superstructure, in zones of welded joints.

It was established that cracks in dangerous places increase at a considerable speed and reach very large dimensions of 0.5 – 0.7 m. This phenomenon is especially developed in the tin casts zones, where the axes of the caterpillar rolls pass; here, horizontal cracks are mainly formed, but in some cases, there are also vertical cracks. When observing these cracks, during the operation of the excavator, a significant opening is revealed - wider than 1.5 mm.

Reinforcement of the frames of mining excavators to some degree reduced the rate of crack development, but did not essentially change the situation; cracks are formed constantly in the same places, especially after sampling and welding. In addition, mainly vertical cracks reach significant dimensions in the support frames, in close proximity to the parting plane, in the zone adjacent to the riveted joint. In the braces of the superstructure, cracks are formed generally at the junction of the pipe with the casting. Cracks in all these places occur in the welds, however, in the support frames, the cracks can also be formed in the base metal. Of all the three places listed where cracks occur, the most dangerous is the crawler frames, cracks occur in this part of the excavator with high probability.

In order to identify the causes of crack formation, the stresses in the main structural elements of the excavators were measured using resistance sensors and a computer oscillograph and the evaluation of rock composition of the blasted rock in the pit face [9].

It was established that the formation of cracks occurs as a result of significant overloads occurring in these elements. In addition, cracks in the crawler frames appear due to some peculiarities of their work, this was most noticeable in excavators with two-crawler frames. In the modified designs of excavators with increased roller-sizes and a decreased number of them, the unevenness of loading of the running frames increases. When the excavator hits a large stone, all the entire load during operation is transmitted through one roller. At this moment, stresses equal to $0.9\sigma_{02}$ (apparent yield point) and more occur in the zones of crack formation. The same was observed when the excavator was operated in stones, having large radius of curvature. In this case, the excavator is forced to move with a constant turn and receive significant overloads in the tidal zone of the running frames that are connected to the axes of the rollers. The increase in bucket from 15 to 18 m³, performed on individual excavators, only leads to accelerating the development of cracks.

During the layout of large pieces of rock, cracks mainly occur in the support frames due to exceeding the permissible loads in the process of face stripping and lateral movements.

When excavators work in heavy faces, 0.236 cracks occur in the struts of the superstructure.

When studying the work of handles and booms, it was found that when operating, even under severe conditions, arising stresses were significantly below the yield point ($0,3 \div 0,4\sigma_{02}$), where σ_{02} - apparent yield point of steels used in making excavator elements.

As a result, the dependencies between the working conditions of excavator in pit face and the loading of its elements were obtained (figure 1).

They show the presence of a large part of the load cycles (up to 15%) when working in pit faces with $d_{av} = 0.45$ m, which yields stresses in individual elements of the excavator above their fatigue limit. To prevent cracking in EKG-12.5 and EKG-15 excavators, it is necessary to reduce the load by improving pit face preparation quality.

The results of the research showed that in most cases, surface and through cracks were visually detected during the exploiting of excavators. The time of detection and elimination of these cracks was usually separated by several months, and in special cases by a year. In this case, a sufficiently large number of cracks was found in the same place immediately after repair. Ultrasonic flaw detection allows us to find subsurface cracks, but since it is done once a year and less often, and that cracks can occur in a short period after repair, it can be assumed that such cracks can exist for a year and more. However, numerous cases show that the using excavators with developing cracks in their metal structures can lead to accidents.

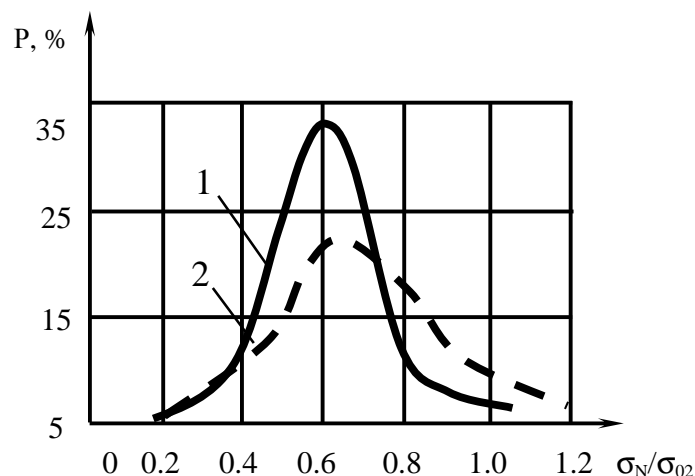


Figure 1. Probabilistic distribution of forces arising in hazardous areas of chassis frame of EKG-15 with a granular rock composition : 1– $d_{av} = 0.3$ m; 2– $d_{av} = 0.45$ m.

Here, P – Probabilistic distribution of forces; σ_N – Nominal stress in boom; σ_{02} – Apparent yield point of steel used for excavators.

Based on the studies carried out, a technique that makes it possible to carry out repair of excavators, having cracks in metal structures, at a time, that is the most technologically favorable or at the time of greatest probability of destruction was developed. At the same time, the risk of destruction is completely excluded. This technique is based on a computer evaluation of the durability of the metalwork of an excavator with a detected or suspected crack.

The essence of this technique is to determine the loads on excavator elements by use of indirect signs: the rock composition of the blasted rocks, the coefficient of rock loosening, the number of substandard lumps in the face, rock strength. Based on this, experimental dependences were obtained between the arising stresses in metal structures of excavators and the factors mentioned.

As a result, it was found that the greatest probability of occurrence of cycles with maximum amplitudes is associated with the presence of substandard pieces in blown rocks; pieces having a size exceeding $0.6 b_w$ (bucket width). In this case, a huge role is played by the location of these pieces in the collapse (on the surface or at a depth) their magnitude, grouping. As a result, the dependences of the cycle amplitudes that caused the growth of crack-like defects, which are allowed by the State Mine Inspector, were obtained from the sizes of the substandard pieces (figure 2).

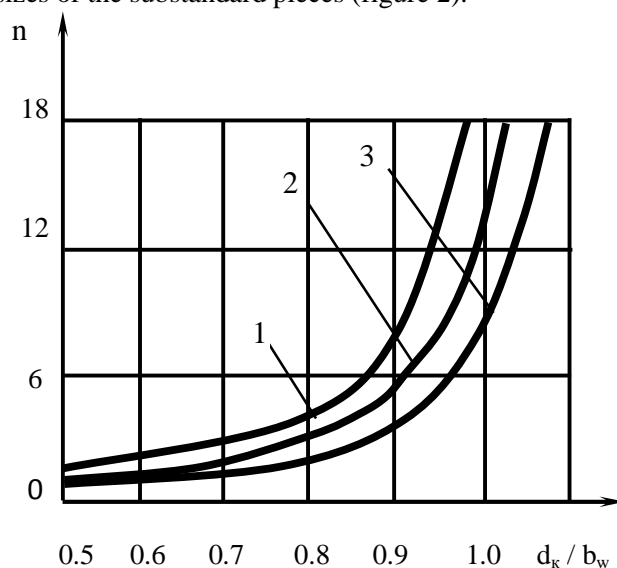


Figure 2. Relationship between the maximum numbers of amplitudes (n) during excavation of substandard piece of rock located in the depths of rock collapse and its relative diameter (d_k): 1 – pulley fork of ESH-13/50; 2 – flange connection of the boom ESH-13/50; 3 – reinforcement of the undercarriage EKG-15 (18).

The results of the study make it possible to evaluate the state of metal structures of excavators in the presence of growing cracks [10]. Knowing the number of loading cycles and the magnitude of the arising stresses in the cycles, determining crack growth rate and durability of structures during subsequent work in a specific pit face, as well as periods of safe operation and setting up the excavator for repairs is possible. To estimate the duration of crack development of in metal structures, methods associated with the failure theory were applied [10, 12].

It is recommended to put up the excavator for repair 45 days before reaching critical cracks.

3. Conclusions

1. Crack formation in excavators' metal structures continuously occurs when machines are operated during rock excavation.

2. The main crack formation zones are:

- Walking excavators ESH-13/50 and ESH-10/70 - the elements of the boom and the superstructure.
- Open-mine excavators ECG-12.5 and ECG-15 (18) - undercarriage (junction of axes of rollers), struts of the superstructure.

3. When excavators are used on hard rocks, there is a significant number of stress cycles as a result of stress concentration in the weld zone above the fatigue limit.

4. The presence of substandard pieces plays a significant role in crack formation in the metal structures of excavators.

5. The theoretical method of evaluating the survivability of metal structures of excavators allows the extension of their overhaul period and simultaneously prevents their emergency stops.

4. References

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