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Determination of reliability and justification of object parameters on the surface of mines taking into account change-over to the lighter enclosing structures

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Abstract
Deviations are defined undesirable, but among designers there is an understanding that there are no faultless technologies, absolutely exact measurements, etc. Besides, parameters of the settlement model, which is accepted for this or that object, are almost always inexact values. Inaccuracies can also be consequence of proximity of the chosen settlement model. The concept of reliability of the bearing designs on a surface of mines and production safety as a component of industrial safety is considered. The main terms and determinations of reliability are provided, the main dangers of technical condition of superstructures of extracting enterprises mines are specified. Basic provisions of the theory of reliability are considered. The mathematical formulations used at an assessment and calculation of critical parameters and parameters of reliability of technical objects are provided. The analysis of the intense deformed condition of superstructures is made upon their change-over to the lighter enclosing structures.
Key words: RELIABILITY, RECONSTRUCTION, SURFACE OF MINES, SUPERSTRUCTURES, DYNAMIC CHARACTERISTICS, REFUSAL OF OBJECT, RESONANCE

The main questions, which are studied by the theory of reliability - refusals of technical elements of surface objects; criteria and quantitative characte- ristics of reliability; methods of the analysis and increase of elements and objects in general reliability on the stages of design, production, operation and reconstruction; test methods on reliability; methods of an assessment of efficiency of reliability increase.

In concrete areas of engineering there were developed and continue developing the applied questions of reliability, thus the issue of the most rational use of the general theory of reliability in concrete area of engineering is solved and development of such new provisions, methods and approaches, which reflect specifics of this direction is conducted. In practice of native mine construction, the significant contribution to development of design of superstructures is made by research, design-and-engineering and educational organizations - «State institute on designing enterprises of mining industry «Krivbassproekt», **"**Mekhanobrchermet" Institute, state design institute "Leningrad Promstroyproekt", Leningrad department of CNIIEP, state design institute "Ural PromstroyNDIproekt", state design institute "Kharkov PromstroyNDIproekt", etc. They created the first method of calculation of superstructures.

Thanks to the conducted researches and the savedup practical experience building and reconstruction of superstructures were implemented widely and with high efficiency into the mining industry. Despite this, there observed long stagnation in dynamics of development of technical and economic indicators of building of superstructures, development and improvement of technological schemes of works and reconstruction is not observed, there is no modernization of equipment, which contradicts a tendency of development of mine construction in the world mining countries. Thus the perspective direction of development of technology of reconstruction of galleries, which consists in replacement of the old ferroconcrete protecting constructions by the modern facilitated materials, is defined.

One of the basic concepts of reliability theory is the concept of refusal (object, an element, system) [6]. Refusal of object – is the event, when the object in whole or in part ceases to carry out the set functions. Full loss of working capacity involves full refusal, partial loss – partial refusal.

Work of any of technical system can be characterized by its efficiency [5] (fig. 1). It is a set of the properties defining the ability of system to carry out certain tasks at its creation.

According to state building norms DBN B.1.2-14-2009 [4] reliability is the property of object to keep in time in the set limits of value of all parameters characterizing ability to carry out the required functions in the set modes and conditions of application, maintenance operation, repairs, storages and transportations.

Thus the basic concepts are formulated: reliability – is the property of object to keep in time the ability to carry out the required functions; fulfillment of necessary functions should occur at values of parameters in the set limits; ability to carry out the required functions should be kept in the set modes and conditions; the object should possess a property to keep the ability to carry out required functions in different phases: at working operation, maintenance operation and repair.

Reliability – is an important indicator of quality of an object. It can neither be opposed, nor to be mixed with other indicators of quality. That is why definition of the concept of reliability includes performance of the set functions and preservation of this property when using the object as intended.

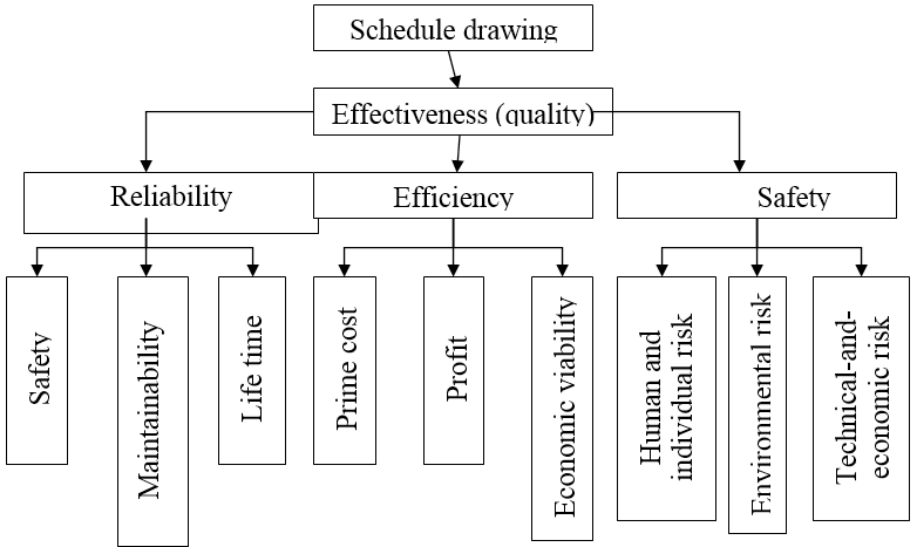

Figure 1. The main properties of schedule drawing

The most important dynamic characteristics of superstructure of gallery is the frequency of own lateral vibrations. At dynamic calculations of galleries it is possible to consider only the first frequency of own fluctuations, which average probable value can be determined by the formula:

$$\theta = \alpha \frac{\beta}{l} \sqrt{\frac{Ehq_1}{R_o q_2}}, \qquad (1)$$

where a - is the coefficient equal for galleries with a conveyor arrangement along the bottom of frames 9, and along the top – 10.5; ß - is the coefficient, which is equal to unit at calculation of the average superstructure and according to the monogram - extreme superstructure with the extension nosing; q_2 - is calculated weight of superstructure with all loadings which have weight, except for loadings from crowd, spillage and details; q_1- is calculated weight of superstructure with all temporary loadings which have weight; R_o, E- are the design resistance and elasticity module of material of main frames; h, l - are the design altitude and length of main frames.

During calculation of bearing constructions on action of periodic loadings calculation accuracy significantly depends on the accuracy of basic data. As basic data (constructive schemes, loadings, ruggedness of elements and joints, weight) for structural steels are set with rather small accuracy, the calculation error near the resonance can exceed many times usual ones for engineering calculations of a limit, especially at small values of inelastic resistance coefficient. Therefore at calculation on harmonious and periodic loadings the possible error in determination of own frequencies, and also possibility of change of own frequencies of designs in use of the building or constructions has to be considered. This error is considered by introduction of frequency zones, where there is a calculated value of own frequency.

The width of resonant zone (area $\theta_1' \div \theta_1''$ of values of lower frequency of own vertical fluctuations of a superstructure) is

$$\theta_1' = 0{,}9\ \theta_{1min} \div \theta_1'' = 1{,}1\ \theta_{1max}; \qquad (2)$$

where θ_{1min} and θ_{1max} - are the minimum and maximum values of lower own frequency of vertical fluctuations of superstructure respectively.

Values θ_{1min} and θ_{1max} – correspond to the smallest and greatest mass of superstructure.

Replacement of the enclosing structures leads to the reduction of constant loads for the corresponding elements of gallery, such as: spans, coverings and walls. In order to follow how the changes of loadings will influence the strength and dynamic characteristics of a gallery, theoretical researches were conducted in several stages.

In result of replacement of ferroconcrete constructions on the lighter ones, constant loading on walls decreased by 33.7% that in its turn led to the reduction of gallery bearer mass for 8%. The other loadings remained without change. When replacing the span, constant loading decreased by 53.3%, and bearer mass - for 16%. When we replaced covering of the gallery, the constant load decreased for 14.93%, and bearer mass - for 16.5%. At the last stage replacement of all enclosing structures was made that finally reduced bearer mass by 40.5%.

So, the lightened enclosing structures depending on their ruggedness and weight increase the size of own vertical fluctuations by 5... 36%.

On the base of conducted researches there follows

that in galleries with a length of bearer 24 and 30 m systematic resonant fluctuations are excluded even at full replacement of the enclosing structures. The bearer with the length of 18 m is dangerous, resonant mode may be realized here. From there, calculations on strength, stability and endurance need to be carried out only for this bay.

Further researches are conducted by means of computer modeling of strength and dynamic characteristics of superstructures.

Calculation is performed with the help of SCAD design computer system. The complex realizes final and element modeling of static and dynamic calculation models, stability testing, a choice of unprofitable combinations of efforts, selection of reinforcement of concrete elements, check of the bearing capasity of steel structures.

Basing on the results of the research conducted, it is established that own frequency of fluctuations of superstructure is in inverse relationship with the mass of its elements and length of the bay. Such dependence is observed for bearers 18, 24 and 30 m long.

There was obtained quite good convergence with the results of theoretical calculations for the existing technique with disalignment of parameters up to 10%.

So, having compared the value of frequency of the forced oscillations with resonant range, it is possible to draw a conclusion that hit into the resonance for bearers of 24 and 30 m doesn't happen. At the same time the resonance is realized in the gallery span of 18 m long at reduction of bearers mass by 40.5%.

Also there was established the dependence of internal efforts in frame elements on the weight of bearer. At calculation from a static component of loading there observed direct dependence of internal efforts on the weight of bearer. With reduction of mass, efforts from static loading decrease. As for a dynamic component of loading, inverse relationship is traced here. The value of dynamic efforts increases in elements of the frame at reduction of bearer mass, and at proximity of frequency of the forced oscillations - to the first frequency of free fluctuations, that is at the modes close to a resonance, even exceeds the value of static efforts.

The analysis of dynamic calculation showed that in the conditions of resonance the affords in elements grow for 30%. It can lead to an emergency, therefore it is necessary to fulfill test calculations on strength, stability and endurance.

Experimental studies of dynamics of superstructure are fulfilled on the operating conveyor gallery. Enclosing structures, floor slabs and covering of the gallery until replacement represented the combined ferroconcrete plates, walls made of ferroconcrete three-layer panels. The gallery was equipped with the tape conveyor.

Comparative analysis of results of theoretical calculations for determination of dynamic characteristics of superstructure of gallery with the results of experimental studies of initial structures specifies that experimental value of frequency of dynamic indignation from the conveyor is higher than the rated one $35.4 > 31.4$ c^{-1}; average rated frequency of dynamic dithering from the conveyor for frames F1, F2, F3, F4 and beams of a covering and blanking doesn't get into the first resonant zone, excludes realization of the resonant mode.

Further experimental studies of vibration of frames were conducted on superstructures of conveyor gallery with the lighter enclosing structures.

Analysis of amplitude ranges and schedules of vibration accelerations shows that fluctuations in frames are formed in low frequencies (3-100 Hz).

According to the obtained results of measurements of frames of F1, F3 and F4 grade with the lighter enclosing structures, the value of vibration acceleration, vibrospeed and motions don't exceed admissible ones, that speaks for reliable work of designs after lighting.

The analysis of measurement results of vibration accelerations for the bearear of 18 m long (F2 frame) showed that during the operation of the conveyor the maximum value of vibration acceleration, vibrospeed and motions both vertical, and longitudinal significantly increases. The increase in vibration accelerations in the vertical direction makes 30-35 times, and in the longitudinal direction - 6-9 times that speaks for hit of dynamic frequency dithering from conveyor in the first resonant zone that leads to realization of the resonant mode.

From the results obtained there follows that value of amplitude of speedup for the frame F2 exceeds the admissible one.

The analysis of measurement results showed that the maximum value of vibration accelerations exceeds the admissible values for 10-15%.

The regularities obtained in result of theoretical, experimental studies and in computer modeling were used for development of recommendations on determination of rational design data of superstructures during transition to the lighter enclosing structures.

According to the results of computer modeling the dependence of the upper and lower borders of a resonant zone on a combination of static loadings was established. So, the less static loading, the higher than

value of resonant zones.

In order to simplify the check of hit of disturbing frequency into the first resonant zone, we introduced the coefficient K considering the influence of the relation of minimum combination of loads to the maximum ones q_1/q_2 on the frequency of own fluctuations.

By results of the conducted researches the diagram of dependence of borders of resonant zones on coefficient K was built (fig. 2).

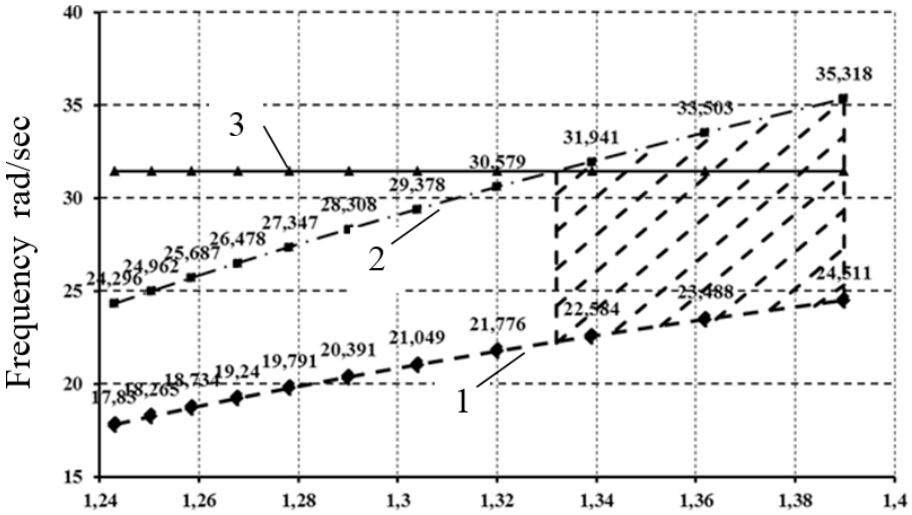

Figure 2. Dependence of borders of a resonant zone on the coefficient K
Coefficient $K=q_1/q_2$ 1 – lower limit; 2 – upper limit; 3 – conveyor frequency of operation

From the diagram (fig. 2) one may see that at the coefficient, which corresponds to lightning of general mass of a bearer approximately for 37,6%, the value of frequency of forced occilations gets to the first resonant zone, that is there appears a resonance.

As a result of fulfilled probes there obtained a number of dependences due to which test calculations at a design stage of reconstruction of superstructures become easier.

Conclusions and directions for future research

1. It is established that in galleries with the length of bearers of 24, 30 m the value of frequency from disturbing frequency of the conveyor do not get into a resonant zone. Bearer with 18 m long, in which at full replacement of enclosing structures the resonance is realized, is dangerous.

2. It is proved that the relation of tension from dynamic and static loadings, which is considered by coefficient of dynamism of supertructure, is in linear dependence on the relation of the maximum combination of loadings of this structure to minimum one and shouldn't exceed 1.7, which is necessary to be considered at calculation of efforts in elements of superstructure for determination of its strength, stability and durability.

3. It is established that application of the introduced coefficient K simplifies the design of reconstruction of superstructures at the beginning even when collecting loadings.

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