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Estimation of the Residual Operation Life Period of Mechanical Transmissions of Mining Machines by Means of Superficial Metal Hardness Measurement in Increased Wear Areas of Their Parts

I.E. Zvonarev[a], S.L. Ivanov[a], D.I. Shishlyannikov[b,]*

[a] *Mining University, 2, 21st Line, St. Petersburg, 199106, Russia*
[b] *Perm National Research Polytechnic University, 29, Komsomolsky pr., Perm, 614990, Russia*

Abstract

The present paper contains a statement of basic provisions of the estimation method for the energy capacity of parts of mechanical transmissions of mining machinery. A method was substantiated for the assessment of the residual operation life period of large-pitch gears by means of regular hardness measurement of the superficial metal layer of the interaction gear surface. Patterns of gear hardness mutations of large-pitch gear transmissions were discovered. In order to investigate the influence of value and type of load upon the reduction of the operation life of the mechanical transmissions of mining machinery, an experimental fixture was built, and laboratory experimental work was done to study the destruction of non-standard elements. The strain parameters of the samples were determined, as well as local metal hardness changes in the areas adjoining the destruction spots. Crucial strain corresponds to the increased hardness with the limit value for the material given in the destruction area. In accordance with the experimental data, it was determined that the observed local hardness changes take place in areas where the stress is increased over the proportionality limit, and the work of the destruction forces assigned to the density of dislocations immediately adjoining the destruction plane is expressed as hardness increment, the latter being a constant value.

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Keywords: mining machine; surveillance; energy capacity; residual operation life period estimation; mechanical transmission; large-pitch gear transmission; destruction; wear; hardness of the superficial layer; stressed state; strain.

* Corresponding author. Tel.: +7-931-25-65-931
E-mail address: ZVano@mail.ru

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Nomenclature	
A	ROL is residual operation life

The substantiation of the intervals of inspections, repairs, and depreciation of mining equipment is carried out by means of the estimation of the technical state-of-order and the ROL period of equipment parts. Traditional surveillance of mechanical transmissions does not provide prompt and sufficiently precise assessment of the ROL period of gears. For the time being, one of the most promising ROL estimation methods of large-pitch mechanical gear transmissions of mining machinery is the monitoring of the superficial metal layer hardness in the areas close to destruction spots.

Investigations on fatiguous destruction of metals [1, 2], friction and wear in machinery parts have shown that the part material is destructed on achievement of a certain part-specific crucial value of inner energy, that is, every element of mechanical transmission has its own energy capacity. The work duration of such element is determined by the tempo, this capacity expires with. The energetic approach to the operation life estimation allows for consideration of the work intensity of both the machine as a whole, and its individual elements [3, 4].

The energy capacity value is constant for machines of the same type, and it is determined by material features of the part, the power train configuration, the technology of its manufacture, and does not depend on the load value if the latter does not exceed the admissible limit. The ROL of the part and the onset moment of the limit state is proportionally dependent on power dissipation in the transmission elements. Thus, the energy capacity is a property of such power drive part of a mining machine, and it can be calculated after the following formula:

$$K_K = \int_0^{T_P} \Delta P(t)\,dt = const, \tag{1}$$

where K_K is the energy capacity, kW·h; T_P is the operation life, hrs.; $\Delta P(t)$ is the power dissipation function within a period t, kW.

Still, this approach considers the whole power plant as a “black box”, regardless of the physical essence of the destruction process, not allowing for efficient clearing reasons of a would-be failure and would-be weak points. That drawback has been eliminated during the development of the calculation method of the energy capacity [5]. Considering the problem of the energy capacity estimation of a transmission gear, considering all destruction types, the energy capacity value should be calculated after the following formula:

$$Э = \int_a^{N_{\lim}} P' dN = \sum_{i=1}^{n} \frac{N_{\lim}^{1-m_i} A_i K_{Bi}}{1-m_i}, \tag{2}$$

where P' is the specific loss value equal to the dissipation during a load cycle, W; m_i is the exponent of the equation of the energy capacity curve; K_{Bi} is the individual influence of a factor of each of the destruction criteria: contact spalling, bending strength and wear of active gear tooth surfaces; N^i_{lim} is the leading criterion (of the following criteria: $N_{н\,max}$ is the number of cycles up to destruction as per tooth contact strength criterion, N_{fmax} is the number of cycles up to destruction as per tooth bending strength criterion, N_{Jmax} is the number of cycles up to discarding as per tooth work surface wear criterion) causing a specific failure; A_i is the constant factor of the energy capacity curve.

An indisputable advantage of the calculatory energy capacity estimation is the possibility of a theoretical and experimental assessment of the ROL period of such transmission elements as gear wheels allowing for joint consideration of wear phenomena, contact and bending tooth loads, for consideration of specific influence of each factor on the operation life of a gear wheel as a whole, dependent upon the transmission parameters and properties of each of the gear wheels.

It is well known, that the destruction work is proportional to the density of dislocations within the sample as a result of inner stress. The stress is, in its turn, the reaction to some external impact. Thus, the assessment of the