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SELECTION OF MATERIALS FOR PARTS OPERATING UNDER BEARING CONTACT AND EROSION-CORROSION WEAR CONDITIONS

by

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13. ABSTRACT

The effects of the simultaneous actions of erosion and friction on the wear of 4 kinds of cast-iron contg. Cr 12.40-14.05 and C 1.15-1.71 wt percent were studied. Two of these cast irons were inoculated. The friction deformation of some of the cast irons had a large accelerating effect on the corrosion resistance. For instance, the corrosion rate of 2 cast irons during friction in a condensate medium without preliminary friction deformation, was 0.0336 and 0.0292 mm/year, resp., while after deformation, the corrosion rate at similar conditions 0.056 and 0.0196 mm/year, resp. This difference is assumed to be the result of considerable changes in the structure of the surface layer. During friction deformation as the result of increased temp., phase and allotropic transformations took place to the depth of 45-60 mu, with the formation of austenite. Although austenite is more corrosion resistant than ferrite, vol. changes during the transformation resulted in the formation of fissures with resulting acceleration of corrosion disintegration. Cr, Mo, and W diffuse inward from the surface layer during the friction deformation and this also accelerates the erosion rate. For proper evaluation of the wear, the materials should be tested by exposure. [AT0046064]

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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

SELECTION OF MATERIALS FOR PARTS OPERATING
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WEAR CONDITIONS

B. A. Kiriyevskiy, V. I. Tikhonovich,
S. S. Zatulovskiy, and G. N. Gordan'

In the practice of operation of parts of units there is frequently encountered the joint action of different forms of friction and wear on material. However, when evaluating the efficiency of material in most cases we consider only the separate effect of the prominent types of wear.

While investigating the process of wear of materials of parts of seal of hydraulic machines, we usually take erosion and sliding friction as prominent. Erosional resistance of materials is evaluated according to the average depth of failure of the working surface and change of weight of the sample, tested on a special stand [2]. Tests are conducted with crevice and impact actions of condensate at definite parameters (velocity, pressure and temperature of condensate).

Processes of wear during sliding friction are investigated on different friction machines, in some degree or another simulating actual conditions. As the most widespread let us note machines MI-1M, AYe-5, MTF-1, and others. Basic conditions of simulation — correct selection of working medium, and also friction and wear parameters. During simulation of friction conditions of parts of hydraulic machines, more acceptable are friction machines with scheme roller-insert with ratio of length of action to circular pitch of friction surfaces close to one.

Scoring resistance of material is determined during forward motion of the tested moving sample relative to a sample fixed on a special stand. Tests of material on this stand are close to natural conditions.

However, the investigations conducted according to the described procedure do not completely characterize the behavior of material of parts of hydraulic units during operation, since the experiment does not reflect the combined action of all types of friction and wear on the material. The combined action of stress during deformation and corrosion (erosion) can cause failure of material under conditions, when each of these factors, acting individually, does not cause it.

For qualitative and quantitative evaluation of the effect of combined action of erosion and sliding friction we conducted special investigations on modified and unmodified chromium cast irons (Table 1). Cast irons Nos. 1, 2, 4 possess very close properties, which is established during the action of some one type of friction on the samples. Thus, the erosive resistance of cast irons Nos. 2, 4, is 0.66 and 0.67 respectively relative to steel Kh18N9T (accepted as standard). The erosive resistance was determined with the following parameters of condensate: $P = 144$ [atm(abs.)], $T = 171°C$; $V_{щель} =$ 132 m/s [Translator's Note: щель = gap]. Duration of test 260 h.

Table 1. Chemical composition of the investigated cast irons.

Chemical elements	No. of cast iron			
	1	2 (modified)	3	4 (modified)
C	1,71	1,68	1,35	1,15
Si	2,09	2,12	2,35	2,15
Mn	0,36	0,40	0,42	0,44
Cr	12,40	12,92	13,87	14,05
Ni	0,12	0,16	0,12	0,13
S	0,02	0,015	0,034	0,028
P	0,014	0,013	0,070	0,070

The indicated cast irons are not prone to the formation of metallic bonds, which lead to seizing and scoring. Under load conditions to 500-700 daN/cm^2 in a water medium the cast irons acquire rough-worn in relief both during work in homogeneous and heterogeneous (with steel 2Kh13L) vapors.

Values of relative wear resistance and friction coefficients with sliding friction materials (Table 2) are also very close in the entire range of loads.

Table 2. Effect of load on the wear of cast irons.

Machine MI-1M $V = 1$ m/s				Machine AYe-5M $V = 7.2$ m/s			Stand of Sumskiy pumping plant $V = 10$ m/s		
No. of cast iron	Load, daN/cm^2	Given wear g/km	Friction coefficient	No. of cast iron	Load, daN/cm^2	Given wear g/km	No. of cast iron	Load, daN/cm^2	Given wear g/km
1	25	0,150	0,40	1	10,2	0,003	1	18,8	0,2256
	50	0,2392	0,405		16,4	0,043			
2	25	0,0669	0,44	2	10,2	0,001	2	13,8	0,2205
	50	0,1389	0.39		16,4	0,026			
3	25	0,1389	0,42	3	10,2	0,011	3	18,8	0,3458
	50	0,2702	0,39		16,4	0,063			
4	25	0,0511	0,43	4	10,2	0,005	4	18,8	0,1370
	50	0,1908	0,40		16,6	0,014			

On the basis of obtained data it is possible to make the conclusion that materials, provided into Table 1, should possess approximately equal wear resistance under natural conditions of operation. The differentiation in the operating life of natural parts made from the indicated material is frequently explained by the subjective factor in the process of manufacture of parts and operation of units. However, this factor is not the only one that determines the difference of wear resistance of these materials under natural conditions, when the action of different types of wear is summarized, inasmuch as with the action of external friction with identical parameters there proceed different changes in the micro-structure and submicrostructure of surface layers of these materials, which substantially affects the erosion-corrosion resistance of the materials.

The given conclusion is confirmed by results of special investigations on the determination of the corrosion resistance taking into account preliminary deformation. Thus, if the values of corrosion resistance of nondeformed materials No. 1 and No. 4 (Table 1) in condensate (pH = 9.25; NH_3 – 70 mg/l; CO_2 – 92 mg/l; Cl – 3.5 g/l) at temperature 60-80°C are close (0.0336, 0.0292 mm/yr respectively), then after deformation the values of corrosion resistance of these materials sharply differ (0.056 and 0.0196 mm/yr respectively). Surface deformation was produced on a friction machine with load 25 daN/cm^2 by a special pin made from steel 2Kh13L (HRC40). One should note that according to data of the investigation for corrosion with preliminary plastic deformation of the surface layer of material it is not possible to make a quantitative estimation of the operating life of parts under natural conditions. However, on the basis of the indicated tests there can be obtained an entirely reliable qualitative characteristic of the process of wear of parts of the seal of hydraulic units. The index of corrosion (erosion) resistance under conditions of deformation of the surface layer of material is the most trustworthy and accurate index of the life of material of the part under erosion and sliding friction conditions.

Investigation of changes, which occur in the surface layers of material as a result of plastic and thermal deformation during friction, permits understanding why the wear resistance of materials in deformed state sharply differs from their wear resistance in initial state.

The structure of the deformed layer of material considerably differs from initial. As a result of increase in the distortion of the lattice under action of sharp temperature drops in the surface layers of material there occur phase and allotropic transformations. The depth of the layer with transformations is 45-60 μm. The quantity and rate of formation of new phase (during the investigation – austenite) depend on the initial structure of material and parameters of external friction.

It is natural that the formation of austenite in a definite manner affects the change of erosion (corrosion) resistance of material. On the one hand, increase of the quantity of forming austenite increases the corrosion resistance of materials, since austenite is more stable than ferrite or pearlite. On the other hand, heterogeneity, caused by the appearance of new phase, sharply lowers the corrosion resistance of material. It is impossible to uniquely determine the character and degree of change of corrosion-erosion resistance of material under conditions of allotropic and phase transformations, inasmuch as they depend on perfection of the structure being formed to a certain extent.

Furthermore, the formation of austenite is connected with volume changes in the alloy. Yu. R. Evans [5] considers that a change of volume leads as if to separation of grains and to formation of "gaps" at intermediate points; atoms in the "gaps" are located at a large distance from one another. The formed "gaps" contribute to sharp lowering of the resistance of grain boundaries with further loading and more intensive occurrance of the process of corrosive failure.

In friction surface layers as a result of multiplication of dislocations in the process of plastic deformation their quantity sharply increases, density reaches a quantity on the order of 10^{13} cm^{-2}. The interaction of dislocations contributes to the appearance of cracks in the surface layer and even if their density is inadequate for the formation of incipient crack, but only causes a change in the stressed state, then such a surface layer is less corrosion resistant. G. V. Akimov [1] explains this process by the fact that deformed and stressed metals under all other equal conditions have high solution pressure, due to which the atom of metal more easily disturbs the metallic bond and leaves the lattice.

An essential factor of decrease in the corrosion resistance of a layer of material deformed during friction is diffusion or stable passivating elements from the matrix of metal. It is known that distortion of the crystal lattice increases the diffusion coefficient. Together with sharp thermal drops this contributes to diffusion of chromium, molybdenum, tungsten from grain and to the formation of special carbides.

Investigation of distribution of chromium near friction layers of cast irons, conducted on a "Kamek" device, visually confirmed the presence of diffusion processes of chromium. Thus, if the matrix of nondeformed metal of cast iron No. 1 contained 6.8-7.4% chromium, then in the friction layer the quantity of chromium in grain is only 4.6%. At a distance of 60-70 μm from the friction surface the content of chromium is increased to 6.21-6.55%, and subsequently is equalized to initial. The matrix of modified cast iron No. 4 in nondeformed state contains 9-13% chromium. For the friction surface the content of chromium is barely changed (10.26% chromium). The indicated content of chromium is noted at a depth up to 0.2 mm. Consequently, under identical conditions of deformation during sliding friction in cast irons No. 1 and No. 4 there proceed sharply differing changes. For the investigated cast irons such phenomenon is explained by the introduction of horophilic elements (yttrium, cetrium) into material, concentrating along grain boundaries and changing the energy state of boundaries. It is natural that the corosion resistance of deformed layers of cast irons No. 1 and No. 4 is different. The deformed layer of cast iron No. 1, containing only 4.6% chromium, does not possess corosion resistance and is subject to intensive failure in aqueous medium; the deformed layer of cast iron No. 4, containing 10.2% chromium, will be corrosion resistant in this medium. Unconditionally, for deformed layers of the indicated materials the erosion resistances under conditions of crevice and impact action of condensate are distinguished, despite the fact that in initial state they are almost identical.

In the process of wear during sliding friction the surfaces of parts acquire relief of various roughness, characteristic for each material. The amount of forming unevenness and especially the presence of local tears and adhesions affect the corrosion resistance of materials. According to the data of [4] roughly ground surfaces have corrosion resistance 2-3 times lower than finely ground.

It is necessary to note that with friction of mated surfaces of metals the film of corrosion products or protective absorptive layers are easily destroyed, since they have less mechanical strength and plasticity with respect to initial metal. Cracks in the protectiv film can be centers of further development of corrosion or corrosion-mechanical cracks in the metal.

From the aforesaid it follows that thermal plastic deformation of materials sharply changes their resistance under conditions of corrosion and erosion failure, and the combined action of erosion and mechanical wear during sliding friction considerably intensifies the process of overall failure of the material. Therefore, the selection of material for parts, which operate under conditions of the combined action of erosion (corrosion) and sliding friction (or another type of deformation), must be produced while allowing for the estimation of their combined action.

When selecting material for parts of joints of the seal of hydraulic units it is insufficient to determine its resistance under conditions of the separate action of erosion and sliding friction For evaluation of the combined effect of these factors it makes sense to somewhat change the procedure of tests. Initially the materials were tested for scorability at loads 50-500 daN/cm^2. The tested samples are subsequently subjected to erosion action, which is compulsory on the part of the deformed layer. In the process of testing for erosion there is possible repeated deformation of the sample during friction (every 50 h of tests). The latter can be performed not only on the stand for scorability test, but also on a friction machine, where samples rub with faces. Friction must be produced in aqueous medium at certain loads. Thus, for the investigated cast irons the load should not exceed 50 daN/cm^2, since at large loads in the surface layer the process of onset of crack and failure of material considerably is ahead of processes of phase and allotropic transformations. Consequently, loading above 50 daN/cr will not give a complete picture of the resistance of cast iron under corrosion and mechanical wear conditions during sliding frictio However, in practice it has been determined [3] that at the moment of contact of parts of the joint of seal of hydraulic units the loads in the contact zone are 150-200 kg (about 30-40 daN/cm^2).

The indicated changes in the procedure of test of material for wear resistance (in reference to parts of seals of hydraulic machines) will allow simulating the actual operating conditions of materials of the part. Before starting the unit because of complete selection of clearance the parts of the joint contact. During slippage of mated parts their surfaces are deformed; all the changes indicated above occur in the friction layer. Subsequently the deformable surface is exposed to the erosive action of condensate. Analogous phenomenon proceeds with stoppings of the unit, when surfaces of the part are again deformed. The erosion resistance of material should be determined under conditions of its deformation.

On the basis of the above it is systematically the most correct to select material for parts of joints of seals of hydraulic units while allowing for their resistance with the combined action of sliding friction erosion – corrosion wear. This is possible either on a natural stand (which is very complex) or according to the indicated procedure.

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