

USING HIGH-CHROMIUM IRON AS MATERIAL FOR PRODUCTION OF THE EQUIPPING COMPONENTS OF MINE SHAFTS

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This paper deals with service conditions of shaft equipment, in particular, inserts of sliding bearings for the purpose of increasing service life due to material substitution and wear resistance increase. As a new material high-chromium irons are offered. Studies are conducted on a microstructure and wear resistance of prototypes is measured. Experimental data are treated by methods of mathematical statistics which confirm reliability of results. The results obtained make it possible to suggest using high-chromium irons as the direct material to produce inserts of sliding bearings.

Key words: chromium iron, mine shafts, sliding bearings, microstructure, mechanical properties

INTRODUCTION

To one of the critical elements of mine skip lifting, providing its high performance and trouble-free operation, is reinforcement of mine shafts. The current trend of increasing depth development of mineral deposits, increase productivity rises vessels in vertical shafts. In this case, there is an increase of dynamic loads in the “vessel - reinforcement.” Therefore, in the complex issues related to the operation of the skip shaft rises, relevant and important is to increase the durability of reinforcement vertical shafts and vanes of skips, repair which is characterized by high metal content and significant costs.

In the operation of lifting equipment is always mechanical and corrosive wear of conductors and shootings.

The service life of executions is determined mainly by corrosion wear. Unlike shootings conductors durability mainly depends on the mechanical wear in contact with the guide devices of lifting vessels. In studies performed discusses mechanical wear.

Mechanical wear of conductors is a consequence of the interaction, in particular, the friction between the guide device and skip the moving conductors. In this case, the wear rate is determined by the magnitude of the horizontal load on the system “conductor - lift vessel” and the coefficient of friction between the conductor and the guide skip.

Analysis of operating experience of existing shafts, as well as measurement data of actual loads on the reinforcement it possible to identify the main causes of static and dynamic loads, and identify ways to reduce them.

Horizontal loads on the conductors on the conductors are classified depending on the properties of structures of lifting vessels, piping and condition of the conductors.

Based on the analysis and evaluation of the causes of the horizontal forces that cause wear reinforcement trunks, possible ways to reduce it and increase the durability of reinforcement:

- the choice of rational structures, schemes and parameters of reinforcement;
- increasing the degree of static equilibrium lifting vessels;
- reducing the impact of torque rope;
- improvement of structures and materials vanes lifting vessels;
- increase the wear resistance of the conductors.

Equipping of mine shafts has decisive impact on productivity and reliable service of a head frame. The sliding bearings are used as the guiding devices in mines. While in service they perceive different percussions, contact-cyclic stresses causing abrasive-mechanical wear. The rapid abrasion of inserts of sliding bearings leading to increase of clearance between directing ones and guide is the main reason for a short life of their service, on average about 14 days for skip winding.

Therefore, the main reserve of increasing service life of bearings is wear resistance increase of inserts.

As is known [1], increasing hardness of material leads to its wear resistance increase, in addition the friction coefficient is decreased [2]. In other words, substitution of insert materials to harder ones will allow increasing service of their life as thus friction force the bearing-guide should be decreased and at the same time increase hardness of the bearing against wear. When choosing a material for the sliding bearings two circumstances should be considered:

- first, the material hardness of bearings should be higher than hardness of guides (250 HB) to provide favorable conditions of friction, soft-hard steam;

– secondly, material chosen should have a high red-hardness as the surface working temperature is considerably increased during the friction.

Thus, considering loading and service conditions of the bearing-guide, requirements for insert materials can be formulated:

1. General surface material hardness should exceed hardness 250 HB.
2. Material red hardness shouldn't be less than 600 °C.
3. Material should have good mechanical properties (sufficiently high values of strength σ_v and the impact hardness An).

According to this principle, only a structure, where solid components lie as the separate fine ones evenly distributed inclusions in a ductile matrix, has high wear resistance.

EXPERIMENTAL STADIES

For the purpose of developing measures to increase wear resistance of inserts detailed metallographic studies of their structure were conducted.

As a result of studies the direct material for production of inserts was established to be mild and medium carbon steel of group brands: St3...St5 depending on the party. The approximate chemical composition and some mechanical properties of these steel are given in Table 1.

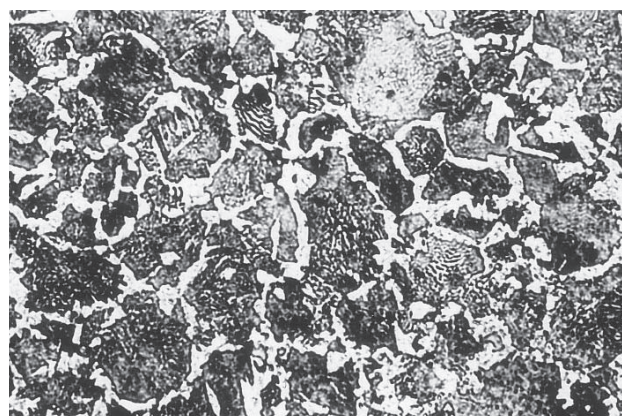
Table 1 **Chemical composition and mechanical properties of steel**

| N | Steel grade | Chemical composition / % | | | | Mechanical properties | |
|---|-------------|--------------------------|-----------|-------|-------|-----------------------|-------|
| | | C | Mn | S | P | Re / MPa | A / % |
| 1 | St3 | 0,14 - 0,22 | 0,4 - 0,6 | 0,045 | 0,055 | 380 - 470 | 24 |
| 2 | St4 | 0,18 - 0,27 | 0,4 - 0,7 | - | - | 420 - 520 | 26 |
| 3 | St5 | 0,28 - 0,37 | 0,5 - 0,8 | - | - | 500 - 620 | 28 |

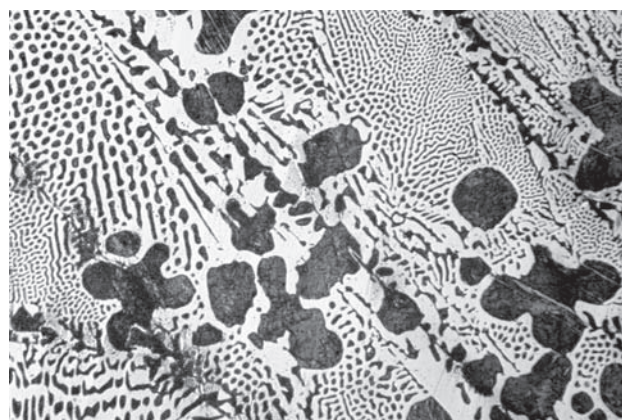
All steel used is related to hypoeutectoid steel. The structure in an equilibrium state is presented by colonies of large-lamellar pearlite and inclusions of ferrite. Average hardness of similar structure fluctuates ranging from 160 to 190 HB, and the microhardness of a soft ferrite network makes about 125 - 150 kg/mm². It is obvious that the similar microstructure has low wear resistance and relatively low mechanical properties.

Application of carbon steel both in annealed, and in quenched conditions as material for production of inserts is represented not exactly inexpedient. With an identical surface hardness after quenching the microstructure of carbon steel has lower wear resistance, than for example, ledeburitic steel or white cast iron (Figure 1). It is explained by that the microstructure of the latter ones is presented by relatively soft matrix with hard excess carbide inclusions, and the matrix acts as a lubricant, as reduces the surface wear degree.

In addition red hardness of carbon steel makes only about 300 °C. As during the friction hot temperatures are developed (to 600 °C), low red hardness causes precipitate abating and material wear resistance on the one



a)



b)

Figure 1 The microstructure: a - hypoeutectoid steel; b - white cast iron

hand and, as a result, the friction coefficient increase on the other hand [2,3].

The reasons stated (heat treatment inefficiency, unsatisfactory microstructure and low red hardness of carbon steel) make inappropriate their application in the case under consideration and, accordingly, require selection of other measures to increase wear resistance of materials for production of inserts.

Use of different surface methods of hardening is possible: thermochemical treatment, beading, spraying, etc. These techniques, however, require significant capital investments that are justified only at large volumes of production.

Thus, a likely way of wear resistance increase of inserts is material substitution for more wear resistant, with the best mechanical properties.

The analysis of properties and microstructure of different materials taking into account the requirements stated above showed that the most acceptable material in this case are high-chromium irons. White cast iron is increasingly used as a material for tools and machine parts and mechanisms subjected to intense wear and oxidation. Traditionally it is attributed to fragile materials that significantly limits the scope of its use. Achieved advances in alloying and heat treatment white irons have changed the understanding of their properties and possible applications.

Modern white cast irons - complexly multicomponent alloys, different in structure and special properties.

They are a separate group industrial iron that solidifies composite structure which is formed. It determines the specific properties of white irons in the cast state.

The chemical composition of some most widespread grades is given in Table 2.

High-chromium irons have good mechanical properties, high hardness in a cast state, low fluctuation of hardness when properties change. High-chromium irons almost don't concede in fluidity to regular gray cast iron that allows using parts sufficiently difficult form directly after casting without the following machining.

Table 2 **Chemical composition of high-chromium wear resistant irons**

| Grade | Content of elements / % | | | | |
|-----------|-------------------------|-----------|-----------|---------|-----------|
| | C | Mn | Si | Cr | Ni |
| 1 | 2 | 3 | 4 | 5 | 6 |
| ICHH28I2 | 2,7 - 3,0 | 0,8 - 1,4 | 0,5 - 0,8 | 28 - 30 | 1,5 - 3,0 |
| ICHH15M3 | 3,0 - 3,5 | 0,3 - 0,6 | 0,5 - 0,9 | 12 - 18 | - |
| ICHH14G2N | 2,0 - 2,4 | 0,5 - 0,7 | 1,8 - 3,2 | 13 - 15 | 1,2 - 2,0 |

It should be noted that casting shrinkage of high-chromium irons is about 2 %, therefore when obtaining castings application of profits or shrinkage compensation is required.

In order to test wear resistant inserts of sliding bearings the pilot batch of inserts of bearings from ICHH28N2 grade cast iron is molded. After cooling the detailed metallographic analysis of samples was made.

Microstructural examination and mechanical properties of pilot castings were made according to the present techniques.

The casting microstructure (increase 400, Figure 2), as expected, is presented by a carbide austenitic eutectic. The high content of chrome (more than 10 %) in cast iron leads to formation of complex carbide of cementitious type $(Fe, Cr)_3C$ which, in turn, has impact on a structure of the eutectic colonies.

Crystallization begins with origin of an austenitic dendrite in which intercenter space the crystallization of complex carbide occurs. In a cast state the microstructure of high-chromium cast iron represents a plastic austenitic matrix with separate inclusions of solid and brittle carbide. Microhardness testing of the studied phases validated their identifications: microhardness of carbides made 1 200 - 1 500 kg/mm², and microhardness of an austenitic phase made about 650 kg/mm² that is in good correspondence with data [3]. Value of average hardness of a casting surface made 48 - 50 HRC.

CONCLUSIONS

The obtained casting microstructure of high-chromium cast iron of the ICHH28N2 grade meets, thus, the Charpy principle on complete inversion of phases.

The expected high wear resistant properties of castings indicate by that fact that they are exploited directly in a cast state after annealing, i.e. with stable structure.

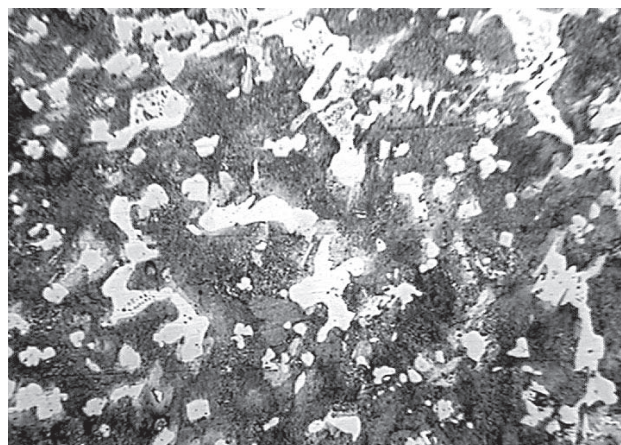


Figure 2 The casting microstructure (x400)

When in operation [4] of similar materials the contour microgeometry change occurs which is followed by some hardening of surface layers.

Thus, the inverted microstructure (hard component microhardness is about 1 500 kg/mm²), its stability, high hardness of a surface make it possible to assume the high resistance to wear during operation and, at the expense of high hardness, decrease of friction forces in couple the bearing-guide.

Wear resistance tests were conducted parallelly in two ways: sample weight change and area change of a wear scar. Tests conducted not less than 5 times for each sample, results of tests were processed by methods of mathematical statistics. As results of conducted tests showed service life of the sliding bearings with wear resistant inserts due to reduction of wear is increased on average by 14 times.

The obtained results of steel inserts substitution for castings from high-chromium iron makes it possible to recommend them for use in other components of the mining equipment where the impact wear takes place.

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LITERATURE

- [1] Gulyaev A.P. Metallography. M. Metallurgy (2004). - 617 p.
- [2] Korshunova T.E. Structure, properties and applications of steels and cast irons. - Vladivostok: publ. VSUES. (2013). - 214p.
- [3] Bobro A.D. Alloy of cast iron. -M., Metallurgy (2009). - 312 p.
- [4] Panchenko V.V., Skakov Y.A., Popov K.V. and others. The laboratory metallography. M., Metallurgy. (2005). - 695 p

Note: The responsible for English language is Nataliya Drak, Karaganda, Kazakhstan