Technological Support of Critical Parts for Railway Transport Working Properties

A V Gabets\textsuperscript{1,a}, D A Gabets\textsuperscript{2,b}, A M Markov\textsuperscript{2,c}, M V Radchenko\textsuperscript{2,d}, S L Leonov\textsuperscript{2,e}

\textsuperscript{1} Limited liability company "Altai steel plant", 656038, 116/52, Kalinina prospect, Barnaul, Russia
\textsuperscript{2} Polzunov Altai State Technical University, 656038, 46, Lenina prospect, Barnaul, Russia

\textsuperscript{a} gabeca@mail.ru, \textsuperscript{b} gabets22@mail.ru, \textsuperscript{c} andmarkov@inbox.ru (corresponding author), \textsuperscript{d} mirad_x@mail.ru, \textsuperscript{e} sergey_and_nady@mail.ru

Abstract. The materials of complex research of operational properties of a new brand cast iron CHMN-35M. Optimal chemical composition was determined. The obtained results allow to conclude about possibility of its use for the manufacture of critical parts of rolling stock of railway transport, in particular of a side bearing cap.

Introduction

The solution on improving the speed and volume of cargo transportation by railway transport is connected with increased requirements to critical parts of the rolling stock. One of such details is a side bearing cap. The cap is installed on the support in the truck bolster and designed to hold a car body of the lateral forces. It is a box construction usually made of steel. Operating conditions of the slide bearing cap are that at certain speeds on curve space interval, arising lateral forces can lead to fragile and fatigue break downs of the cap, that in turn can lead to the rolling stock descent from the ways.

In most cases, the main material for the slide bearing cap manufacturing is steel (steel 20GL, GOST 977-88). At the same time, the long-term experience of the rolling stock use in terms of increased speed and freight volume indicates that this material cannot fully provide truck van specified run. According to the regulatory documents the run is no less than 160 thousand km or 3 years of operation.

The structure of refusals (defects) of the freight-car truck is received on the basis of data collected during the first depot repair at the JSC “Carriage Repair Company – 2” [3, 4].

The reasons of the freight-car truck refusals can be divided into two main groups: fatigue breakdown defects and ware surface damage. Besides, up to 43\% of the freight-car truck cuts to the current repair are connected with the slide bearing cap: 9\% of them is slide bearing cap defect and 34\% is exceeding of the permitted clearance points between the effective areas.

In use of the slide bearing cap, the bearing area is worn down (Figure 1). The amount of wear is defined as the distance between its effective area and the center of the bottom opening. The excessive wear is considered to be more than 3 millimeter.
Materials and methods

The previous researches [3, 7] demonstrate that the effective material, shown satisfactory operational characteristics in case of high load is gray cast iron, in particular SCH35 iron. In comparison with the steel, the iron hardness is much higher (steel hardness 20GL – 140…160 HB; iron – SCH35 – 210…275 HB), gray cast iron contains graphite which in the frictional couples can serve as cutting oil. However, these properties are not always sufficient for the buffing loading conditions, subjected to the slid bearing cap. In this regard the task on the development of particular iron brand, providing the following operational indicators becomes urgent:

- hardness in the range 250…300 HB, providing increased wear resistance, in comparison with existing, which will extend slide bearing cap wear-life;
- high margin of strength for reducing construction material intensity (temporary resistance in case of stretching (σb) at least 380 MPa);
- high level of lamellar perlite in the structure, improving tribological behavior in the formed frictional couple.

The research results, carried out by Russian and foreign scientists N.G. Girshovich, N.N. Aleksandrov, B.S. Milman, K.I. Vatchenko, V.S. Shumikhin, Thorbjorn, J. Bolton, K.D. Millis and others indicate that the stated requirements can be achieved on the basis of alloying and modification technologies use of existing iron brands [1, 2, 6, 8]. Herewith, the use of ligatures based on manganese, molybdenum, chromium, nickel and vanadium, and also complex modifiers comprising strontium, zirconium, barium, selenium, manganese, and rare-earth elements alloys is of interest.

The basis for a new brand ware-resistant cost iron (base material) development has become gray cast iron SCH35 (GOST 1412-85). This iron is currently used for manufacture such details of freight-car truck as “Friction Wedge” (TU 3183-234-01124323-2007), and can also be used for manufacturing slide bearing cap. The feedstock has the following chemical makeup, presenting in the table 1.

| Brand | Weight content, % |
|-------|-------------------|
|       | C     | Si     | Mn    | P    | S    |
| SCH35 | 2.9…3.0 | 1.2…1.5 | 0.7…1.1 | 0.2 | 0.12 |
|       | No less |        |       |       |      |
|       | Rest - Fe |      |      |      |      |

For determining the optimal chemical makeup of the new ware-resistant cost there was conducted varying percentage of chemical elements in the feedstock. Within the LLC “Altai Steel Plant” (Barnaul, Russia) conditions experiment samples with various chemical makeup were received (Table 2):

- experiment samples 1 – iron SCH35 (base material);
– experimental sample 2 – iron alloyed with nickel and vanadium;
– experimental sample 3 – iron alloyed with molybdenum;
– experimental sample 4 – phosphor-doped iron.

Results and discussions

The research of the received experimental samples structure has shown that existence of alloying elements of enhanced concentration has led to austenite stabilization and receiving ledeburite structure. Conceivable, this is due to the rapid cooling of test bars, as indicated by the material structure; sample 2 and 4 (Figure 2 and Figure 3).

Figure 2 – Honeycomb ledeburite and perlite (experimental sample 2)

Figure 3 – Lamellar ledeburite and perlite (experimental sample 2)

To evaluate the working properties of experimental samples the mechanical tests were carried out. The experiments show (table 3) that the higher values of mechanical characteristics were received in the alloy cast iron, containing alloying elements as ferromolybdenum FeMo 60, ferronickel FeNi 75, and ferrovanadium FeV 50.
Table 2 – Chemical makeup of alloyed iron experimental samples

| Experimental sample | C    | Si   | Mn  | P   | S   | Cr  | Ni  | Cu  | Mo  | V   |
|---------------------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|
| 1                   | 3.24 | 1.59 | 0.69| 0.040| 0.11| 0.04| 0.08| 0.03| 0.002|
| 2                   | 3.36 | 1.54 | 0.82| 0.036| 0.12| 1.56| 0.34| 0.005| 0.60 |
| 3                   | 3.12 | 1.56 | 0.83| 0.045| 0.12| 0.39| 0.19| 1.18 | 0.006|
| 4                   | 2.57 | 1.44 | 0.74| 0.754| 0.009| 0.12| 0.39| 0.14 | 0.03 | 0.010|

Table 3 – Mechanical characteristics of alloy cast iron experimental samples

| Experimental sample | Hardness, HB | Temporary resistance, MPa |
|---------------------|--------------|----------------------------|
| 1                   | 324…358      | 140…158                    |
| 2                   | 430…378      | 165…179                    |
| 3                   | 407…450      | 220…235                    |
| 4                   | 372…403      | 145…162                    |

Influence of modifiers chemical makeup on the iron mechanical characteristics is estimated during the series of experiments with the use of various complex modifiers. As it was distinguished above [3, 4] for the required iron tribological behavior as a modifying agents, containing zirconium and silicium it is required to use zirconium dioxide (ZrO$_2$) and silicon dioxide (SiO$_2$). Zirconium interaction with free nitrogen creates zirconium nitride inclusions that lead to decrease the formation of core blows. Therefore, it was chosen the modifier of Z-GRAPH®T group, containing the following chemical elements: silicium (60…70%), manganese (6.0…7.0%), zirconium (6.0…7.0%), barium (2.0…4.0%), aluminium (1.0…2.0%), calcium (1.0…2.0%), ferrum (76.0…92.0%).

Consequently, to decrease the chill effect, increase strength, and wear resistance of the iron, the technology of its receipt should include operations of alloying cast iron SCH35 with molybdenum and nickel, and the subsequent modification by the GRAPH®T modifier. The two types of this technology are worked out:

− the first variant (samples 1, 2): the whole weight of the liquid synthetic iron, alloyed with molybdenum and nickel, modified by complex modifier GRAPH®T;
− the second variant (samples 3, 4): the whole weight of the liquid synthetic iron, alloyed with molybdenum and nickel, modified by complex modifier GRAPH®T.

The chemical makeup of experimental samples, received on the stated variants is shown in the table 4.

Table 4 – Chemical makeup of the alloy cast and modified iron

| Experimental sample | C    | Si   | Mn  | P   | S   | Cr  | Ni  | Cu  | Fe  | Mo  | Cu  | P   |
|---------------------|------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 1                   | 3.00 | 1.82 | 0.86| 0.062| 0.032| 0.06| 0.06| 0.16| 0.55|
| 2                   | 2.91 | 1.41 | 0.85| 0.066| 0.029| 0.06| 0.06| 0.17| 0.59|
| 3                   | 2.95 | 1.50 | 0.87| 0.059| 0.034| 0.06| 0.47| 0.17| 0.57|
| 4                   | 2.99 | 1.49 | 0.88| 0.066| 0.036| 0.06| 0.47| 0.17| 0.57|
Investigation of mechanical properties of experimental samples has shown that the second variant of iron receiving provides much higher operation factors: samples 3 and 4 have much higher hardness and temporary tear resistance in comparison with samples 1 and 2 (table 5). At the same time, the value of temporary resistance in all four samples significantly exceeds the value of temporary resistance of the iron SCH35 GOST 1412-85 (feedstock).

Table 5 – Mechanical characteristics of the alloy cast and modified iron samples

| Experimental sample | Hardness, HB   | Temporary resistance, MPa |
|---------------------|---------------|----------------------------|
| 1                   | 276…302       | 540…558                    |
| 2                   | 253…286       | 400…424                    |
| 3                   | 291…312       | 490…411                    |
| 4                   | 308…330       | 549…570                    |

Achieved results and the patent search allowed declaring the resulting iron as an invention (patent number 2562554). The material assigned an index CHMN-35M. Its chemical makeup and main mechanical characteristics are described in the tables 6 and 7.

Table 6 – Chemical makeup of the modified iron CHMN35

| Main elements of chemical makeup, % | CHMN-35M |
|-------------------------------------|----------|
| C                                  | 2.5…2.8  |
| Si                                 | 1.3…1.5  |
| Mn                                 | 0.7…1.0  |
| Mo                                 | 0.6…0.9  |
| Ni                                 | 0.5…0.8  |
| Zr                                 | 0.0005…0.1|
| Al                                 | 0.0005…0.1|
| Ca                                 | 0.0005…0.1|
| Ba                                 | 0.05…0.3 |
| Cr                                 | 0.05…0.3 |
| Cu                                 | 0.05…0.3 |
| S                                  | 0.05…0.1 |
| P                                  |          |

The rest - Fe

Table 7 – Mechanical characteristics of the modified iron CHMN35

| Brand     | Temporary tensile resistance, MPa, at least | Brinnel hardness, HB |
|-----------|---------------------------------------------|----------------------|
| CHMN-35M  | 350                                         | 250                  |

The minimum value of the temporary tensile resistance can exceed not more than 100 MPa

The quality of the new iron and its characteristics are assessed within laboratory and stand tests. Polished sections analysis of non-etching type allowed identifying graphitic phase. Study of metal matrix has shown that metal backing of the alloy cast iron has perlite alongside with acicular perlite and iron carbide.

Besides, this iron CHMN-35M metal matrix has perlite-ferritic metal backing, 85% of which are occupied by perlitic ranges, and 15% occupied by ferrite, saturated by the net of carbide inclusions (Figure 4-6).
Figure 4 – Lamellar swirling form of graphitic inclusions

Figure 5 – Perlite and acicular ferrite

Figure 6 – Carbide inclusions
To evaluate working properties of the iron CHmn-35M it was conducted its tribological tests with serial gray cast iron SCH35 by simulating work of “Car body – slide bearing cap”.

As research equipment it was chosen a friction machine of 2168 UMT type. Experimental samples were made in the form of frictional couple “hob – shaft”. Shafts material is iron of CH35 and CHMN-35M types, hobs material is steel 20GL, 30KHGSA, and 09G2S. During the experiment, we controlled the change of weight wear during the various combining of hubs and shafts materials. The achieved results are presented in the table 8.

Table 8 – Results of ware resistance study

| №  | Sample | Material     | Weight wear mass, gr | Accumulative wear of friction couples, gr. |
|----|--------|--------------|----------------------|-------------------------------------------|
| 1  | Hob    | 30KHGSA      | 0.12                 | 1.13                                      |
|    | Shaft  | SCH35        | 1.01                 |                                           |
| 2  | Hob    | 30KHGSA      | 0.05                 | 0.56                                      |
|    | Shaft  | CHMN-35M     | 0.51                 |                                           |
| 3  | Hob    | 20GL         | 0.04                 | 1.02                                      |
|    | Shaft  | SCH35        | 0.98                 |                                           |
| 4  | Hob    | 20GL         | 0.12                 | 0.78                                      |
|    | Shaft  | CHMN-35M     | 0.66                 |                                           |
| 5  | Hob    | 09G2S        | 0.45                 | 0.80                                      |
|    | Shaft  | 20GL         | 0.35                 |                                           |
| 6  | Hob    | 09G2S        | 0.13                 | 0.69                                      |
|    | Shaft  | CHMN-35M     | 0.56                 |                                           |

As reflected by the results, in all combinations iron of CHMN-35M brand has shown the best (approximately in 1.5 times) wear resistance in comparison with SCH35 iron. Therefore, the total value of accumulative wear (hob and shaft wear) in couples with CHMN-35M iron is also lower.

**Conclusion**

Summing up what has been said, the developed new composition of the alloyed modified cast iron CHMN-35M, different from analogs by the distribution of graphite inclusions (combination of equilibrium and nonequilibrium distribution), and the presence in its structure free ferrite, has increased wear resistance. It can be recommended for manufacturing details of heavy-duty freight-car truck.

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