The investigation of high-temperature properties of metal by a method of sclerometric

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Abstract. The technique for high-temperature sclerometric tests of deposited wearproof metal are developed and various types of heat-resistant alloys are investigated on the basis of iron and nickel, build-up on steel by arc way in helium. The new criterion of an estimation of resistance of metals and alloys is offered to high-temperature deformation.

1. Introduction
The metallurgical tool, punch press for high-temperature deformation of metals and other equipment under conditions of cyclic temperature power loading, are worn very quickly. The build-up weld such equipment of thermostable alloys it is possible to improve wear-resistant. Is known [1], level of wear-resistant of strengthening by hard-facing depend on type of build-up weld metal first of all.

The choice of rational type of build-up weld metal for high-temperature condition of usage is the important and fairly complicated research problem. For decision on this problem connected with rated and experimental determination of kinematics and thermodynamic parameters of wear-resistant process. Also the relationship between these parameters and high-temperature properties of build-up weld metal, his chemical composition and microstructure need be determination.

The relationship between thermomechanical act upon metal, his structure, the resistance of plastic deformation and wear-resistant at working temperatures can be possible to reveal various methods. However, the procedure for determination by means of direct testing is enough complicated and expensive. Quickly value and with sufficient accuracy to forecast the behaviour an alloy in condition high-temperature power influence allow the laboratory methods of the test. The majority of them are founded on measurement of hot hardness of build-up weld metal, value which, as it is installed experimental [2 - 5], can serve the indirect estimation to his wear capability under raised temperature.

Test methods which one imitate real conditions of maintenance of workpieces are known [6 - 8]. They give the generalised factors of wear resistance in the manner of loss of the mass wearing metal and about his relative wear resistance, but do not allow quantitative to value the influence an counterbody on metal under fixed to temperature, load and speed of the movement.

Already long time for estimation of wear-resistance of material under abrasive wearing-out is used methods of sclerometric trials [9], concluding in deformation (scratch) by indenters of polished surface of the metal under normal temperature. These methods allow quantitative to value of energy intensity destructions alloy and volume of the deformed metal at action of the abrasive particle, as well as enable the metallography to define structured-phase conversions in zone of the track from indenter, and finally to motivate capacity to work of the under investigation types of hard-facing metal. But in literature source no given about high-temperature sclerometric trials and are absent the methods of their undertaking.
2. The laboratory equipment
The investigation of high-temperature properties of build-up weld metal produced with use the new methods of sclerometric trials [10], concluding in scratch of polished surface sample of build-up weld metal heated before given temperature, from diamond indenter in inert ambience. The methods allows to change the load on indenter, is sailed to adjust the speed of sclerometric and change the temperature of the test within 20-1200 °C.

The laboratory equipment consists of basis, with consolidated on him through layings by electric motor of alternating current with reducing gear and directing for ensuring the rectilinear moving the carriage with indenter. In the tight room from polymethylmethacrylate holes for an application of welding cables and a hose pipe giving an argon are envisioned.

During tests in the inert environment the diamond cone-shaped indenter with a corner at top 120° and radius of sharpening 200 microns under loading 0.5 - 1.0 N with a speed no more than 5.5 mm/second with move down to surfaces warmed passing current sample. The temperature of build-up weld metal on sample check the thermocouple, junction which it is closed up in the build-up weld metal.

The set form of indenter, as against acute-angled cone-shaped and pyramidal, providing only plastic deformation of metal without his cuttings. It allows to receive more authentic experimental data because the probability of cutting of a metal shaving which volume is difficult for taking into account in total amount of the deformed metal decreases.

Chosen as a material for indenter diamond has the maximal hardness in a combination to high temperature of the melting and does not wear out at high-temperature load in the inert environment. It as against others used for fabrication of indenter of materials, provides identical physical and chemical conditions in contact a sample - indenter. It promotes increase of reliability of results sclerometric.

The choice of the range of the loads is explained by high resistance of tested materials to deformation, that at load less than 0.5 N leads to unsatisfactory formation of a track from indenter and complicates an estimation of results. At loading more than 1.0 N probably fragile destruction of indenter. The set range of speeds sclerometric is caused by feature of plastic deformation of hot metal and the size of a sample, on which it to build-up weld. The maximal speed of the movement of indenter (5.5 mm / sec) is limited to occurrence in a track of characteristic waves which nature is connected to accumulation and moving of dislocations.

The sizes and the form polished T-bar (Hammerhead) samples (fig. 1) chose from conditions of their effective heating by passing current from power source VDU-504 on current 300 A and voltage 20 V.

![Figure 1. The sizes of samples](image)

The microstructure of researched alloys in a zone of a track, as well as geometrical parameters of a track investigated on microscope Olympus-BX61 (increase 50 … 1000) and MIN-9 (increase 50 … 200).

Estimation of the resistance hot build-up weld metal to deformation made on volume \( V_a \), mm squeezed out of a track in process to scratch of metal (on a site 10 mm):
\[ V_a = 5 \overline{b_a a_a} \]  

(1)

where \( b_a \) and \( a_a \) – width and length of the track average on 5 measurements accordingly.

This volume can serve as a parameter (criterion) of the resistance of alloy to high-temperature deformation.

High-temperature hardness of the build-up weld metal was measured on modernized device TSH-2 by hard-alloy bead covered by beryllium in diameter 5 mm at load 7.35 kN and endurance 10 sec.

3. Testing Procedures

Experimental samples to build-up weld in the arc way not fusing electrode in helium with an additive powder wire.

As the temperature on length of build-up weld samples is distributed unevenly, that is established experimentally (fig. 2), the sclerometric carried out in their central part where heating is uniform. In process of the experiment build-up weld a samples fixed in current contact jaws of the welding source of the current and installed on it indenter with load. The camera is pressurized and blew out the argon for 2 minutes at the charge of 10 liters /min

![Figure 2. The scheme for probe of distribution of temperature on length of its narrow part: 1 – slots for the thermocouple; 2 – the control thermocouple; 3 – sample; 4 – the thermocouple; 5 – multichannel potentiometer](image)

The sample heated up within 1-2 minutes and at achievement of the set temperature of tests included the drive of the installation for scratch build-up weld of the metal.

After tests measured geometrical parameters of the track from indenter and metallography researches defined character of deformation of metal in a zone of a scratch.

4. Discussion

As a result of researches microsections longitudinal and cross-section section of the received tracks, it is established, that the structure in a zone of deformation is changed as a result of phase transformations into build-up weld metal at high temperature.
Figure 3. The relationship between volume of the deformed metal $V_D$ and temperature of tests $T$

The results of calculations under the formula 1 are submitted on fig. 3 from which follows, that greatest resistance to hot deformation alloys possess on the basis of nickel (260Cr24) and Intermetallic Ni$_3$Al (80Cr4) which are resulted in the table 1. The small volume of the deformed metal is indicative about good thermostable and high resistance thermal and power to influence of their heterogeneous structure.

Table 1. Structure and high-temperature properties of the build-up weld metal on samples

| Number of the wire | Structure of the build-up weld metal                                      | $T$, °C | High-temperature hardness, HB | Volume of strained metal, mm$^3 \times 10^{-3}$ |
|-------------------|--------------------------------------------------------------------------|--------|-------------------------------|-----------------------------------------------|
| 1                 | Alloy martensite, decay products of martensite, retained austenite, carbides | 850    | –                             | 1.3                                           |
|                   |                                                                          | 950    | –                             | 7.07                                          |
|                   |                                                                          | 1050   | –                             | 9.24                                          |
| 2                 | Alloy martensite, decay products of martensite, retained austenite, carbides | 850    | 60                            | 0.975                                         |
|                   |                                                                          | 950    | 50                            | 2.09                                          |
|                   |                                                                          | 1050   | 40                            | 3.6                                           |
| 3                 | Solid solution $\alpha$-Fe, carbides, the carbide eutectic               | 850    | 110                           | 0.58                                          |
|                   |                                                                          | 950    | 75                            | 1.67                                          |
|                   |                                                                          | 1050   | 50                            | 2.31                                          |
| 4                 | Solid solution $\gamma$-Ni, carbides, the carbide eutectic, intermetallic | 850    | 160                           | 0.325                                         |
|                   |                                                                          | 950    | 130                           | 0.577                                         |
|                   |                                                                          | 1050   | 70                            | 0.9                                           |
| 5                 | Matrix on the basis of intermetallic Ni$_3$Al, carbides, intermetallic   | 850    | 170                           | 0.052                                         |
|                   |                                                                          | 950    | 160                           | 0.092                                         |
|                   |                                                                          | 1050   | 150                           | 0.577                                         |
The complex structure of wires №4 and №5 causes excellent resistance build-up weld of the metal to deformation at high temperatures.

At alloys on the basis of iron (№ 1, 2, 3) the volume of the deformed metal is essentially more, that is explained smaller thermal stability of a matrix a basis α-iron, containing as strengthening phases carbides, in comparison with in a complex strengthened structure having γ-NI a basis.

Correlation between the received data sclerometric and high-temperature hardness build-up weld of the metal owing to what the size of resistance to hot deformation is offered for estimating under the formula is established.

\[ K = \frac{1}{V_D} \left[ \frac{1}{mm^3} \right], \]

where \( V_D \) – volume of the deformed metal [mm³].

5. Conclusion

On the basis of comparison of the value to hot hardness of heat-resistant alloys and values of resistance to hot deformation (K) at high-temperature sclerometric tests it is established, that between them there is a correlation. It allows to apply results sclerometric tests for indirect estimation of high-temperature wear resistance of various types build-up weld of the metal and alloys.

6. References
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