Displaying structural property and inheritance of cast iron surfacing on steel base

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Abstract. Graphite inclusions heredity in deposited layer from remelted special cast iron billets was established. The possibility of controlling the structural state and the quality of the deposited layer due to technological parameters of welding and heat treatment of parts is shown. Ways of improving cast iron wear resistance durability are proposed.

A fundamental factor in the stabilization and achieving a high level of parts resource is to improve the quality of the surface layer, as it is in all cases the most loaded. Depending on the type and degree of loading and the nature of the medium, etc. for most efficient technologies are recognized hardening contact surfaces based on the coating, doping, thermal effects and deformation, as well as by their combination. In some cases, an undoubted advantage is the use of alloys with high specific properties. The key parts of the engine, determining its durability are part timing, which are manufactured with a wide range of materials.

Reliability and durability to operate a pair of “camshaft-tappet” is directly dependent on the performance of the cam contact surface of the camshaft with the end of the valve tappet. A characteristic feature of this pair is the case of the contact of dissimilar materials, namely steel hardened cemented surface of the camshaft with cast iron tappet. Special demands to the contact surface of the tappet representing special cast iron weld on a steel base parts (Figure 1). These requirements include hardness values (not less than 61 HRC) and structure (ledeburite and sections of martensite with residual austenite). In addition, a small amount of cementite and dotted, evenly distributed graphite is allowed. A disadvantage of the tappets in operation is a dispersion of resistance (uneven wear, chipping, etc.), despite the fact that they are manufactured and hardened under the same conditions of production, having high and a predetermined structural state (Figure 2). However, the stability of individual elements of the structural state of iron on the part such as graphite inclusions are not always achieved and important role here is the macro- and microstructure inherited from cast billet used for surfacing.
The end of the valve tappet (fig.1), working on the cam of the camshaft is surfaced by special cast iron of the following composition (wt.%): C - 3.1 ÷ 3.4%; S - 2.1 ÷ 2.35%; Mn - 0.8 ÷ 1.0%; Ni - 0.4 ÷ 0.75%; Mo - 0.4 ÷ 0.60%; S ≤ 0.1%; R ≤ 0.2%. Cast billet of Ø10 × 48mm is used for surfacing and a weight from 27.0 up to 28.5 gramm. Surfacing was carried out on UNT-1 with the heating TVC of the steel parts up to 1100 °C, and cast iron billets to 1250ºS.

Cooling the items is carried by water under pressure from 1.0 to 2.0 atm., feeding into the inner cavity of the part. After the final machining of parts subjected to oxidation in a moist nitrogen atmosphere of the US made shaft furnace 8.12 / 6 at a temperature of 450 ± 5 °C during 4 hours. Microphotometer MFS-51 and analyzers AN-7529 and AS 7232 have been used for chemical and spectral analysis of alloys.

The methodology of the macro and micro studies based on the use of standardized methods for monitoring and testing using reliable and licensed equipment. Control patterns before and after etching of 4% solution of picric acid was performed on microscope “Neofot-2” and “Epitip” at 100 and 400 *enlargement. The hardness was measured by Rockwell and micro hardness of the individual structural components was measured on “Durimet” (Germany). The content, appearance and character of the distribution and structure of the graphite layer deposited on the parts was evaluated in accordance with GOST 3443-87. Macroanalysis performed after etching of deposited items in 70-85°C for 10 minutes in a 50% aqueous hydrochloric acid. Detection of pores and cracks in the finished products is carried by magnetic and powder technique on a flaw detector DN200P.

Currently used for surfacing of special cast iron has good wear resistance, but the durability of these parts in the operation of the alloy is limited by the presence of undesirable macro- and micro-defects. To those clusters should include graphite inclusions, pores, cracks, presence nonmartensitic conversion products and residual austenite. Despite a wide range of research in the field of structure
and graphitization iron undoubted interest are issues relating to heredity structure and properties of the alloy after remelting. We studied the influence of the silicon content as essential graphitizing elements, the structure and condition of the metal substrate graphite nodules in the deposited layer formed with a high crystallization rate and subsequent cooling of the remelted iron. It is found that the variation of the silicon content in the iron from 0.98 to 2.2% retains high hardness of the deposited layer (60-61 HRC), the structure of which is composed of cementite, ledeburite, martensite, residual austenite and graphite. Under reduced silicon content (0.98 and 1.3%) in the alloy is observed grinding martensite-austenite sections and according to X-ray structure analysis of residual austenite is 3-5%. Along with dotted and uniformly distributed graphite in an increased silicon content in the iron (2.2%) is observed further selection eutectic (in the form of rosettes) graphite. Silicon has a marked influence on the properties of structural components in the deposited iron. Increasing its content from 0.98 to 2.2% contributes to the continuous improvement of ledeburite micro hardness which reaches 1080HV. Regarding martensite we revealed that a maximum micro hardness occurs when the content of the deposited layer is 1.95% of silicon. Changes in the content of this element in the direction of increasing or decreasing from this value decrease the micro hardness of martensite.

Key attention is paid to succession layer of weld shape and distribution of graphite from the cast billets. It was found that the melting temperature range of cast billets and shutter speed of the metal in the liquid state has a significant impact on the character of graphite inclusions in the deposited layer of detail. The results of metallographic studies and long production experience convince us that there is a connection between the state of graphite in the workpiece and the weld layer of the part and give grounds to assert that there is a real opportunity to manage this phenomenon by changing the process parameters surfacing. The presence of lamellar graphite and female connector in the workpieces not only reduces their hardness, but also retains the undesired state of graphite in the deposited layer, regardless the temperature and the boiling time of iron in the test range. Having dot rosette with inclusions of graphite in the white iron contributes to the hardness 46-54 HRC blanks and such a state is retained in the deposited graphite layer, if the boiling point of iron is 1230ºC and lower. Increasing the exposure time to 12 seconds of the alloy in the liquid state at a temperature 1230ºC as an increase of the boiling point of iron up to 1250ºC favor for the dissolution of the graphite clusters and uniform distribution of dotted of its discharge into the structure of welding. The results are in good agreement with the opinion of well-known scientists [1, 2, 3], indicating that one of the effective methods of controlling heredity is the melting of iron, followed by a certain overheating.

A noticeable effect on the properties of cast iron has a special cooling process of parts after surfacing. Reducing the pressure of water supplied into the parts for cooling from 1.2 atm. to 0.4 atm. decreases microhardness of martensite to 504-530 HV while maintaining ledeburite microhardness on the level 1000-1100 HV. One of the reserves of increasing martensite microhardness up to 700-725 HV, increase of steel base hardness 47-50 HRC and the deposited layer up to 61-62 HRC, as well as reducing the depth of the pores is the introduction of an additional external cooling under the plate of details after surfacing (table, 1 and table 2). In addition to this effect as a result of the accelerated cooling is observed directional solidification of the alloy throughout the volume of the deposited layer and create a positive environment for the formation of a dotted, stable, evenly distributed graphite surfacing.

### Table 1. Properties of the parts and the deposited layer after different cooling conditions.

| Way of cooling                  | Hardness, HRC | Microstructure of deposited layer |
|---------------------------------|---------------|----------------------------------|
|                                 |               | Steel base | Deposited layer | Base | State of graphite |
| Water delivery into the part    | 45-47         | 59-60      | Cementite, ledeburite, martensite areas and dotted and eutectic |
With additional external cooling

With additional external cooling

|                | 45-50 | 61-62 | Cementite, ledeburite, martensite areas and austenite | Dotted, evenly distributed |
|----------------|-------|-------|-------------------------------------------------------|-----------------------------|

Note: Pressure of water supply is 1.2 atm., temperature is 17°C.

An additional condition for improving wear resistance of parts can serve increasing the antiscoring property of working surface, which is achieved by thermal oxidation. Particular attention deserves oxidation technology of valve tappets, which would significantly increase the wear resistance of parts (Table 2).

The technology provides cleaning and degreasing parts in hot (70-80°C) KM-1 detergent by drying, heating to 300°C in a nitrogen-based protective atmosphere, then the feed of nitrogen is stopped and heated to 450°C in a humidified atmosphere created by the putting water into the furnace in an amount of 1.0-1.4 l / h upon 1 m³ of the workspace, kept for four hours and then cooled to 180-200°C in this environment and then in air.

Table 2. Effect of oxidation parameters on properties of parts.

| Oxidation parameters | Thickness* of oxidation layer, mkm. (steel, cast iron) | Magnitude of wear, ** mkm. |
|----------------------|--------------------------------------------------------|---------------------------|
| 400                  | 1,2 5/4 10,5 10,5                                      |                           |
|                      | 1,4 5/4                                                 |                           |
| 450                  | 0,5 4/2 17,5 17,5                                       |                           |
|                      | 1,0 5/4 11,0                                            |                           |
|                      | 1,2 5/4 11,5                                            |                           |
|                      | 1,4 6/5 10,0                                            |                           |
|                      | 2,0 7/5 19,5 (chalking)                                |                           |
| 500                  | 1,0 6/4 12,5                                           |                           |
|                      | 1,2 6/4 13,0                                            |                           |
|                      | 1,4 7/5 10,0                                            |                           |

Note: * - oxide layer is formed at 150 minutes of exposure
** - magnitude of wear is determined after 53 hour test on the stand

Conclusion.

1. Heredity of graphite inclusions is established and shows the ability to manage the structural state of deposited layer by technological parameters of special cast iron surfacing and heat treatment of parts.

2. Workpiece surface purity and the cooling rate of the parts after surfacing have a direct effect on the formation of pores and their depth in the deposited layer.

3. Additional increase in wear resistance of the deposited layer is achieved by thermal oxidation of the parts.

References:
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