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Investigation of Mechanical Properties of Cast Tool Steel of Ledeburite Class after Hardening

D.A. Savega, V.S. Savega /Ph.D. (Eng.)/

National Metallurgical Academy of Ukraine
4 Gagarin Ave., Dnipropetrovsk 49600, Ukraine

Abstract

Mechanical properties of cast hardened high-chromium steel are studied. Cast sections have lower properties as compared to forged blanks. Increase in cooling rate and isothermal annealing permit recommending the cast section instead of the forged blank.

Keywords: *cast tool steel, mechanical properties, isothermal annealing, section, cast sections, hardening of cast sections, ledeburite, austenite*

Statement of the problem and analysis of scientific literature

Domestic and foreign cold rolling mills and metal-forming manufacture in mechanical engineering as well use cast or forged tool steel of ledeburite class Cr12M, Cr12V and Cr12TV. These steels have high wear resistance and hardenability while after hardening in oil at 1060 °C they change the volume minimally. The qualities specified are especially necessary when manufacturing various stamps [1].

Steel Cr12M and Cr12V found the most extensive application in practice of CIS countries. Steel Cr12M contains 0.4-0.6 % Mo that promotes increase of hardness and good grindability and which is important when manufacturing rolls and stamps. Steel Cr12V is 0.7-0.9 % vanadium-alloyed, has a little smaller hardness and wear resistance after hardening. The steel grades specified are used in mechanical engineering in the form of sections with 300 mm in diameter only after hot forging because of substantial carbide heterogeneity. After forging, the carbide network on grain boundaries failures, and mechanical properties of steel enhance [2].

The sections of 300 mm diameter are obtained from casting. Hot forging of such sections is impossible, in this conjunction, various kinds of heat treatment are used in mechanical engineering. However, properties of as-cast ledeburite steel are not well-studied till the present. Besides, investigation of cast hardened steel properties will enable to develop the technology of casting with uniform or desired physical and mechanical properties across the section. Therefore, research of mechanical properties of specified steel grades is an urgent problem.

The purpose of research is to study mechanical properties of cast hardened high-chromium steel alloyed with molybdenum and vanadium.

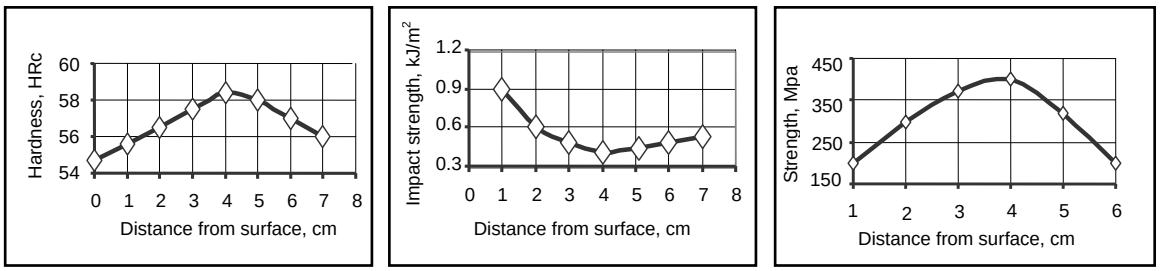
Primary results

Mechanical properties of high-chromium steel Cr12M in the form of sections with diameter up to 300 mm after forging are known in technical literature. Thus, strength of forged steel depends on section diameter. In particular, at hardness 60 HRc the strength of bar with 15 mm in diameter decreases from 220-250 MPa down to 110-125 MPa in the rod with 100 mm in diameter [3].

Sections with 700 mm in diameter were cast in sandy-argillaceous molds for investigation of mechanical properties of steel Cr12M and Cr12V. Samples for mechanical tests were cut out from the castings after annealing and hardening.

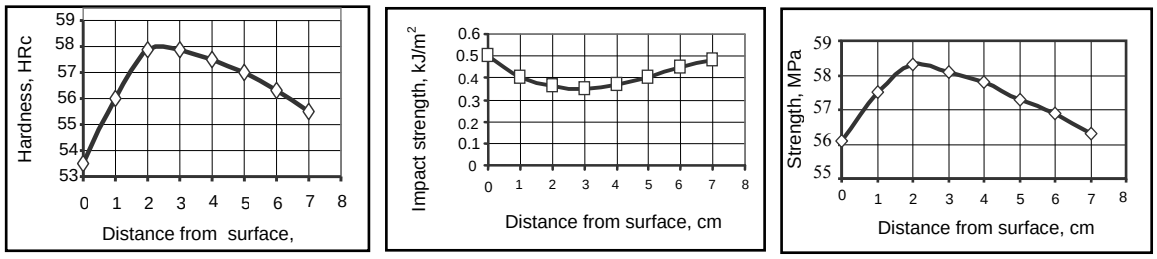
Changes of properties in depth of hardened cast sections made of steel Cr12M with 700 mm diameter are presented in Figure 1a, b, c. Hardness and breaking strength are non-uniform across the section of cast bar and have the maximum values at a depth of 35-45 mm.

Enhancement of mechanical properties can



a b c

Figure 1. Change of mechanical properties of cast sections made of steel Cr12M:
a – hardness, HRc; b – impact strength, kJ/m^2; c – strength, MPa



a b c

Figure 2. Change of mechanical properties of cast sections made of steel Cr12V:
a – hardness, HRc; b – impact strength, kJ/m^2; c – strength, MPa

be explained by less content of residual austenite when moving away from a working surface. Impact strength at a depth of 35-45 mm has a clearly defined minimum related to content of great amount of martensite in the center of section. Thus, for cast sections made of chromium steel Cr12M the breaking strength varies from 17 up to 40 kg/mm^2, impact strength from 0.4 up to 0.8 kgm/cm^2 at hardness 55-58 HRc.

Analysis of change of mechanical properties in depth of section made of high-chromium steel Cr12V (Figure 2) shows that breaking strength and hardness at a depth of 20-30 mm from working surface have a maximum value, while impact strength at this depth is minimum.

Such a change of properties is related to non-uniform cooling rate during hardening and, in this regard, to various amount of residual austenite in the center and at the periphery. Vanadium alloying of high-chromium steel as compared to steel Cr12M increases the breaking strength up to 30-42 kg/mm^2 and impact strength up to 0.35-0.45 kJ/m^2, however, at the same time, section hardness in a surface layer decreases.

These investigations allowed correcting the technology of casting. In particular, moulding is recommended to be performed in paired flasks with the use of antipenetration wash, which should have a layer thickness of 30 – 40 mm. The cores are recommended to be made from nonrigid mixes for preventing sections from failure because of shrink stresses.

Also, for stress relief and balancing of properties across the section of the rolls it is recommended to increase cooling rate of section in the mould.

The temperature of metal casting was corrected. In particular, the rolls were recommended to be cast at 1440-1480 °C to obtain fine-grained structure.

It is known that high-chromium steels have high cooling rate sensitivity, which can cause their failure at further working operations, especially at low air temperatures [4.] That is why directly after cooling, it is necessary to carry out homogenizing annealing using cast heating. For this purpose, the sections are removed from moulds without application of shakeout tables and are put immediately in a thermal furnace.

After machining, the sections are subjected

to isothermal annealing to obtain pearlite structure and to dissolve surplus carbides. Then, secondary hardening and repeated temper are carried out.

Conclusions

1. It is established that as compared to forged blank with 300 mm in diameter, cast sections made of high-chromium steel Cr12M and Cr12V have lower properties, which depend upon amount of residual austenite in a surface layer and at a depth.

2. To balance properties across the section it is necessary to raise cooling rate in the center of section.

3. With the purpose to decrease amount of residual austenite in the middle part of section, isothermal annealing is recommended.

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Исследование механических свойств литых инструментальных сталей ледебуритного класса после закалки

Савега Д.А., Савега В.С. /к.т.н./

Изучены механические свойства литой закалённой высокохромистой стали. По сравнению с кованой литые заготовки имеют более низкие свойства. Увеличения скорости охлаждения и проведение изотермического отжига позволяет рекомендовать литую заготовку взамен кованой.