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Effect of Cementation and Heat Treatment of Steel 10Г12 on Metastable Austenite in the Structure, Abrasive and Impact Wear Resistance

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This work reveals the effectiveness of cementation and further heat treatment of steel 10Г12 for obtaining metastable austenite in the surface layer and stability optimization, thus providing the high-level abrasive and impact wear resistance.

Keywords: AUSTENITE, STABILITY, DEFORMATIONAL MARTENSITE TRANSFORMATIONS, ABRASIVE AND IMPACT WEAR RESISTANCE

Introduction

High-carbon manganese austenite steel 110Г13Л is used in the industry to produce details working under high dynamic and static loads. The disadvantages of this steel are: low resistance under mainly abrasive wear, comparatively low yield stress (σ_{02} ~400 MPa) and extremely bad machinability. The latter is the reason why steel 110Г13Л is not used in production of details with precise geometry.

In works [1-5] low-carbon manganese steels containing 4-10 % Mn are recommended as new carburized steel. The key feature of new steels is that there is not martensite and carbides in surface layer providing high hardness but metastable austenite carbide-reinforced which is able to control by self-transformation under loading. Wear resistance of these steels is higher than that of serially applied Hadfield steel. However, now there is lack of information on this issue which prevents the application of these steels in the industry.

Results and Discussion

Steel 10Г12 with good machinability is the research object in this work. Chemical composition of this steel is given in **Table 1**.

Meanwhile, the investigated steel is essentially inferior to 110Г13Л in relation to wear resistance. There are no data about the effect of cementation and further heat treatment on the structure and wear resistance of steel 10Г12 in the literature, that is why we conducted this research.

Steel 10Г12 is melted in the induction furnace with capacity 150 kg with basic lining. 14-kg ingots are subjected to homogenization at 1150°C during 10 h and forged to bars with section 12×12 mm, which are used as research samples.

The cementation is carried out in solid carburizing material at 930 °C during 8 hours. Oil hardening is carried out at 850, 900 and 950 °C, tempering temperatures are 200, 550 and 650 °C, soaking time is 1 hour.

Phase composition is studied by X-ray method on DRON-3 device in iron K_α-radiation. Metallographic and durometric investigations are accomplished.

Abrasive wear resistance is determined by Brunnel-Hawort method [6], abrasive is sand with the particle size ∅ 0.3-0.5 mm. Impact wear resistance is defined on the device in which samples fastened on the rotating disk collided with steel fractions ∅ 0.8 mm. Annealed steel 45 is a standard.

In most cases, when defining the level of abrasive particles effect (weak, average and strong effect), qualitative assessment is used more often than others. In [7], Petrov I.V. suggested dynamic factor C_d which quantitatively characterizes the various conditions of abrasive particle effect. It is defined as a correlation of work surface hardness of steel 110Г13Л sample after wear to its initial hardness. In the investigations C_d under abrasive wear is 1.1 and under impact wear – 2.1.

The microstructure of steel 10Г12 in its initial (before cementation) state is a phase mixture (α' + ε + γ). Immediately after cementation near the surface at a depth of 0.3–0.4 mm the structure is presented by troostomartensite with carbide network along the grains. Precipitation of carbides from austenite and carbon and manganese depletion occur as a result of slow cooling after cementation. The latter causes partial decomposition during austenite cooling with the formation of ferritocarbide mixture.

Raise of steel 10Г12 heating temperature for hardening from 850 to 950 °C (tempering at 200°C, 1 h) after cementation leads to increase of austenite amount and reduction of high-carbon martensite and carbides in the surface layer. Hardening from 950 °C results in austenite grain growth both in the surface layer and in the core. In this case, amount of austenite in the surface layer, according to X-ray scattering analysis data, increases from 77 to 100% (**Table 2**).

Also effect of tempering temperature (soaking 1 h) of cemented steels 10Г12 after hardening from 950 °C on microstructure is studied. Tempering at 200 °C keeps the austenite structure of cemented layer surface. And during tempering at 550 °C there is a partial decomposition of austenite surface layer with formation of troostite along the grain boundaries.

Tempering at 650 °C preserves mainly austenite structure with dispersed carbides. The amount of austenite in the surface layer during tempering at 550°C is minimal, which is related to partial austenite decomposition and troostite formation. Depending on tempering temperature, the amount of austenite in the surface layer changes ambiguously (**Table 3**).

The analysis of microhardness measurement results after hardening from 850 ° and 950 °C and tempering at 200 °C proved that microhardness near the surface is essentially higher than that of austenite structure layer (**Figure 1**).

In the process of investigation we obtained data about the influence of heating temperature for hardening and tempering at 200 °C, 1 h on abrasive and impact wear resistance of steel 10Г12 after cementation (**Figure 2**). As heating temperature for hardening grows from 850 to 950 °C, abrasive wear resistance of this steel reduces while impact resistance increases. This is caused by austenite stabilization against the dynamic deformational martensite transformation during temperature raise due to more complete carbide dissolving [3, 4].

Table 1. Chemical composition of steel 10Г12, mass. %

C	Mn	Si	S	P
0.10–0.12	11.34–11.65	0.10–0.16	≤0.01	≤0.02

Table 2. Effect of heating temperature for hardening on hardness and residual austenite content in the surface layer of cemented steel 10Г12

Heating temperature for hardening, °C	Hardness, HRC	Amount of residual austenite, %
850	33	77
900	31	81
950	19	100

Table 3. Effect of tempering temperature (soaking 1 h) after hardening from 950°C on hardness and residual austenite content in the surface layer of cemented steel 10Г12

Tempering temperature, °C	Hardness, HRC	Amount of residual austenite, %
200	19	100
550	27	88
650	25	95

Considerable part of abrasive particle energy is spent on the development of dynamic deformational martensite transformation and, respectively, smaller part is spent on destruction. And, vice versa, under large dynamic loads in case of impact-abrasive influence higher austenite stability should be ensured. This is caused by the fact that martensite of deformation is featured by comparatively low ductileness and fractured under impact loads [3, 4].

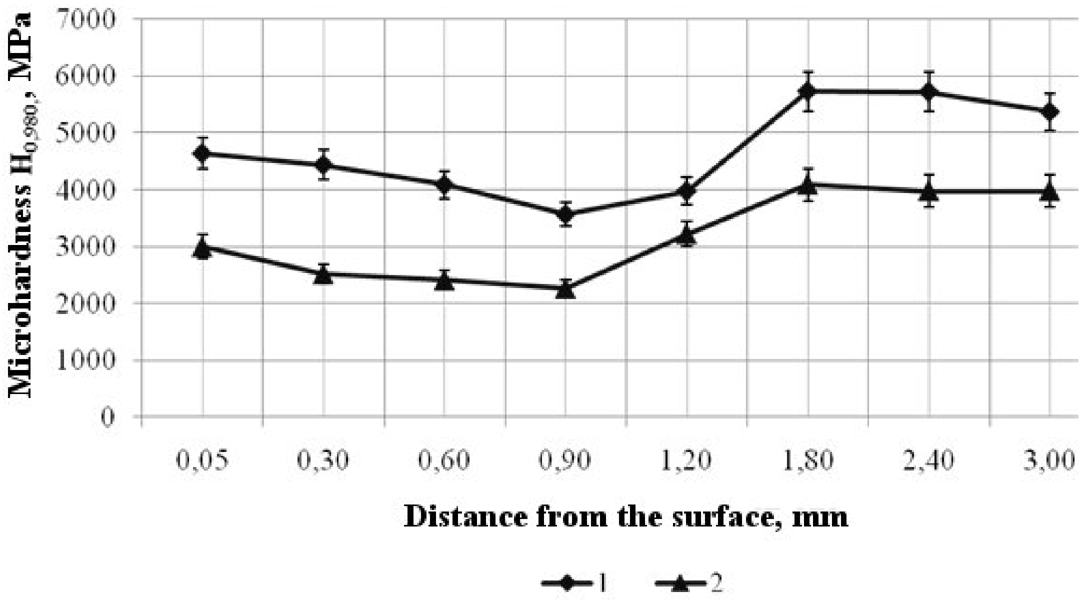

Figure 1. Microhardness change along the section after hardening from 850 °C (1) and 950 °C (2) (tempering at 200°C, 1 h)

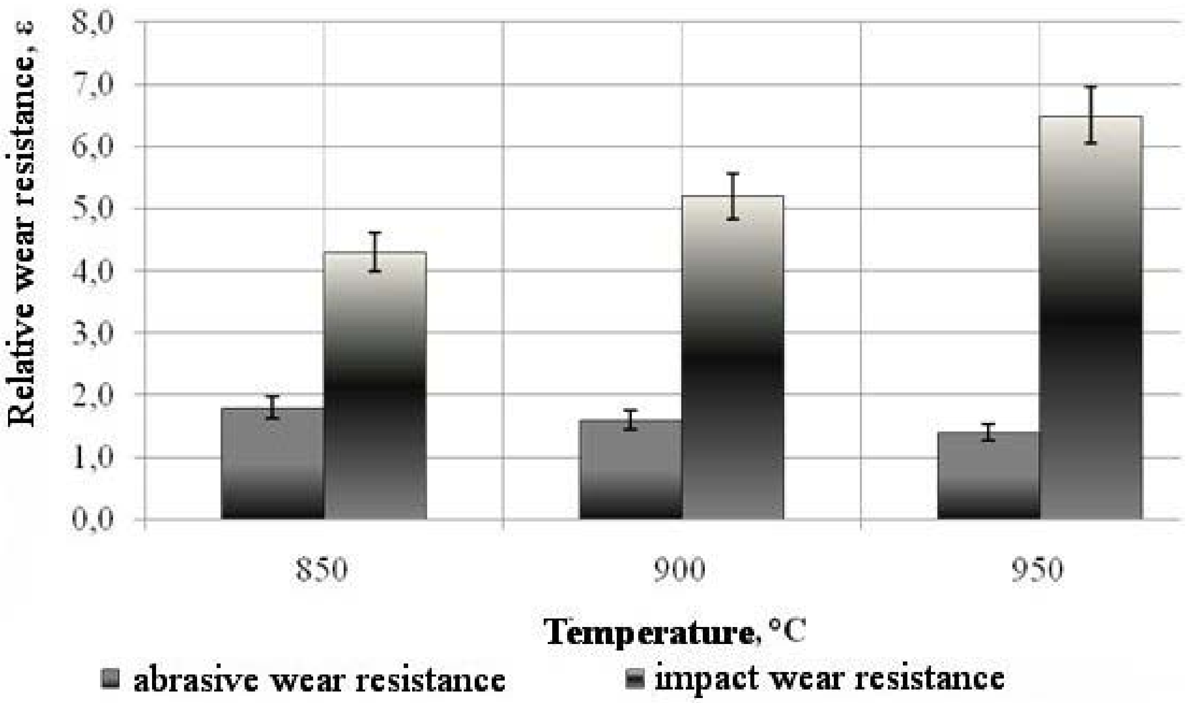

Figure 2. Effect of heating temperature for hardening on abrasive and impact wear resistance of steel 10Г12 after cementation

Effect of tempering temperature (soaking 1 h) on wear resistance of cemented steel 10Г12 is studied after hardening from 950 °C (**Figure 1, 3**). Tempering at 200 °C that stabilizes austenite in relation to dynamic deformational martensite transformation, reduces its abrasive wear resistance and increases impact wear resistance [8].

Heating temperature raise from 200 to 650 °C leading to partial austenite decomposition and destabilization increases hardness and abrasive wear resistance. Impact wear resistance changes ambiguously. It reduces essentially after tempering at 550 °C, as tempering troostite appearing at such temperature reduces resistance to destruction under dynamic loads.

When tempering at 650 °C, impact wear resistance is higher than at 550 °C, because there is mainly austenite structure. However, its level is lower than the level of structure after tempering at 200 °C, because austenite stability against dynamic deformational martensite transformation is lower due to depletion of solid solution with carbon and manganese as a result of carbide precipitation.

Data obtained in the research show that to provide improved abrasive and impact wear resistance of steel 10Г12 it should be cemented and heat treated for obtaining austenite in the surface layer. Then the stability of austenite should be optimized as applied to specific conditions of abrasive effect.

In this case, the reasons of surface layer wear resistance are as follows:

- martensite transformation under the effect of abrasive particles with definite intensity for certain conditions of loading;
- dynamic ageing of austenite and martensite;
- better ability to high-carbon austenite hardening;
- superdispersed and nanocrystalline structure formation in the surface layer in the process of abrasive wear [9].

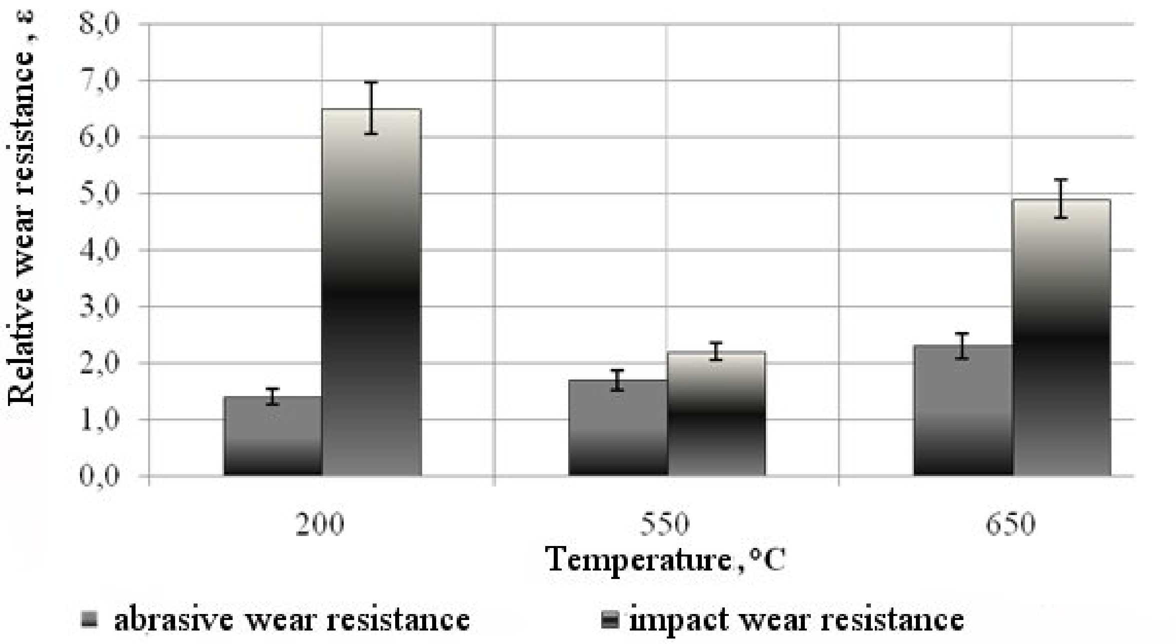

Figure 3. Effect of tempering temperature after hardening from 950 °C on abrasive and impact wear resistance of steel 10Г12 after cementation

Conclusions

1. Low-carbon steel 10Г12 after high tempering has good machinability as compared to steel 10Г13Л, moreover, its wear resistance is not lower as compared to Hadfield steel at the expense of cementation and further heat treatment.

2. To increase abrasive wear resistance steel 10Г12 should undergo cementation and further heat treatment, as a result, metastable austenite with carbides is in the surface layer. And this austenite intensively transformes into martensite during deformation under abrasive particles effect. This is ensured by hardening from 850 °C and in greater degree hardening from 950 °C and tempering at 650°C, which destabilizes austenite in relation to dynamic deformational martensite transformation.

3. In case of intensive impact-abrasive wear, the austenite should be obtained in the surface layer with increased stability as compared to the

required one under abrasive influence. This is achieved by hardening from 950 °C after cementation.

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Влияние цементации и термообработки стали 10Г12 на получение метастабильного аустенита в структуре, ее абразивную и ударно-абразивную износостойкость

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В работе показана эффективность применения цементации и последующей термической обработки стали 10Г12 для получения в поверхностном слое метастабильного аустенита и оптимизации его стабильности, что в свою очередь обеспечивает высокий уровень абразивной и ударно-абразивной износостойкости.