INVESTIGATION OF STRUCTURE AND PROPERTIES OF CHROMIUM WEAR RESISTANT STEEL WITH NICKEL ADDITIONS

V.V. Gorbatenko, V.V. Pashynsky, S.I. Marchuk

Donetsk National Technical University, Artyoma 58 Donetsk 83000 Ukraine   E-mail foreign@pop.dgtu.donetsk.ua

Abstract.
Development of new high-performance metallurgical equipment demands the using of materials with increased properties. Well-known 12% chromium wear-resistant steels have high hardness but decreased plasticity in massive cross-sections after certain heat treatment. The influence of nickel additions on structure and properties of chromium steel after different regimes of heat treatment was investigated. It is shown that alloying by nickel extends the stability of austenite and permits to obtain the martensitic structure after cooling on air in wide range of quenching temperatures. It provides the more favorable conditions for heat treatment of parts with complex shape and large cross-section.

1. STATEMENT OF THE GOAL OF INVESTIGATION
The comparing of wear resistance of different materials shows that increasing of it with increasing of strength and plasticity is the general tendency. But alloys with the same level of mechanical characteristics may have different wear resistance in dependence on structure peculiarities [1]. The high-chromium alloys with Cr content more than 12% are the basis for wide range of tool and wear-resistant materials. Carbon content for such application must be rather high (1,3-1,4% and higher). Alloys of such composition have ledeburite structure. Presence of eutectic component in structure provides the high hardness and wear-resistance, but causes the decreasing of plasticity and make the machining of them more difficult [2].

The hardness in quenched chromium steels decreases more slowly with increasing of tempering temperature in comparison with ordinary carbon steels due to effect of secondary hardening. It permits to use some grades of chromium steels as heat-resistant. Additions of nickel in these stels may extends the stability of austenite and permits to obtain the martensitic structure after cooling on air in wide range of quenching temperatures. It provides the more favorable conditions for heat treatment of parts with complex shape and large cross-section. Besides that, residual austenite, that presents in structure of quenched steel may be transferred in metastable state by corresponding heat treatment. Transformation of such austenite to martensite during service of part may additionally increase the wear resistance.

Goal of current investigation was the investigation of structure and properties of steel with mentioned above composition after different regimes of quenching and different duration of tempering.

2. EXPERIMENTAL PROCEDURE
Experimental alloy with carbon content 1,52% and chromium content 12,8% with nickel additions was subjected to quenching in oil from different temperatures from 850 to 1150 °C with step 50 °C. Another part of samples was subjected to cooling of air from the same temperatures. Tempering was fulfilled at temperature 550 °C with duration from 1 to 10 hours. The structure of samples was investigated by the methods of optical metalography in the range of magnifications x100 – x1000. Hardness after tempering was measured after every 30 minutes of tempering. Phase composition of samples was studied by X-ray structure analysis on the diffractometer DRON-3.
3. OBTAINED RESULTS AND THEIR DISCUSSION

Investigation of structure and hardness of samples, quenched in oil and on air shows that in cross-sections 20-50 mm there is no considerable difference between these treatments due to high hardenability of alloy. Structure of alloy is formed by the austenite-martensitic matrix and eutectic carbides. Carbides form the fragmented eutectic net around matrix dendrites (see Fig. 1). This net was formed during crystallization of alloy and save the cast structure.

![Figure 1. Morphology of eutectic net in cast alloy, x250](image)

According to results of metallographic and X-ray analysis, with increasing of temperature of heating for quenching the volume fracture of retained austenite in quenched steel increases and eutectic component begins to dissolve. At temperature 1100 °C and higher the eutectic net fully dissolve. It is the evidence of metastable nature of eutectic in nickel-added alloy in contrast to usual chromium alloy. These transformation cause the decreasing of hardness of quenched steel from 59-61 HRC for quenching from 900 °C to 28-30 HRC for quenching from 1150 °C. It connected with dissolution of carbides and increasing of volume fracture of retained austenite (up to 85-90%). Possibility of full dissolution of eutectic carbides net is the very important advantage and may be used for control of morphology of carbide phase by the methods of heat treatment without plastic deformation.

In order to study the influence of tempering on structure transformation the treatment was carried out at temperature 550 °C, that is typical tempering temperature to realize the secondary hardening effect. The following results were obtained.

- Hardness of samples, quenched form temperatures 850 – 900 °C decreased from 59-61 HRC to 42-47 HRC during 60 – 90 minutes of tempering. Following treatment causes very slow decreasing of hardness and its stabilization at level 40-43 HRC. Decreasing of hardness connected with decomposition of martensite and formation of troostite structures. Effect of secondary hardening practically does not take place because low degree of chromium dissolution in solid solution before quenching.

- Hardness of samples, quenched from 1000 °C keeps practically constant on the level 43-45 HRC. It may be explained by the compensation of the influence of two effects – decomposition of martensite and transformation of retained austenite, which have opposite influence on hardness. Additional hardening may be caused by formation of special carbides during high duration of tempering.

- Quenching from temperatures 1050-1100 °C provides the realization of process of secondary hardening. This process starts after 90-120 minutes of tempering duration and at the end of tempering the hardness of material is higher than directly after
quenching. Dissolution of eutectic carbides during heating for quenching permits to form very fine and uniform structure without coarse particles of brittle carbides.

- Further increasing of temperature of heating before quenching causes drastic decreasing of hardness for the value 27-29 HRC. This decreasing can not be explained by increasing of retained austenite fracture only. X-ray analysis fixes the presence of b.c.c.-phase in structure. Probably it may be not the martensite, but δ-ferrite. Possibility of this process is confirmed by the ternary Fe-C-Cr equilibrium diagram. Low hardness of δ-ferrite. may be the reason of decreasing of total hardness of alloy. Tempering of this structure causes the decreasing of hardness at short durations with following increasing above the values after quenching. But high stability of austenite, saturated by the alloying elements in result of carbide dissolution, prevents the full its transformation and hardness keeps at rather low level.

Therefore additions of nickel to chromium alloy permits to increase the stability of supercooled austenite and, therefore the hardenability of alloy. Varying the temperature of quenching we can obtain different types of structure and combination of properties according to conditions of service.

BIBLIOGRAPHY