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Traditional Technology of Chromium-Tungsten Steels Facing, its Disadvantages and Suggestions for their Eliminations

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Abstract. To reveal the disadvantages of the traditional technology of facing with chromium-tungsten steels analysis of the given technology was completed. The analysis showed that the main disadvantages of the technology are high-temperature heating and underutilization of high-alloyed metal properties. To eliminate the disadvantages we developed the methods of facing allowing obtaining faced metal which state is close to that of the hardened one without cracks.

Introduction

Facing materials developed on the base of chromium-tungsten heat-resisting high-speed steels are applied to strengthen the components of mining and metallurgical equipment. A characteristic feature of the given group of steels is the structure of the deposited metal consisting of martensite, retained austenite and carbides. Basically all variety of faced metal composition is further development and modification of traditional well-known and widely used tool steels of 3H2V8 and R18 types. The basic alloying elements in chromium-tungsten facing materials are carbon (0.2–1.5 %), chromium (1–6 %) and tungsten (1–18 %) [1]. Chromium-tundsten electrode materials are widely used when facing hot rolls, press matrices and hollow bars, grippers of crab cranes, blank dies, blades, scissors, fillerings, drift pins, cutters, rolls of the roller-tables, various axles, reels of the rolling mills, components of hammer breakers and other parts [2, 4].

Work objective – analysis of traditional technology of facing hardening chromium-tungsten steels and development of suggestions to eliminate its disadvantages.

The main difficulty which appears when facing with chromium-tungsten steels is formation of cold (hardening strain) cracks during the process and after the facing. Crack formation is impeded by temperature increase of martensite transformation and slowing down the cooling rate. The most efficient and the easiest method of preventing cracks is regulation of the thermal cycle by means of choosing corresponding methods and facing conditions as well as application preliminary heating if necessary. “Ideal” thermal cycle ensuring highest resistance against cold cracks formation is shown in Figure 1. Such thermal cycle allows avoiding overheating due to high-speed heating and cooling of metal under the temperatures over point A_1. Slowed down cooling under the temperatures below point A_1 decreases the possibility of hardening structures, thus, improving steel resistance to static fatigue and cold cracks formation as slow cooling contributes to development of pearlite and intermediate transformations of overcooled austenite in the faced metal and eliminates or dislocates γ→α – martensite transformation into the high temperature region. It is rather actively promoted by slowed down cooling of the faced component in the interval of martensite transformation. As a result of martensite self-tempering under the temperatures below 350 C the crystalline structure of metal in the areas adjacent to the grain boundaries becomes more regular, general metal ductility increases and formation and development of cracks impedes. Real thermal cycles close to the “ideal” ones can be obtained under electron-beam welding with preliminary heating or under multilayer arc welding of thick metal with preliminary heating. These are the basic theorizes which underlie the traditional technology of facing hardening chromium-tungsten steels [2].

To obtain faced metal free of cracks and ensure required hardness and wear resistance when facing mining and metallurgic equipment components major attention is paid to the thermal conditions of facing: temperature of preliminary heating, thermal condition of the component in the process of facing and in the process of cooling after facing. Special attention is paid to more uniform and slow heating as too fast heating of certain places up to 350–450 C and cold neighbouring areas may lead to crack formation.

Temperature of component heating for facing depends upon many factors: composition of base and faced metal, form of the component, facing conditions and required properties of the faced metal. The more the faced metal is liable to crack formation the higher the temperature of preliminary heating must be as it is considered that otherwise crack prevention is impossible. To prevent cracks, reduce internal stresses and produce quite plastic structure of the faced metal we apply obligatory preliminary heating of components up to 350–400 C when facing with highly alloyed electrode wire PP-3H2V8 or whole-drawn EI-701. To eliminate cracks when facing high-speed steels we need preliminary and concurrent heating of the workpieces up to 500–700 C.

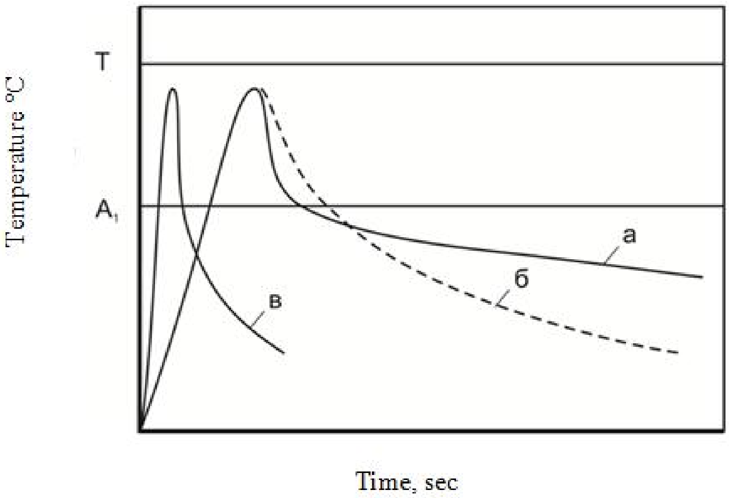

Figure 1. Welding thermal cycles: a) “ideal”, providing the highest resistance to cold cracks formation; b) under electric arc welding; c) under electron-beam welding [4, p. 719]

The cooling rate after the heating is of special importance. It determines the structure of the faced metal and, thus, hardness, wear resistance and other properties. To obtain more plastic products of austenite deterioration we ensure slow cooling in a heat-insulated bucket and for massive components we complete tempering under $T_{tempering}$ =520–540 C and cooling together with the furnace [2].

Structure of the faced metal of R18 type is also determined by the cooling rate. Under the moderate cooling rate (facing with heating up to 500–600 C and further cooling with the furnace) crystals of δ–ferrite (contained in the solid solution of W and Cr) with reduced carbon content are the first to be formed. The melt is carburized with peritectic reaction taking place and δ–ferrite partly transforming into austenite. At the end of the hardening process ledeburite eutectic is exuded in the form of a net along the boundaries of dendrite crystals [1, 2].

The faced components are usually machined with preliminary annealing. When facing with steel of R18 type we recommend the following rather complicated cycle of the faced workpieces treatment [9]. Heating up to 660 C and holding for 4 hours, heating up to 880 C and holding for 9 hours, cooling with the furnace up to 750 C during 3.5-4 hours and holding under 750 C for 6 hours, cooling with the furnace up to 400 C and bloom discharge. After annealing hardness of the faced metal is 220-270 HB. Isothermal annealing of the faced metal of 3 H2V8 type is completed with holding under 750 C during 6 hours. Hardness after the annealing is 190-220 HB.

Application of slow cooling rates of the faced metal recommended for prevention of cold cracks formation results in the low hardness of the faced layer and, thus, in low wear resistance. Current technology of facing hardening chromium- tungsten steels does not allow producing faced metal without cold cracks and with high hardness right after the facing. To improve the service properties of the faced metal we complete hardening and tempering of the bimetallic item. For chromium-tungsten steels after hardening we recommend heat treatment – 3-4-time 1-hour tempering under 560–580 °C. After that the given steels have optimal structure and high hardness HRS 60-62 and red hardness.

As we can see traditional technology of bimetallic items production (facing with heating – annealing – hardening – tempering) is unreasonably time and labor consuming. A significant disadvantage of the technology is mandatory application of high-temperature heating ($T_{heating}$=350–700^{o}C), slow cooling and, as a result, further hardening of the faced component while high working properties of hardening steels are not made maximal use of. Application of high-temperature heating when facing chromium-tungsten steels significantly complicates the technological process of producing a bimetallic faced product. The costs for the facing increase due to the necessity of heating and high temperature maintenance. The process of facing with application of high-temperature preliminary and additional heating and slow cooling significantly prolongs. Slow cooling of the component recommended to prevent cold cracks generates a need for conducting further hardening of the bimetallic product which, by itself, is a difficult task due to different properties of faced high-alloyed layer and low-alloyed core. Hardening of some large-sized components is practically unrealizable. Current technological processes of tool steels facing do not allow complete enough application of the faced layer metal properties [2, 4].

That is why the problem of developing new methods of chromium-tungsten steels facing allowing elimination of the mentioned above disadvantages of traditional technology and complete use of high hardness and wear resistance designed by metallurgists and metallographers. It is rational to combine the facing and hardening processes which allows producing a faced layer in the condition close to the hardened one. It is also necessary to avoid heating or, at least, decrease its temperature applying new methods of cold cracks elimination.

We can produce faced metal demonstrating high resistance to cold cracking and high mechanical properties right after the facing by regulating the thermal cycle of facing. The thermal cycle for the multi-layer facing chromium-tungsten hardening steels is shown in Figure 2 [2-3].

The specific feature of the suggested thermal cycle is in three stages of heating. The first provides limited time of heating and increased cooling rate in the high-temperature region which prevents growth of grains and austenite deterioration with formation of equilibrium low-strength structures.

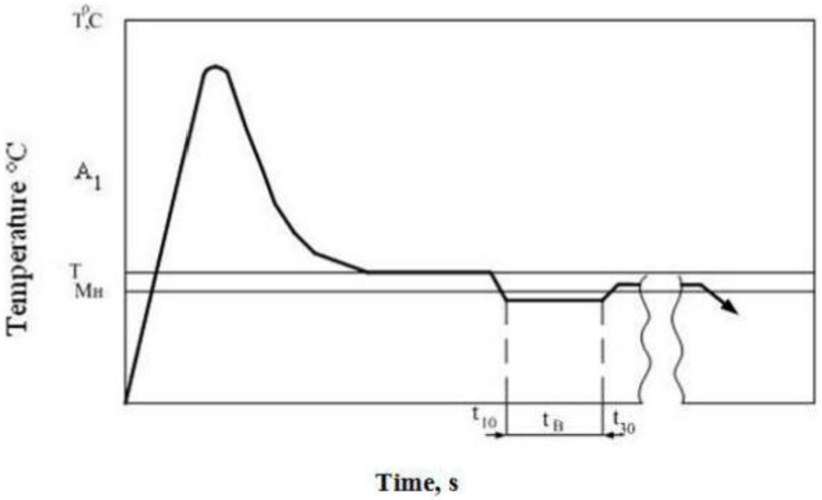

Figure 2. The diagram of the thermal cycle when facing with heat-resisting steels

The first stage of the thermal cycle is provided by application of highly-concentrated heating sources (constricted or plasma arc) and additional heating of the faced component. The second stage of the thermal cycle ensures faced metal remaining in the austenite condition when completing all layers in the process of facing. It is achieved by application of preliminary heating by 50–100 C over the temperature of abnormal plasticity occurrence. Cooling of the faced component at the third stage of the thermal cycle after the facing is finished is caused by phase transitions in the chromium-tungsten faced metal accompanied by abnormal plasticity (superplasticity) occurrence. The internal stresses partly relax which allows producing faced metal with low level of retained stresses and, thus, with low liability of cold cracks formation.

Cooling of the faced metal after the process is over leads to formation of martensite. In this case there is no necessity of hardening the faced component to improve its strength, hardness and wear resistance. There is also no necessity in completing further complicated thermal treatment of the faced component (annealing – hardening – tempering). According to the suggested method it is only necessary to conduct one additional operation – tempering – to improve hardness and wear resistance.

To produce faced metal with low capability of forming cracks we suggest regulating the level of temporary stresses in the process of facing. Such regulation may be implemented by lowering the temperature of heating by 20–100 C below the temperature where phase transformations start. This allows decreasing the temporary stresses due to their partial relaxation under phase transformations accompanied by abnormal plasticity. The degree to which the heating temperature is lowered down depends upon the required level of temporary stresses decrease to produce faced metal structure with the certain amount of austenite and martensite and phase transformation interval. Formation of insignificant amount of martensite in the structure is aimed. The heating temperature should be increased after partial relaxation of temporary stresses. After the facing process is finished the component must be cooled down to the temperature where phase transitions stop (the third stage of the thermal cycle) [4-6].

The suggested method is efficient when facing high-speed chromium-tungsten steels with low temperatures of phase transformations start (M_s=180° – 380 C). It allows significantly decrease the temperature of preliminary heating for R18 steel from 500–600°C to 230–280°C and even to 80–160°C in the suggested method which simplifies the technology of chromium-tungsten steels facing. The suggested method of hardening steels facing ensures high resistance of the faced metal to formation of hardening cracks and allows obtaining high hardness and wear resistance of the layer hardened in the process of facing. The structure of the faced metal in the area of fusion with the base metal is shown in Figure 3.

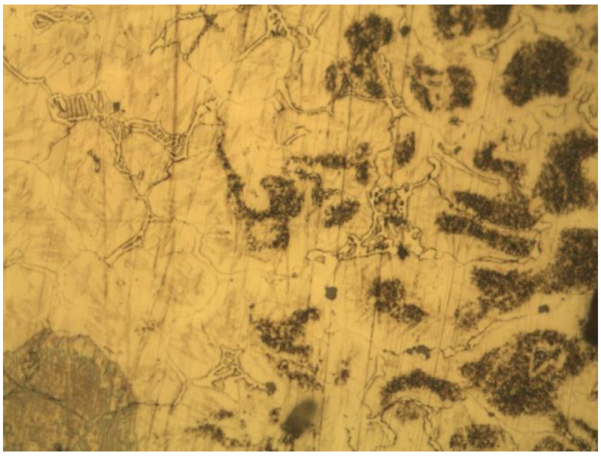

Figure 3. Structure of the faced metal in the area of fusion with the base metal, × 1000

Metal hardness after the facing according to the given method approaches hardness of hardened steels (HRC 52-58). Due to high tempering hardness can be increased up to HRC 62-66. Facing completed according to the suggested method allows full use of the properties of the faced metal [7-8].

Conclusion

1. The traditional technology of facing chromium-tungsten steels with high-temperature heating and slow cooling is labor-consuming and does not allow full use of service properties of the faced metal.

2. It is possible to produce faced metal, hardened, without cracks and with low level of residual stress, through application of new facing methods according to the thermal cycle of facing which specific features include three stages of thermal heating and application of low-temperature heating.

3. It was suggested to regulate the stressed state in the faced components with application of kinetic plasticity effect due to short-time lowering of the heating temperature and time-wise holding the component under the given temperature conditions.

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