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Manufacturing Component Parts of Mining Equipment With Application of Hardening Technologies

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Abstract. To ensure highest hardness and wear resistance the authors develop an aggregate technology of manufacturing mining equipment component parts. The aggregate technology of manufacturing faced component parts includes the following operations: plasma-jet hard-facing with high-speed steels; high-temperature tempering after the facing, ultrasonic surface strengthening treatment, additional tempering, reconstructive facing.

Introduction

The materials developed on the base of chromium-tungsten hot-working and high-speed steels are the ones that most completely correspond to the requirements for the added metal applied for strengthening mining equipment component parts. Hot-working steels like R18, R6M5, R9, R2M8, 3H2V8 and other combine high working properties with insufficient weld ability. Normally, to prevent cold cracking the traditional facing technology involves mandatory application of high-temperature preliminary and additional heating ($T_{heating}$ = 400 - 700°C) and retarded cooling of the work piece. This process is accompanied by the formation of plastic products of austenite degradation characterized by low hardness and low wear resistance which, in its turn requires complicated thermal processing. In the process of heat treatment of a bimetallic work piece it is not always possible to take advantage of the properties of high-alloyed metal and provide its highest hardness [1-4].

Objective of the work – development of aggregate strengthening technology for manufacturing mining equipment component parts on the base of plasma-jet hard-facing with hard hot-working steels.

The peculiarity of hard-facing methods developed in Siberian State Industrial University is application of low-temperature preliminary and additional heating ($T_{heating}$ = 230-280 $^{\circ}$C). To obtain the added metal with low crack formation capability we regulate the level of temporary stress during the hard-facing process by their partial relaxation due to kinetic plasticity effect which accompanies martensitic or bainitic transformations. The suggested thermal cycle of hard-facing consists of three stages. The first one provides limited time of heating and increased cooling rate in the region of high temperatures, prevents grain growth and austenite degradation with formation of equilibrium but low-strength structures. This stage can be implemented with application of high concentrated heating sources (for example, constricted or plasma arc) and cooling. The second stage of the thermal cycle provides the austenite state of the added metal when depositing all layers in the process of hard-facing.

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It is achieved by application of heating with $T_{heating} = M_{н} + (50 - 100^{\circ}C)$. To obtain added metal with low capability of fracture formation we regulate the level of temporary stresses in the process of hard-facing at the third stage of the thermal cycle by temporary reduction of $T_{heating}$ below $M_{н}$. The temporary stresses reduce due to partial relaxation in the moment of martensitic or bainitic transformations. It allows obtaining added hard surfaced metal with low level of residual stresses. This facilitates the process of hard-facing in comparison to traditional technology, productivity of hard-facing increases, the properties of the high-alloyed added layer are implemented at their most [2 - 4].

The methods of multilayer hard-facing with high-speed steels developed and studied by us were taken as a basis for the technology of manufacturing bimetallic cold rolling work rolls [2, p.124]. The technological process of deposited work rolls manufacturing comprises the following stages: mechanical processing of the workpiece for hard-facing, plasma-jet hard-facing, facing of the deposited work roll, finishing mechanical processing, quality control of the active layer.

We recommend to apply 30HGSA steel as the base metal due to its high mechanical properties. When we complete facing according to the recommended thermal cycle the cooling rates in the region of minimal stability of 30HGSNA steel austenite are lower than the tolerance ones equaling 2.5–6.0°C/s. That prevents formation of cold cracks in the base metal when facing according to the developed method.

Facing of the workpiece was completed with application of the plant for plasma-jet facing of rotation bodies. The rollers were faced with plasma arc with feeding non-current-carrying welding powder wire PP-R181YuN into the weld pool. Argon was used as the plasma-supporting gas, nitrogen was used as the shielding one. Plasma-jet facing was completed according to the thermal cycle presented in Figure 1[3].

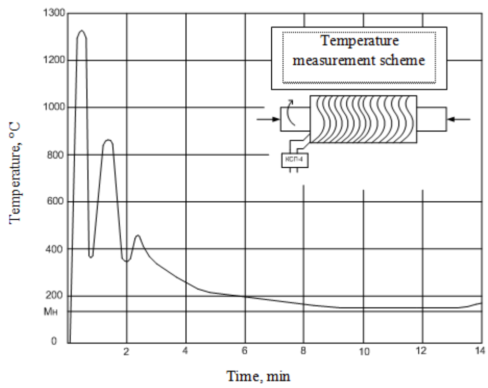

Figure 1. Thermal cycle under plasma-jet facing of the first layer of the roll 10 mm in diameter

The workpiece with the allowances for facing of 10-12 mm for one side is placed in the centers of the facing plant, previously heated up to 230 °C, and the roll neck cooling with water flow up to 2 l/min was applied. Cooling of the rolls with internal opening was completed with the help of a special device. After the preparation 5-6 layer facing was completed. Time duration of facing is 3 hours, when facing finished the roll is cooled in the air.

Pilot lots of rolls were faced for the rolling mill 6/100×315, rolling mill 425 and for ceramic sheet rolling according to the given technology. Visible inspection did not reveal any defects of facing. The quality of the faced surface is satisfactory. Hardness of the faced metal is HRC 54–58. Four-time one-hour tempering under 580 °C was completed to increase hardness and wear resistance. Influence of the number of tempering times upon chromium-tungsten metal is shown in Figure 2. As we can see from Figure 2 hardness of the active layer of the faced rolls answers the requirements imposed for the surface layer of the work rolls for cold rolling. After the tempering finish machining was completed.

It has been established that the work rolls of the cold mill produced with the application of plasma-jet facing of the active layer by hot-working high-hardness steels demonstrate increased wear resistance (by 1.5 … 2.0) in comparison to batch rolls.

Increased wear resistance of the faced rolls can be explained by fine carbides M_6C и MC in their structure. Compressive stresses in the surface layer of the faced rolls and absence of abrupt transition of compressive stresses into the stretching ones may be one of the factors contributing to the wear resistance increase. A typical structure of the faced metal (surface layer) is shown in Figure 2 (microscope OLYPUSGX– 51, pickling solution–HNO_3, 3% alcohol solvent).

Figure 2. Structure of the faced metal (surface layer) × 1000

The main causes of failures of the faced rolls as well as those of rolls produced according to traditional technology include natural wear, delaminating and spalls. In [2, p.102] the authors note that delaminating is related to formation of fatigue failure sites inside the roll. Fatigue failure sites are situated in the weakened zone of the weld joint – the fusion area where the base metal was welded with the deposit one and where the metal properties change abruptly.

To improve the properties of the faced highly alloyed metal as well as to ensure favorable stressed condition we can additionally apply high temperature tempering after the facing. So, metal hardness after facing is HRC 52–57 and after tempering for secondary hardness it reaches HRC 62–64 which corresponds to 95–102 HSh (see Figure 3).

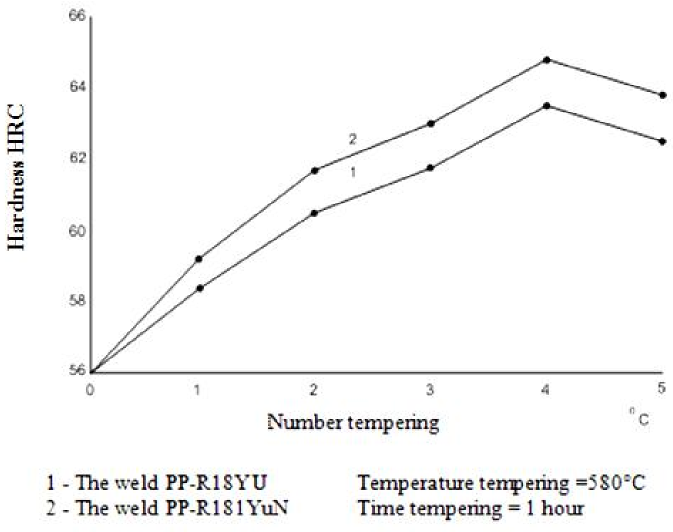

Figure 3. Influence of the number of tempers upon the hardness of the faced rolls

Additional application of ultrasonic surface hardening treatment after the facing allows increasing hardness up to HRC 64–66. Under the certain values of ultrasonic treatment intensity some characteristics of the hardened layer may deteriorate. At the same time there is the area of optimal values (P ≈ 10 daN, A ≈ 20 um, V ≈ 20 m/min) of the technology factors of ultrasonic surface treatment where we observe abrupt increase of all characteristics of the hardened layer of the faced metal [6].

Hardness of the surface of the faced disks is up to HRC – 65 and microhardness H_{100} is up to 12200 Mpa, hardening depth reaching 4 mm. In the work we reveal the optimal area of ultrasonic treatment parameters ($P_{ст} \approx 10$ daN, A ≈ 20 um, V ≈ 20 m/min) which, after certain adjustage and correction, can be used for surface strengthening of the faced rolls resulting in increase of the wear resistance of the rolls [3-8].

Additional application of nitrogen hardening of the faced high-speed metal is not recommended as the hardening effect is insignificant as it is shown in the work. Attempts of application of the faced metal for further nitrogen hardening showed that with high-alloyed steels of R18 type we cannot produce layer with the depth over 0.20-0.25 mm and hardness of 1100-1240 HV after nitrogen hardening. That is why introduction of additional hardening technology, such as nitrogen hardening, is inappropriate [9].

For laser-jet facing of the surface layer of metallurgic equipment component we developed low-alloyed flux-cored wire of steel 38HMYuAT type which allows increasing wear and corrosion resistance of the surface layer. Faced and nitrogen hardened components (flattering rolls) showed high wear and corrosion resistance which proves efficiency of complex application of plasma-jet facing with low-alloyed wire with further nitrogen hardening. The reserves for increasing the quality of the components faced by hot-working high hardness steels are included into the process of their exploitation by application further high-temperature tempering [10].

Application of high-temperature tempering in the process of exploitation of faced rolls for cold rolling brings the plastically deformed metal into more stable structural condition and the recrystallizing process removes strain hardness of the base and deposit metal fusion area and restores fatigue resistance of the base metal up to its initial values. Removal of the strain hardness prevents formation of the fatigue failure sites and significantly decreases the possibility of flaking. Thus, the main cause of rolls failure – strain hardness of the transition area – is eliminated and their resistance improves. The aggregate technology flow scheme of working efficiency increase of the faced components at all stages of their production and exploitation is provided in Figure 4.

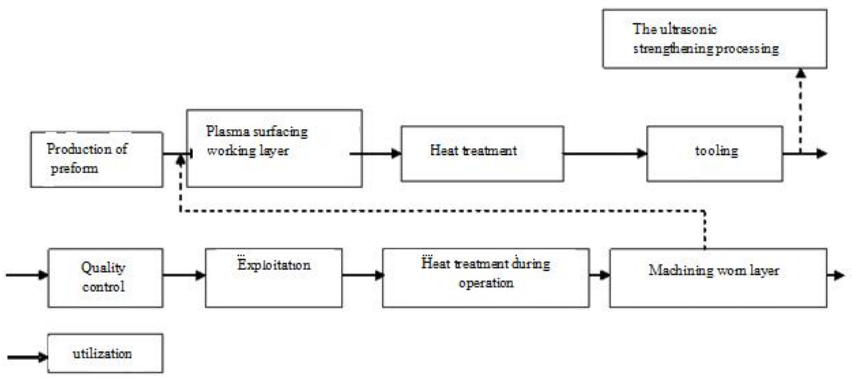

Figure 4. Aggregate technology of working efficiency increase of the faced components

We suggest applying active working layer of the roll by means of plasma-jet facing with high-speed high harness steels. To improve the properties of the faced high-alloy metal and to ensure favorable strained condition we can apply additional high-temperature tempering after the facing. Application of high-temperature tempering in the process of exploitation of the faced rolls results in additional increase of their resistance. In case of roll failure it is possible to complete its reconstructive facing.

Industrial tests showed that the suggested aggregate technology can be successfully used for producing faced metal with high hardness (≥HRC 64) and avoiding cold cracking.

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The developed technology with application of the suggested facing methods, facing materials and other strengthening technologies was used for manufacturing a number of components for mining and metallurgical, mining equipment and agricultural machines.

Conclusion

1. Basing upon the completed research we developed an aggregate technology of manufacturing faced component parts based on the application of plasma-jet facing with non-current-carrying welding powder wires in the shielding and alloying atmosphere of nitrogen.

2. We developed an aggregate technology of faced component parts production which includes the following operations: 1) the basic technology – plasma-jet facing with high-speed steels; 2) additional operations – high-temperature tempering after the facing, ultrasonic hardening surface treatment after the finish-grinding, additional tempering in the process of exploitation, if further exploitation of the worn layer restoring facing is completed.

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