PLASMA SURFACE HARDENING OF WHEELSETS

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EXTENDED ABSTRACT

1.INTRODUCTION

Wear of train wheels and rails has been catastrophically increasing during the last decades. It is the opinion of the experts that there is a real threat of loss in performance of a number of railways or tremendous costs to be incurred for prevention of problems with traffic of trains and maintenance of safe railroad cars.

Wear of wheels and rails is a complex process, depending upon many factors.

The use of volumetric hardening of rails is a factor which has greatly changed conditions of wear of both wheel and rail. It increased hardness of rails 1.5 times, as compared with that of wheels, although, according to the investigation results, it is recommended that both wheels and rails have approximately the same hardness.

Analysis of damage in wheelsets showed that damage in the form of wear in the neck and spalling was predominant.

This work was aimed at development of a technology and equipment for plasma surface hardening to provide an increase in contact-fatigue strength of metal and, as a result, an increase in service life of the wheelsets.

This method of plasma surface hardening is among the cheapest and most efficient methods used at repair enterprises to increase wear resistance of the wheelsets.

Among the methods of heat treatment involving the highly concentrated heat sources, the plasma method has the highest efficiency and capacity. It is characterized by reduced costs, affordability of process equipment and larger dimensions of the hardened zone.

2.METHODS

Computational Modeling of the Plasma Surface Hardening Process. An increase in service characteristics of the hardened parts can be achieved by ensuring the optimal thermal cycle (heating-cooling) on the basis of principles of structural, phase and polymorphic transformations of the component material.

Heating for hardening is performed by the high-enthalpy plasma jet of the products of combustion of a hydrocarbon gas with air. The jet creeps over the surface being heated with an opposing relative displacement speed. The heated zone is cooled immediately after it goes out from the plasma, primarily because of removal of heat into the body of a massive steel part, as well as conductive and radiation removal of heat from the surface into the atmosphere. Heating of each region of the surface occurs with an increasing density of the heat flow, in accordance with variations in the thermal-physical parameters of the plasma with an approach to the jet mouth. In turn, these parameters can be regulated over wide ranges.. A specific feature of such a process is the so-called 'soft' heating at a temperature which increases relatively slowly up to the beginning of austenization of steel. This is the case where parameters of the heating medium and time of interaction, allowing for thermal conductivity of the material, match so that they provide the maximum possible heating through. The 'soft' heating smoothly changes into 'hard', having rapid temperature increase in the surface layer to accomplish austenization, homogenization and dissolution of carbides.

The flow diagram of the process of plasma surface heating for hardening is characterized by high efficiency, equal to 60-80 %, and the match between the rates of growth of the heat flow from the heating medium and the thermal-physical properties of steel.

The problem of investigation of the plasma surface hardening process is reduced to solving the conjugate internal and external heat transfer problems. The internal problem is associated with solving the heat conduction equations. The external problem is related to solving the equation which describes cooling of the plasma flow in contact with the treated surface as a result of losses of heat through the module walls. To solve the internal and external problems in combination, it is necessary to determine the outlet temperature of the plasma. In this work the authors used the method of 'fitting' which consists in the purposeful iteration inspection of the outlet plasma temperature to minimize the mismatch.

The non-linear character of variations in the thermal-physical parameters and the wide range of variations of the metal and plasma temperatures make the analytical solution of the problem impossible.

At the next stage of plasma hardening, i.e., cooling, there occurs decomposition of austenite formed under different temperature conditions. To determine the type of structures formed in the HAZ and, hence, their properties, it is necessary to determine the rates of cooling in each microvolume and then compare them with the continuous cooling transformation curves for decomposition of austenite at a certain concentration of austenite and maximum temperature.

Equipment for Plasma Surface Hardening. Commercial application of the technology for plasma surface hardening of the wheel necks is done using the plasma machine.

It is advisable to harden the wheelsets using an automatic production line. Such a line can be established, requiring no major construction operations, in the gap in the rail track. Here, the entire cycle, beginning with feeding a wheelset, its mounting on a rotator in a noise-proof box, hardening and unloading into a collector is done automatically. The process is monitored and controlled from a control panel.

Plasma surface hardening is a complex multifactorial process. The automatic line prevents operator mistakes.

The process line for hardening the wheelsets requires no extra capital investments for construction operations, can be readily added to the repair lines of car sheds or factories manufacturing the wheelsets and can be used to harden all types of passenger, cargo and motor car wheels.

3.RESULTS

Analysis of dependencies shows that the rates of heating and cooling the surface layer of metal depend primarily upon some localization of heat input into a workpiece.

The important factor at each stage of heating is the ratio of the fuel gas to air in the plasma mixture. A small addition of fuel gas to the plasma air provides a substantial intensification of heating by increasing transmission of heat from the plasma to the surface being heated.

The most important feature of structures formed during plasma hardening, in the case of other methods of treatment using highly concentrated heat sources, is a high degree of dispersion of a material in the hardened zone, which determines the combination of its service properties.

The first hardened zone 0.4-0.8 mm wide, which is difficult to etch, is characterized by a structure of the so-called 'structureless martensite', this being proved by magnification of more than 2000 times. In the second transition zone 0.5-1 mm wide, troostite begins to precipitate along the grain boundaries. Microhardness of the martensite grain is 473 kg mm^{-2}

and that of troostite is 303 kg mm^{-2}. In the third transition zone, 0.6-0.9 mm wide, the amount of troostite grows along the grain boundaries. The fourth zone is the parent metal, the grains of which consist of laminated pearlite with ferrite along the grain boundaries.

Industrial tests were conducted on wheelsets with plasma hardened necks and mass-produced wheelsets (for comparison). In all the cases the intensity of wear of the plasma hardened wheel necks was much lower (2.5-3 times), as compared with the untreated wheels.

Observations showed a change in the character of wear of the plasma hardened necks. They had no spalling in the microvolumes of metal within the zones of contact with the side surface of a rail, and roughness of the surface was much lower. This circumstance suggests more favourable conditions of contact of the plasma hardened wheel with the rail.

4.DISCUSSIONS

The authors used a prolonged heating for hardening with the jet of the plasma of the hydrocarbon gas-air combustion products. In this case the duration of heating is increased from 0.9-1.2 s (typical process of plasma hardening) to 10-20 s and the duration of cooling is increased from 1.5-1.8 s to 6-10 s. This provides an increase in the efficiency of heating from 40-50 % to 60-80 %, in the depth of hardening of steel - from 0.5-1 mm to 2.5-3.5 mm and in the hardening mirror width - from 8-10 mm to 25-35 mm.

Because of specific operation and damage of the wheels, when specifying the optimal conditions for their hardening, one of the basic criteria, along with an increase in their wear resistance, should be resistance to initiation and propagation of cracks. Therefore, extra technological measures should be taken to improve crack resistance of the plasma hardened parts operating under conditions of intensive dynamic loads.

Crack resistance can be improved by:

- increasing the degree of dispersion of the hardened zone material;
- providing a ‘soft’ tempering zone with a large transition zone structure between the hardened zone and the untreated parent metal;
- decreasing tensile stresses at the boundary of the hardened zone.

5.CONCLUSIONS

(1) The process was developed and the specialized equipment was manufactured for plasma surface hardening of wheelsets, using non-deficit plasma-forming environments.

(2) The equipment provides a hardened layer depth of 2-3 mm and a hardened path width of 25-35 mm at a hardening rate of 1.5-2 cm s^{-1}.

(3) Hardness of the treated layer can be regulated within wide ranges (300-700 HB). The layer has a finely dispersed structure.

(4) The equipment is characterized by new capabilities for increasing the contact-fatigue strength of metal and, hence, improving the reliability and increasing the service life of the wheelsets.

(5) Intensity of wear of the plasma hardened wheel necks is much lower than that of the mass-produced ones (2.5-3 times).