CHROMIUM PLATING OF STEEL IN VACUUM, USING HIGH FREQUENCY INDUCTION HEATING

(UDC 621.785.53:621.785.545.45)

G. V. Zemskov and L. K. Gushchin

Odessa Polytechnical Institute
Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 10, pp. 26-28, October, 1965

We investigated chromium plating of steel heated in vacuum by high frequency induction. The chromium plating mixture was low carbon ferrochromium. We used steel No. 10 and steel U8 in our experiments.

The current source was the GL-15M 8.5 kW tube generator, the frequency being 575-715 kHz. The diagram of the apparatus for chromium plating in vacuum is shown in Fig. 1.

The samples were 10-20 mm long and 10 mm in diameter. Their temperature was kept constant at 1000-1200°C ±10°. The temperature was measured with a thermocouple electrically soldered to the surface of the sample (the diameter of the wire was 0.2 mm). The temperature was kept constant by changing the induction circuit of the anode connected to the control voltage of the generator tube. A filter consisting of an inductance and a shunting capacitance was connected in the circuit to protect the galvanometer from the induced current.

During thermodiffusional saturation of the sample the material of the thermocouple is also saturated and, as the result, its thermo-emf changes. We investigated the variation of the thermo-emf at different temperatures and heating times. The proper corrections of the temperature indications were made during the experiment.

The steel was subjected to diffusional saturation in a mixture consisting of 50% ferrochromium and 50% fire clay; the pressure in the chamber was $1 \cdot 10^{-3}$ mm Hg. We also used a mixture consisting of 50% ferrochromium, 48% fire clay, and 2% NH_4Cl. When this latter mixture was used, the vacuum pump was disconnected after a pressure of $1 \cdot 10^{-3}$ mm Hg was reached and the metal was heated. Since ammonium chloride undergoes decomposition, the pressure in the working chamber increases to 10-50 mm Hg.

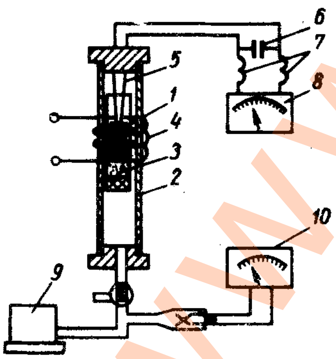

Fig. 1. Diagram of the apparatus for chromium plating in vacuum with high frequency induction heating. 1) Sample; 2) quartz cylinder; 3) vessel with the saturating mixture; 4) inductor; 5) thermocouple; 6) capacitance; 7) inductance; 8) galvanometer; 9) vacuum pump; 10) vacuum meter.

Figures 2 and 3 show the dependence of the thickness of the chromium layer on the time and temperature of the process in the case of saturation in vacuum. The rate of the process is greatest at the beginning and then decreases gradually. The curve is parabolic. The thickness of the layer increases with increasing temperature, particularly at 1200°C and above.

The thickness of the diffusion layer is much greater in the case of the mixture containing ammonium chloride (Fig. 4). Apparently, the rate of the reaction is accelerated as the result of ionization of gases and vapor, and the flow of ions of the saturating components improves as the result of "electron wind."

To check this assumption, we saturated a steel cylinder closed with a cover. The mixture of ferrochromium and fire clay was poured inside and outside the cylinder. Thermocouples were soldered to the inner and outer surfaces of the wall (which was 1.5 mm thick). After a short heating time the temperature of the wall was the same throughout. After 30 min the chromium layer on the outer surface of the wall was almost twice as thick as that on the inner surface of the wall. Thus,

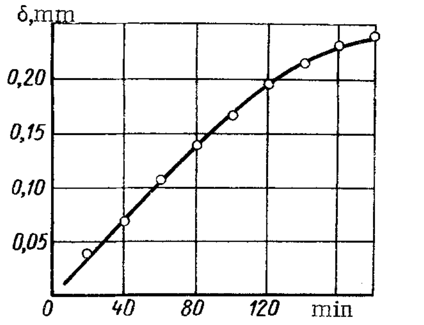

Fig. 2. Dependence of the thickness of the chromium layer on the duration of the saturation of steel No. 10 at 1000°C in vacuum in a mixture of 50% ferrochromium + 50% fire clay.

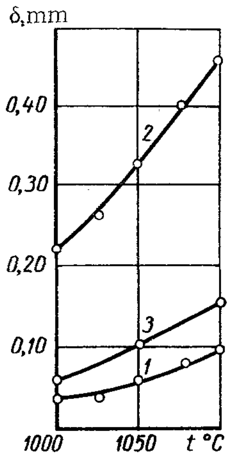

Fig. 4. Thickness of the chromium layer on steel No. 10 produced by different methods of saturation. 1) High frequency induction heating in vacuum in a mixture of 50% ferrochromium + 50% fire clay for 30 min; 2) heating by high frequency induction and disconnecting the vacuum pump during heating in a mixture of 50% ferrochromium + 48% fire clay + 2% NH_4Cl for 30 min; 3) heated in the furnace in a hermetically sealed container in a mixture of 50% ferrochromium + 48% fire clay + 2% NH_4 for 6 h.

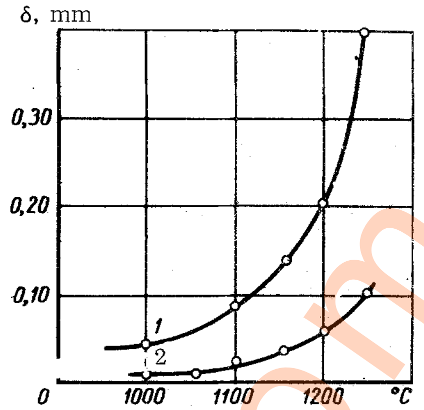

Fig. 3. Dependence of the thickness of the chromium layer on the saturation temperature (mixture of 50% ferrochromium + 50% fire clay, 30 min saturation). 1) Steel No. 10; 2) U8.

the saturation process is less active on the inner surface of the cylinder in spite of the fact that the temperature was the same. This can be explained by the fact that the wall and the cover of the cylinder play the role of screens of the inner surface and weaken the electromagnetic field and, consequently, the ionization and the "electron wind" inside the cylinder.

CONCLUSIONS

1. Heating by high frequency induction accelerates the formation of the coating in mixtures of powders and ammonium chloride in vacuum.

2. The process is accelerated as the result of ionization of gases and metal vapors in the working area and acceleration of surface reactions.

The formation of the "electron wind" in the alternating magnetic field apparently favors the supply of fresh portions of the reagent to the surface of the metal and the removal of the reaction products.