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Using the coating for the diffusion layer OBTAINING on the walls of the mold (CCM)

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Abstract
The paper carried out researches of ways of stability increasing of the narrow walls of the mold continuous casting machines (CCM). To increase the lifetime of molds on their caster worked narrow walls of copper M1 and copper alloy MN2,5KoKrH the diffusion layers coated with alumina were created and followed by heat treatment. Thickness and microhardness are used as main working capacity indicators of diffusion layer. Covering of narrow working walls in the mold with aluminum thermal coatings is recommended. Then it should be followed by heat treatment in the protective environment of the adjusted modes. Testing of the mold in the continuous casting machine with the assessment of the walls state during operation and changing the quality of the cast metal are carried out.
Keywords: NARROW WALL, MOLD CCM, THERMAL COATING, HEAT TREATMENT, DIFFUSION LAYER

Relevance of the work

Many details of metallurgical equipment (molds, converter and blast furnace tuyere etc) are made of copper and its alloys which have high electrical and thermal conductivity [1]. At the same time copper has a low heat resistance and wear resistance [2]. Experiments have shown that copper oxides do not resist thermal shock. They are destroyed after the first thermal cycling and exfoliate when tested on friction.

Thermal diffusion saturation of the surface by alloying elements is one way to improve the operational properties of products made of copper [3]. Aluminum is one of the key elements used to saturate. Alitizing may be carried out, for example, by saturation of the powder mixture consisting 50% of aluminum powder, 49 % of Al_2O_3 and 1 % of NH_4Cl [4].

Examination [5] of copper grade M1 with the coating on oxidation at 850 ° C in air have shown that the thermal diffusion alitizing is promising copper protecting method from oxidation. Alitized samples are oxidizing more slowly and stabilization process comes quickly; apparently, their oxidation occurs on a logarithmic dependence. Samples of alitized copper after oxidation have dense and durable oxide layer which does not flake under thermal cycling.

As for wear resistance in the alitized copper samples it increases by 1.3 times [6].

However, the method of diffusion saturation in powder mixtures is a relatively laborious and has a low productivity. Currently, a method of thermal spraying of coatings with subsequent heat treatment is used for the diffusion layers on the details of metallurgical equipment [7]. Standard equipment for the spraying of such coatings is relatively compact and cheap, coating parts are not limited in dimensions, the local spraying and one-sided coatings are possible [8, 9]. The technological process of spraying allows obtaining the desired performance of the coating and which is characterized by relatively low labor content [10].

A diffusion layer is formed as a result of thermal spraying of coatings on copper and its alloys with the subsequent heat treatment [11]. It has heat resistance and wear resistance not inferior to those obtained using the method of diffusion saturation from powders essential for increasing the life of the metallurgical equipment.

Work objective

To improve the quality of the cast metal by coating of aluminum thermal spraying on the working surface of the narrow walls, continuous casting machines molds.

Materials and research results

Currently, the number of plants as materials for the manufacture of the mold walls(CCM)we use copper grade M1, as well as copper-nickel alloy MN2, 5KoKrH. Therefore, for studies we have used spent narrow mold walls of these materials.

When working the diffusion layers war creating on the surface of copper and copper alloy M1 MN2, 5KoKrH spraying of aluminum about 1.5 mm thick with the subsequent diffusion annealing at t = 800 ° C for 10 hours in an oxidizing atmosphere.

It was determined that the copper M1 surface strenthening diffusion layer with thickness up to 1.5 mm is observed, and in the alloy MN2,5KoKrH is 0.6-1.4 mm, which is explained by restraint of diffusion process contained therein alloying elements. In any case, the thickness of the diffusion layer is not greater than the thickness of the sprayed coating.

To clarify the reasons for reducing the thickness of the diffusion layer on the alloy MN2,5KoKrH metallographic and electron microprobe analysis were conducted. The coating was sprayed to the wall from alloy MN2,5KoKrH and microhardness of diffusion layer was measured on the microhardness tester PMT-3 (Table. 1).

The microstructure of diffusion layer consists of a eutectoid (α + γ2) and α-phase and γ_2-phase precipitates along the grain boundaries. Several zones can be distinguished in the structure of layer:

- In the surface zone gray grains are observed on the background of eutectoid γ_2-phase;
- The middle area consists of light α- phase grains and the dark eutectoid fields ($\alpha + \gamma_2$) of different dispersion degree (Fig. 1);
- A zone adjacent to the separation line metal-layer is light α-phase grains.

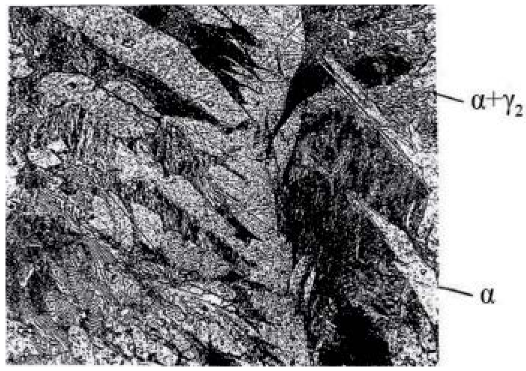

Figure 1. The microstructure of diffusion layer (sample No 1), × 500

The surface layer of the researched samples is characterized by pore depth of 0.1 to 0.4 mm.

The phase composition of diffusion layer, the distribution of Al and other elements in the zone adjacent to the separation line metal-layer was determined by microprobe analysis using the device «Camebax». Results are shown in Table. 2.

It is known that the service life of the diffusion layer produced on copper details of the metallurgical equipment is determined primarily by its thickness.

Increasing the thickness of sprayed coating, temperature and heat treatment time usually leads to an enlarging in thickness of the diffusion layer. However, increasing the thickness of sprayed coating is ac-

Table 1. Microhardness of diffusion layer

No treat.	Coating content	Microhardness, kg / mm^2			
		Diffusion layer surface	Diffusion layer middle	Boundary layer - metal	Main metal
1	Al	367	272	190	110

Table 2. The results of microprobe analysis of diffusion layer

No treat.	Coating composition	Content of chemical components, %									
		phase near the surface of diffusion layer			phase in the middle of diffusion layer				phase near the boundary of metal-layer		
		Al	Ni	Cr	Al	Ni	Cr	Si	Al	Ni	Si
1	Al	18.1-22.3	1.5-1.6	0	14.0-14.8	3.5-4.1	0	0.1-0.3	11.5-11.8	4.0-4.2	0.8-1.7

companied by decrease in its adhesion, and increase of heat treatment temperature is followed by an intense oxidation of coated and uncoated parts of the copper base. In this regard, to increase the thickness of the diffusion layer of diffusion annealing of copper coatings was performed in the shielding atmosphere (95 % N_2, 5 % H_2 or H_2) at temperatures 800-900 ° C for 10 hours.

The samples from aluminum-coated copper M1 were investigated in the work. Specimens designation are No 1 without the diffusion annealing, the others after the diffusion annealing (Table. 3).

The main results of the researching coated samples are shown in Table. 3.

Table 3. Influence of the thickness of the aluminum coating, heat treatment conditions and shielding atmosphere on the thickness and microhardness of diffusion layer

No	h_c, mm	t, °C / τ, h	Medium	$H_{D.L.}$, mm	Microhardness, H_μ, MPa
1	1.1-1.5	–	–	–	310
2	1.0	800/10	95 % N_2 5 % H_2	0.7-0.9	1650-3010
3	1.5	850/10	H_2	3.8-4.0	1490-3880
4	1.0	900/10	95 % N_2 5 % H_2	2.3-2.4	1180-2100
5	1.0	900/10	H_2	2.6-3.0	1420-1510
6	1.5	900/10	H_2	3.3-4.0	1350-2750
7	2.5	900/10	95 % N_2 5 % H_2	4.0-4.6	1140-3330

Then on the surface of the two pairs of decommissioned narrow walls of the mold was coated with an aluminum thermal spray coating about 2.0 mm thick.

One pair passed the heat treatment in a shielding atmosphere (95 % N_2, 5 % H_2) at 800 °C for 10 hours and the other in the shielding (H_2) at 900 °C for 10 hours (Fig. 2).

As a result of samples investigation from the first wall pair thickness of the diffusion layer was 0.9-1.2 mm and the microhardness was equal to 1650-3250 MPa. However, such thickness is insufficient for the

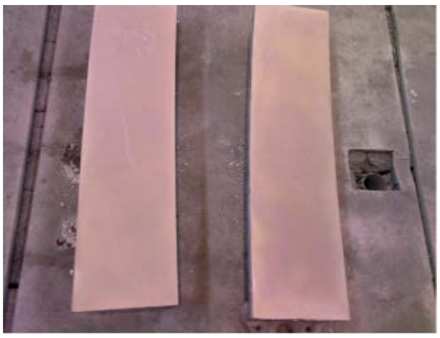

Figure 2. The walls of the mold after the heat treatment in a shielding atmosphere (H_2) at 900 ° C for 10 hours

mechanical surface treatment by coating of the walls and obtaining residuals thicknesses providing substantial increase of their life service.

Inspection of the second pair of walls has shown that their heat treatment in shielding atmosphere at a temperature of 900 ° C and a holding time of 10 h leads to distortion as a result of this process, which is not removed by mechanical means.

Conclusion

The results of research of resistance increasing of narrow walls of the mold CCM allow us to conclude following:

- there are conditions of heat treatment that ensure obtaining of the diffusion layer on the surface of the copper samples without pitting and washing with greater than 4.0 mm thick and high hardness;
- increasing the thickness of the sprayed coating and the heat treatment temperature usually lead to an increase in thickness of the diffusion layer;
- changing the shielding atmosphere from 95 % N_2 + 5 % H_2 to 100 % H_2 does not affect the thickness of the diffusion layer;
- the maximum thickness of the diffusion layer $h_{D.L.}$ = 4,0-4,6 mm is reached at t = 900 °C and h_C = 2,5 mm;
- microhardness of the diffusion layer in 2-6 times greater than copper microhardness. It is 1140-3880 MPa against 460-590 MPa in copper-based;
- it is necessary to spray on the narrow working mold walls of aluminum thermal coatings with following heat treatment in the shielding atmosphere of the adjusted modes and test the mold CCM with the assessment of the state of the walls during operation and changing of quality of the cast metal.

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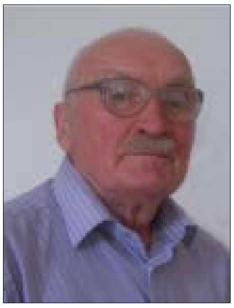
New means for determination of metal and its alloys hardness according to Kotrechko method



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Abstract
New means for determination of metal and its alloys hardness with isotropic and anisotropic behavior are developed. Indenter design, which provides transfer from elastic to plastic deformations when the value of work hardening is smaller, is suggested for isotropic metals. Indenter construction for anisotropic metals allows to determine the hardness taking into account grain flow. Hardness values of isotropic and anisotropic metals and alloys, determined according to Kotrechko method, are more precise as compared with the known ones.
Key words: METAL HARDNESS, ISOTROPY, ANISOTROPY, INDENTER, PLASTIC DEFORMATION