CHEMICAL HEAT TREATMENTS FOR MOLD LINERS

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The outside surface of tubular refractory products is formed by the mold liners. The liners wear rapidly as a result of attrition by the particles of the refractory mix during molding and when the molded product is extracted from the mold.

At refractories plants, these liners are machined from low-carbon structural steel grades 20, 20Kh, 15KhM, etc. (GOST 4543-61) followed by carburizing and quenching. The useful life of these liners is only a few shifts (70h).

An increase in the durability of mold liners is one of the pressing problems in the refractories industry. The frequent downtime of presses for the purpose of replacing worn components reduce labor productivity and output, increase the cost price of the refractories, and adds to the difficulties of mechanizing and automating the production processes.

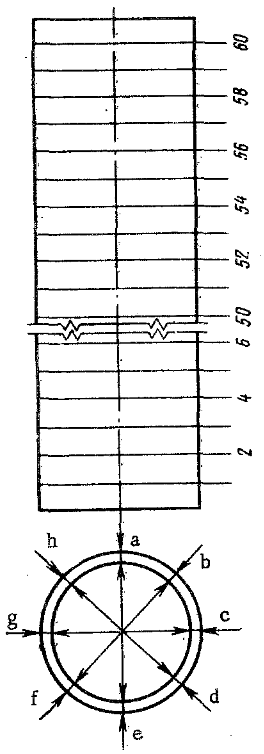

Fig. 1. The points of measurement (1-60) of the absolute wear of the liners (a-h are the generators).

An investigation was carried out at the Zaporozh'e Refractories Plant of the wear resistance of an experimental batch of liners 485-575 mm in length with a wall thickness of 5-6 mm. The liners were used for molding Sp-8 and Sp-3 stopper tubes.

The experimental liners were produced from thick-wall tubing of steel grade 15KhM. After machining, viz., turning and grinding, the liners were subjected to cementation in a solid carburizer and then to quenching.

The absolute linear wear (h, mm) of the liners was determined after the tests by measuring the wall thickness at intervals of 10 mm along eight generators (Fig. 1) with the device shown in Fig. 2. The liner 1 is placed on

TABLE 1. The Properties of the Experimental Liners After the Chemical Heat Treatment

Chemical heat-treatment schedule	Carburizing conditions		Quenching temp., °C	Hardness of working surface HRC	Rel. wear resistance ε
	temp., °C	time, h			
I	920	16	820	63	1
II	1080	7	1080*	36	0,82
III	960	12	960*	52	1,57
IV	960	12	960	60	1,19

*Quenching from the carburizing temperature.

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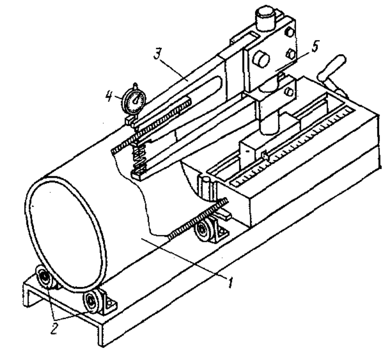

Fig. 2. Device for measuring the liner wear.

supports 2 inside a rigid bracket 3 between the probe 4 of the indicator and the lower support of the bracket which is pressed continuously to the inside (worn) surface of the liner. The bracket can be rotated in the vertical plane in its holder 5 and is moved along the liner generator with a screw-and-nut transmission.

The measurements of the liners tested on a press showed (Fig. 3) that surface wear is at maximum in the area where the top and bottom edges of the product are formed, i.e., on the level of the edges of the rams at the end of the forming process.

Maximum wear in these areas did not exceed 0.95 mm owing to the permitted variation of the diameter of the molded product to facilitate its extraction.

On the SM-143 press, the wear of the liner in the zone where the top edge of the molding is formed was lower than in the zone of the bottom edge (see Fig. 3) as a result of the difference in the molding actions of the top and bottom rams.

The wear resistance of the liners was expressed in terms of the maximum absolute wear in the zone of the bottom edge of the molded product.

The level of the wear resistance was determined from the specific wear Δh, i.e., the attenuation of the wall in microns during the molding of one product. Reliable results were obtained by determining the specific wear as the mean of a batch of four liners.

The experimental liners were tested in comparison with industrial types produced by the technology employed at the plant. The relative wear resistance ε was determined from the equation

$$\varepsilon = \frac{\Delta h_{\mathrm{pl}}}{\Delta h_{\mathrm{ex}}},$$

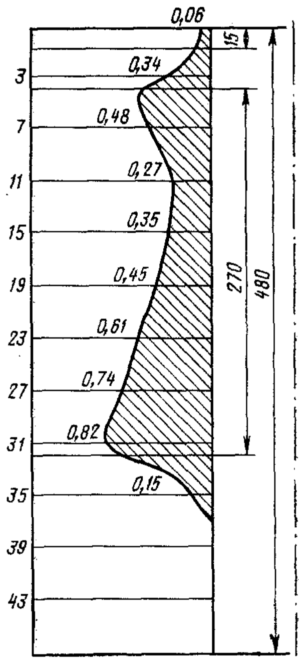

Fig. 3

Fig. 4

Fig. 3. The pattern (shaded area) and magnitude (in mm) of the wear of Sp-8 liners at the Zaporozh'e Refractories Plant (SM-143 press).

Fig. 4. The structure of the working layer of liners heat-treated by the schedule employed at the Zaporozh'e Refractories Plant. ×100.

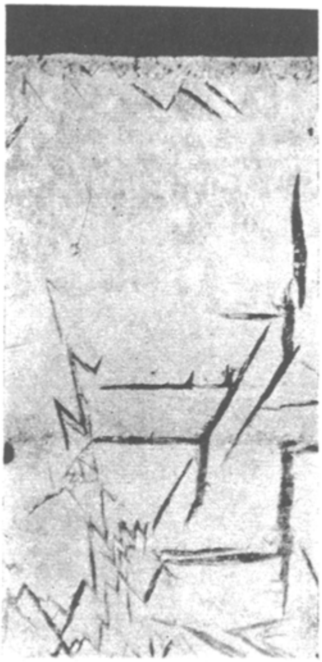

Fig. 5. The structure of the working layer of liners heat-treated by the schedule employed at the Borovich Refractories Combine. ×100.

where Δh_{pl} is the average specific wear of liners produced by the technology employed at the plant; Δh_{ex} is the average specific wear of the experimental liners.

There is no standardized method of producing mold liners in the refractories industry so that the structure of the carburized layer of the liner varies from plant to plant. The worn zone of liners made at the Borovich Refractories Combine consists mainly of remanent austenite and a small proportion (10-12%) martensite. The base of the working layer of liners made at the Zaporozh'e Plant is almost wholly martensitic. The carburized layer of the liners made by other factories contain varying proportions of martensite and austenite.

When only the outside (working) layer of the liner is carburized, a high degree of deformation (ellipticity) is inevitable and forms one of the principal causes of lining fracture in the pressing-in operation. The quality of the asbestos packing between the outside surface of the liner and the container is often unsatisfactory so that this surface of the liner is subjected to partial (sometimes local) cementation and the liner is deformed in the quenching process.

The degree of deformation is within permitted limits when the liner is carburized on both sides which gives a more evenly carburized layer.

The experimental liners were heat-treated by four different schedules which produced dissimilar structures in the working part of the carburized layer.

Schedule I gives the chemical heat treatment employed at the Zaporozh'e Plant which gives a martensite—carbide structure in the working part of the carburized layer. The liners were carburized for 16 h at 920°C and quenched in water after reheating to 800-820°C. The residual stresses were relieved by annealing for 2 h at 150°C. The structure of the carburized layer is shown in Fig. 4. The hardness of the working surface was 62-64 HRC.

Schedule II is the schedule employed at the Borovich Refractories Combine. The liners were carburized for 7 h at 1080°C and quenched in water from that temperature. This gave a structure which consisted mainly of residual austenite and a small proportion of large martensite needles (Fig. 5). The hardness of the working layer was 35-38 HRC.

Schedule III, is intermediate between schedules I and II and gives a carburized layer containing 50-60% residual austenite. The liners were carburized for 12 h at 960-980°C and quenched in water from the carburizing temperature. The hardness of the liners after this treatment was 47-54 HRC.

Schedule IV made it possible to determine the difference in the wear resistance of liners quenched from the carburizing temperature and after reheating to that temperature. Quenching after reheating is called for in cases were a large liner embedded tightly in the carburizing box cannot be quickly extracted after the carburizing process. The carburizing temperature and time are the same as in schedule III. The liners are air-cooled to room temperature and then quenched in water after reheating at 960-980°C. The hardness of the liner surface is 59-61 HRC.

Production trials with batches of liners produced experimentally under industrial conditions showed that the wear resistance depends directly on the structure of the carburized layer, more particularly on the percent residual austenite.

Thus the liners heat-treated by schedule III (Table 1) exhibited the best resistance to wear. The structure of an alloy containing 60-70% residual austenite (with martensite as the remainder) appears to be near-optimal for the service conditions of mold liners.

In contrast to schedule III, heat-treatment schedule IV gives a surface hardness of 60 HRC although the quenching temperature was again 960°C. The explanation lies in the fact that the holding time in reheating at 960°C was very short compared with the holding time in schedule III so that less carbides were dissolved in the austenite, the result being that the percent austenite after quenching was lower and the surface hardness greater [1]. The holding time in the reheating process cannot be extended owing to the rapid oxidation of the working layer and the consequent decrease in the wear resistance.

The high proportion of residual austenite after the treatment by schedule II (see Table 1) gives a much lower wear resistance ($\varepsilon = 0.82$), and the resistance is low also when the structure contains no residual austenite (schedule I).

It follows that the best chemical heat treatment schedule for mold liners of 20Kh grade steel consists of carburizing at 960°C and quenching in water from that temperature which gives a 60/40 ratio of austenite and martensite in the structure. The wear resistance of these liners is at maximum (i.e., 1.5 times higher than at the Zaporozh'e Refractories Plant and 1.9 times higher than at the Borovich Refractories Combine), and their low hardness renders them immune to destruction by fracture.

The sources of the greater wear resistance of an austenite—martensite structure compared with all-martensite or predominantly austenitic structures were elucidated elsewhere [2] and lie in the structural conversions, development of new phases, and even redistribution of high-density zones throughout the working layer of the liner in service.

The possibilities for steel grade 20Kh subjected to a chemical heat treatment by this schedule can be considered exhausted, and if the durability of liners is to be increased still further, they will have to be fabricated from a material with a still greater resistance to wear.

CONCLUSIONS

Cementation in a solid carburizer for 12 h at 960°C followed by direct quenching in water from the carburizing temperature represents best the chemical heat treatment schedule for mold liners of steel grade 20Kh and gives a reliable combination of high water resistance and adequate plasticity.

LITERATURE CITED

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