Treatments 5 and 9 can be used when water or a water–air mixture is used as the quenchant. In this case the necessary heat flow or heat-exchange coefficient can be expressed by the input characteristics of the quenchant, using the data from [1, 2].

Thus, the method proposed makes it possible to analyze different variations in order to select the optimal cooling parameters and hold experimental work on parts to a minimum. Data on the temperature distribution through the section of a part make it possible to calculate thermal stresses if necessary. The most suitable treatments of those tested were 5 and 9.

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LASER HARDENING OF FERRITIC MALLEABLE IRON

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UDC 621.787:621.3.038.8

We present results from a study of the structure and properties of ferritic malleable iron KCh 35-10 after laser treatment. Laser hardening without impairing the surface finish (i.e., melting) is a very promising treatment, although it is difficult to achieve. This is due to the change in the coefficient of absorption of laser radiation, which varies with several factors that are difficult to determine, leading to inconsistent results. To increase the coefficient of absorption approximately twice and ensure repeatable results, the samples were phosphatized in the Mazhef or KPF-1 compounds. An even black surface was obtained. The optimal treatment of KCh 35-10 malleable iron was determined from the variation of the microhardness of structural components and the depth of hardening with the power density of laser radiation. The highest microhardness without melting was achieved with the following parameters: continuous CO_2 gas laser ($\lambda = 10.6\ \mu m$) in multimode operation with power density $q = 7.5 \cdot 10^3\ W/cm^2$; neodymium glass solid-state laser ($\lambda = 1.06\ \mu m$) in free operation, pulse duration $\tau = (5\text{-}6) \cdot 10^{-3}$ sec, energy density 270 J/cm^2.

Metallographic analysis was conducted with the Neophot microscope and x-ray analysis in the URS-50IM diffractometer with use of Fe K_α radiation.

The microstructure of the malleable iron was revealed by successive etching in solutions of picric and nitric acids. The original microstructure consisted of ferrite with flaky graphite; the microhardness was $H_{20} = 150$. After the laser treatment there were decided changes in the microstructure (Fig. 1): The ferrite grains were refined and distorted (Fig. 1a) due to the high rate of heating and cooling; light fields that are only slightly etched are visible around graphite, which occur during cooling at the point of contact between ferrite and graphite. The possibility of ferrite melting at points of contact with graphite was reported in [1, 2]. In regions melted in the course of the treatment one can distinguish two sections – a darker section along the periphery with a distinct dendritic structure and a lighter section bordering the graphite. X-ray analysis showed that high-carbon phase in the form of large dendrites of austenite is formed in the periphery in the direction of heat removal, while an austenite–cementite mixture is formed near the nucleus. The dendrites of austenite are mostly perpendicular to the surface of the sample after treatment with the gas laser and parallel to the surface after treatment with the solid-state laser.

After treatment with the gas laser the microhardness of the ferrite rises to $H_{20} = 220$. The increase in the hardness of ferrite is evidently due to a large number of defects, the distortion of the fine structure, and stresses. The cooling rate during treatment with the solid-state laser is larger than with the gas laser, and therefore the hardness of the ferrite after the treatment increases much more ($H_{20} = 250$).

The hardness of the austenite reaches $H_{20} = 470$ and $H_{20} = 670$, respectively, after treatment with the gas and solid-state lasers, while the hardness of the austenite–cementite mixture is the same in both cases – $H_{20} = 960$.

AZLK. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 4, pp. 16-18, April, 1980.

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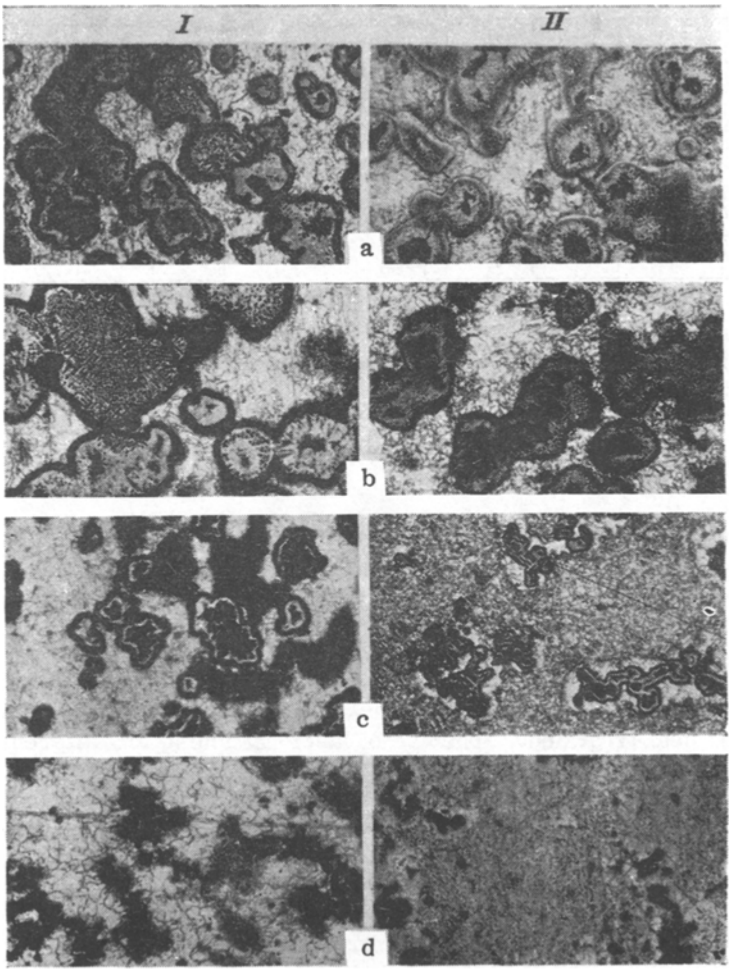

Fig. 1. Microstructure of KCh 35-10 malleable iron after treatment with gas (I) and solid-state (II) lasers and tempering at different temperatures (200 ×). a) 0°; b) 300°; c) 500°; d) 600°.

Layer-by-layer metallographic analysis of the malleable iron treated with the solid-state laser revealed no further traces of the treatment at a depth of 40 μm — ferrite refining and melting around graphite. After treatment with the gas laser a zone affected by heat was observed to a depth of ~ 90 μm, although the elevated hardness extended to a larger depth (Fig. 2). The higher hardness of the ferrite beyond the limits of visible changes due to the treatment evidently indicates waves of deformation at the boundary of the heated and the cold zones [1]. After treatment with the solid-state laser the zone affected by heat is smaller than after treatment with the gas laser, although the total depth of the zone with high ferrite hardness is the same in both cases.

After the laser treatments the samples were tempered 1 h at temperatures up to 600° (100° intervals). With increasing tempering temperatures there are noticeable changes in the microstructure due to decomposition of austenite to a ferrite—graphite mixture and diffusion of carbon to graphite (Fig. 1). Tempering at 500° leads to complete decomposition of austenite and also to some grain growth of the ferrite matrix (Fig. 1c). With tempering at 600° the structure is close to the original structure (Fig. 1I, d). It should be noted that decomposition of austenite and diffusion of carbon to graphite occur at lower temperatures in the malleable iron treated with the solid-state laser (Fig. 1II, b-d).

Raising the tempering temperature leads to a monotonic reduction of the hardness of the ferrite matrix, which is equal to the original hardness after tempering at 600°. The variation of the hardness of austenite with tempering temperature is complex in character (Fig. 3). At 100° the hardness decreases, especially after irradiation with the solid-state laser (ΔH_{50} = 80). This reduction of the hardness is probably due to partial stress relaxation. The subsequent increase in hardness is evidently due to decomposition of austenite to a ferrite—cementite mixture.

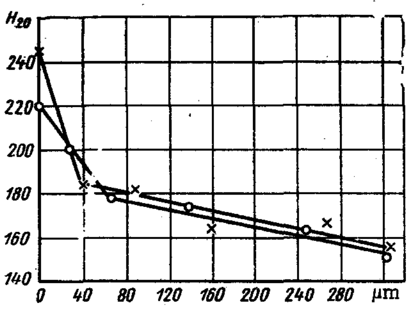

Fig. 2

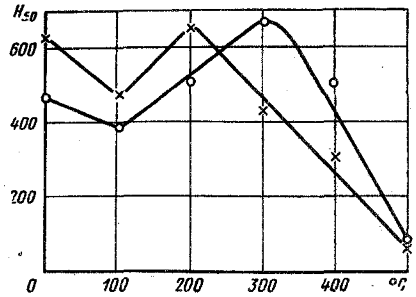

Fig. 3

Fig. 2. Change in the hardness of ferrite through the depth of the affected zone after treatment with solid-state (×) and gas (○) lasers.

Fig. 3. Hardness of austenite in relation to tempering temperature. ×) Solid-state laser; ○) gas laser.

As analysis of the x-ray patterns showed, the austenite contains ~2% C. The austenite, supersaturated with carbon, is unstable and, as was shown in [3], may decompose to a ferrite–graphite mixture with intermediate stages of decomposition to ferrite and martensite.

CONCLUSIONS

To harden the surface of parts made of KCh 35-10 malleable iron operating at temperatures up to 300° one can recommend laser heat treatment. The use of laser hardening for differential gears at AZLK has produced savings of 303,000 rubles.

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HEATING OF WIRE OF REFRACTORY METALS BY MEANS OF INFRARED RADIATION

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UDC 621.78:061:621.535-15

For treatment by pressing (drawing, flattening, rolling) refractory metals and alloys are first heated to high temperatures in a protective atmosphere or in vacuum [1]. Heating is carried out mainly with heaters of the resistance and induction types, which are cumbersome, sluggish, complex, and time-consuming in maintenance and regulation of the heating conditions [2].

We have developed an apparatus – the IR heater – for rapid heating of wire by means of an infrared radiant beam that permits heating in any medium (including vacuum). The IR heater ensures sterility with regard to contamination from the source of radiation, has low inertia, is simple, with high efficiency, easily automated, and easily mounted in production or automatic lines, making it possible to increase production substantially as well as quality.

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Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 4, pp. 18-19, April, 1980.

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