this rate with specified values of the allowance for wear were determined (Fig. 5b). It was established (Fig. 5b) that the longest service life of the hardened case is obtained with $v_{opt} \simeq 0.7$ m/min if the allowance for wear $\Delta \geq 0.3$ mm. With $\Delta < 0.3$ mm the optimum rate of movement of the heating zone increases.

Microplasma hardening under the optimum conditions made it possible to harden a number of automobile, tractor, and petroleum equipment parts. As an example Fig. 6 shows a hardened steering ball journal of a group of automobiles of Minsk Automobile Plant. Microplasma hardening of its spherical working surface made it possible to significantly increase the service life of parts of this class.

The expected annual saving from the introduction of microplasma hardening is about 500,000 rubles.

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LOCAL DIFFUSION MICROWELDING IN LASER ACTION ON STEEL

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UDC 621.9.048:621.791.72

It has been established [1-3] that in laser radiation of steel diffusion interaction occurs between the nonmetallic inclusions and the steel matrix including exchange by atoms of the elements in them through the interphase boundaries. As the result the matrix close to the inclusions is impregnated with the components of the inclusions, which leads to local hardening of it, and atoms of the components of the matrix penetrate into the thin surface layer of the inclusions. The specific conditions of laser radiation (high pulse energy, short time of action, high heating and cooling rates) provided the conditions for fusion of refractory and melting of low-melting inclusions. The diffusion processes occurring through the inclusion—matrix boundaries are eased with heating to high temperatures and the appearance of a large quantity of defects of the crystalline structure and plastic slips [4]. The components of the inclusions penetrating into the matrix are held in it in subsequent sharp cooling and form supersaturated solid solutions [1-3]. The purpose of this work was an investigation of the processes of interaction of the inclusions and the matrix in laser action, their mechanical interaction in plastic deformation, and the mechanism of formation of microfractures in the steel.

Dnepropetrovsk Metallurgical Institute. Translated from Metallovedenie i Termicheskaya Obrabotka Metallov, No. 5, pp. 13-15, May, 1988.

0026-0673/88/0506-0331$12.50

The investigation was made on flat specimens of ShKh15, NB-57, R6M5, 08kp, 08Yu, 08T, 08Kh, and 12GS steels. Such a selection of steels made it possible to obtain a large quantity of objects of investigation of inclusions of various types located in the matrix of steels with different structures. The surface of the specimens was polished and reference points with a spacing of 10 μm were applied on a PMT-3 hardness tester with a load of 0.005 N for observation of specific inclusions and determination of the degree of deformation of the steel. Deformation distribution curves were drawn on the basis of the investigation results [5]. The variation coefficient K characterizing the level of spread of the values of microdeformations was 0.42. The mean-square error in determination of the degree of deformation of the individual microintervals (distances between the reference points) σ_ε, 0.0021, was determined with a fiducial proability of 0.95.

The inclusions were identified by metallographic and petrographic methods. The surface of the specimens was irradiated on Kvant-16 machine. The pulse energy was 10.5 J, the time of action $4 \cdot 10^{-3}$ sec, and the density of radiation power $4 \cdot 10^4$ kW/cm^2. The specimens were placed in tension on an IMASh-5S—65 machine at 20°C with a rate of movement of the clamps of 1680 mm/h. The size of the nonmetallic inclusions and of the microfractures close to them were determined using the earlier developed method [6-11]. Six specimens were tested for each steel and on each of them 12-38 inclusions were investigated depending upon the character of nonmetallic inclusion content of the steel. The inclusions of each type were divided into dimensional groups within which the results were averaged. The inclusions located outside the zone of laser action but within the spots of radiation were investigated if defects of thermal origin were not formed at the inclusions [12]. The size of the spots of radiation was 3.8 mm and the maximum size of the inclusions 30-38 μm.

Since nonmetallic inclusions are stress raisers localization of deformation leading to the occurrence of microfractures was observed in the matrix close to inclusions of all types. For many inclusions the formation of voids (ductile cracks) by separation along inclusion—matrix interphase boundaries was characteristic [6]. In earlier conducted investigations it was shown that the voids occur close to oxides in 08Yu [7], 08kp, and 08Kh steels, to sulfides and sulfide eutectics in NB-57 [8], ShKh15 [9], and 08Kh [10], and to silicates in 12GS steel [11]. At the same time for inclusions with titanium in 08T steel the formation of brittle cracks in the inclusions themselves is more characteristic, which is related to the structure of the interphase boundaries as determined by the degree of wettability of the inclusions by the molten steel [6].

In this investigation voids which are ductile cracks were observed at inclusions of the oxides Al_2O_3, MnO, $MnO \cdot Al_2O_3$, Cr_2O_3, $MgO \cdot Al_2O_3$, $MnO \cdot Cr_2O_3$, and $FeO \cdot Fe_2O_3$ (Fig. 1a), of the sulfides and the sulfide eutectics FeS—FeO, (Fe, Mn)S—FeS, and (FeCr,Mn)S—FeS (Fig. 1c), and of the silicates $MnO \cdot SiO_2$ and $FeO \cdot SiO_2$ (Fig. 1e) not located in the zone of radiation [6]. At the same time voids were not observed at a single inclusion within the limits of the spot of radiation. Clearly expressed localization of deformation (Fig. 1b) was observed with ε = 10-15%. It is interesting to note that at the inclusions without preliminary laser action on the steel voids appeared at lower degrees of deformation, as established in earlier conducted investigations, at oxides in 08Yu steel at $\varepsilon = 2\%$ [7], at sulfides in NB-57 steel at $\varepsilon = 2\%$ [8], in ShKh15 steel at $\varepsilon = 3\%$ [9], and in 08Kh steel at $\varepsilon = 4\%$ [10].

Depending upon the composition of the steel an increase in the degree of deformation above 15% led to the formation along the interphase boundaries of thin separations which were brittle cracks (Fig. 1d, f). They appeared in the zone of laser action at inclusions of sulfides and silicates having an irregular and frequently angular form and large size (more than 30 μm). In the majority of cases the oxides had a spherical or oval form and their size was less than 30 μm. Therefore practically no brittle separations were observed along the interphase boundaries with the matrix. Inclusions of all types the size of which exceeded 30 μm sometimes failed brittlely. It should be noted that in formation of voids in steels without preliminary laser radiation of them the critical (minimum) size of the inclusions was 6-12 μm [6], that is, significantly less than the critical size of the inclusions observed in this work.

In the concluding stages of deformation preceding fracture of the specimens, when the degree of deformation of the steel reached 15-20%, brittle cracks, which were continuations of the brittle separations at the interphase boundaries (Fig. 1d) or occurred at inclusions as the result of retarding of slips in the matrix (Fig. 1b), were observed in the matrix

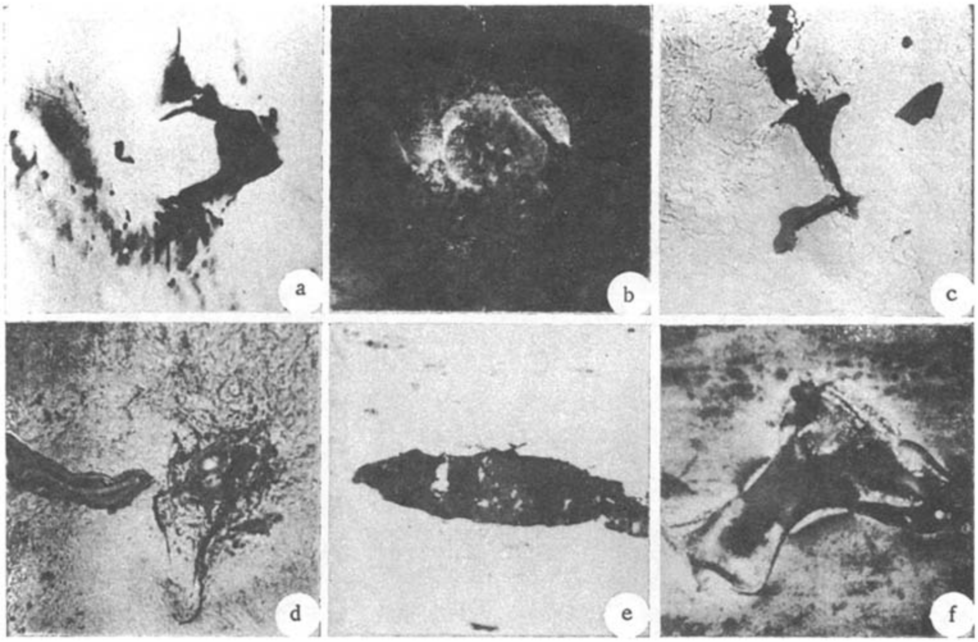

Fig. 1. Nonmetallic inclusions in the investigated steels after deformation (500×): a, c, e) without laser radiation; b, d, f) after laser action; a, b) $MnO \cdot Al_2O_3$ oxides in 08Yu steel; c, d) FeS—(Fe, Mn)S sulfide eutectic in NB-57 steel; e, f) $MnO \cdot SiO_2$ silicates in 12GS steel.

close to inclusions in the zone of laser action. The development of these cracks also led to fracture of the specimens.

Both in the zone of laser radiation and outside it localization of deformation close to inclusions caused the occurrence of microfractures. While for the investigated steels and inclusions without laser action the origin of ductile voids is characteristic, laser radiation promotes the formation of brittle cracks and separations along the inclusion—matrix boundaries. Therefore diffusion interaction between the inclusions and the matrix in laser action leads to a change in the mechanism of formation of microfractures.

Brittle separations along the inclusion—matrix boundaries appear at higher degrees of deformation than ductile voids without radiation [6-11], which is an indication of local microwelding of the inclusions with the matrix at the moment of laser action. This leads to strengthening of the steel in the early stages of deformation.

In the case of preliminary laser action the development of microfractures occurs in three stages. The first stage consists of localization of deformation close to inclusions. Brittle separations abong the interphase boundaries and cracks at the inclusions occur in the second stage. The occurrence of brittle cracks in the matrix at inclusions and propagation of cracks from separations into the matrix or directly from inclusions lead to the formation of a main crack and is the third stage of development of fracture of the specimens. The development of ductile voids close to inclusions also occurred in three stages [6-11] but basically the form of microfractures occurring (brittle or ductile cracks), that is, the mechanism of their formation and also the critical parameters of the microfractures (the degrees of deformation of the steel and the inclusion size), differed.

Conclusion. Diffusion interaction between nonmetallic inclusions and the steel matrix during laser action leads to their microwelding at the interphase boundaries, leading to a change in the mechanism of formation of microfractures near inclusions in plastic deformation of the steel.

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FEATURES OF THE CRYSTALLIZATION OF LASER REMELTED $Fe_{83}B_{17}$ ALLOY

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UDC 621.9.048:699.15'781

The overwhelming amount of work on hardening from the liquid state and obtaining of amorphous alloys has been done under conditions of a quite long existence of the molten material, which led to practically complete homogeneity of it. In the case of melting of a thin surface layer of alloys with the use of pulsed concentrated flows of energy, in particular laser radiation, complete homogeneity of the molten material is far from always obtained [1]. In addition, the molten layer is in direct contact with the crystalline base.

The purpose of this work was an investigation of the influence of interphase boundaries and nonhomogeneity of the molten material on crystallization in superrapid hardening and subsequent heat treatment of the surface layer of $Fe_{83}B_{17}$ alloy obtained by laser remelting.

The investigations were made on 20 × 20 × 2 mm polished plates of cast $Fe_{83}B_{17}$ alloy which were irradiated with a pulsed-periodic action CO_2 laser with a pulse length of 5 μsec in a vacuum of on the order of 1 Pa with a pulse energy density of 120 J/cm^2. The pulse-repetition frequency (10-15 Hz) and the rate of movement of the specimen relative to the light beam (1.8-6.7 mm/sec) were such that each point of the surface was subjected to N pulses of radiation (N = 6-33). After laser treatment the working surface of the specimens was pickled in a concentrated hydrofluoric acid solution to remove contaminants.

The influence of annealing on the phase composition of the remelted layer was investigated on specimens of irradiated alloys of series A and B. The radiation energy of a pulse was 280 and 100 J/cm^2, the repetition frequency of the laser pulses 40 Hz, and the number of

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0026-0673/88/0506-0334$12.50