

# Technology ability of laser bonding of compacted graphite iron

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**Abstract.** Laser welding features of compacted graphite iron are described in this paper. An approach that allows to reduce residual stresses and the probability of occurrence of "hot" cracks in the weld seam as well as to increase the absorption coefficient of laser radiation due to the use of metal powder Ni-Cr-B-Si-Fe, BoroTec-Eutalloy® 10009-chromium-nickel alloy are proposed. Recommendations are given when conducting a welding with compacted graphite iron.

## 1. Introduction

Compacted graphite iron (CGI) is becoming more and more popular in engineering. They replace gray cast iron, due to their unique physical and mechanical characteristics, economical casting, manufacturability in the producing of parts with high mechanical properties.

Progressive technological processes (PTP), including laser welding (LW), have not been developed at present. Therefore, the problem of laser welding of CVG, providing a welded seam with a given quality, with increased physical and mechanical properties and performance characteristics, is relevant.

With a system approach to the processing of CGI, which is a form of integrating scientific knowledge in the field of laser technologies, it is necessary to consider a set of problems. These are the temperature conditions, the heating and cooling rates of the welded product, the gas medium in which welding takes place and its consumption [1], as well as the positioning of laser radiation (LR) relative to the joint of the welded parts [2]. The solution of the questions as well as the specification of the TP parameters ensure the successful implementation of the required quality of drugs.

## 2. Welding process

One of the necessary stages of the laser welding process is the preliminary preparation of the welded surfaces [3]. Pollution and moisture create conditions for the formation of porosity, oxide inclusions, and in some cases, cold cracks in the welded iron and the zone of thermal influence due to hydrogen saturation and high cooling rate. After cleaning the surfaces, the parts are degreased.

Figure 1 shows the microstructure of the seam at a high cooling rate, welding was carried out in argon (on top of the seam) and helium (from below the seam).





**Figure 1.** General view of the CGI plates weld 30 (left) and CGI 35, magnification x 50, (grinding is etched)

Investigation of the microstructure was carried out in cross-section of a cross-section microsection relative to the welded seam of the plates. The presence of "hot" cracks is revealed in the welded seam.

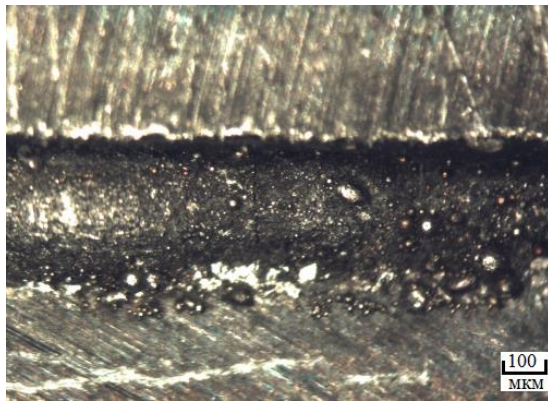
The microstructure of cast iron plates was evaluated in accordance with the scales of GOST 3443-87, identical and represents graphite: - the form of inclusions of graphite - spherical regular SHGf5 and meandering VGf2;

The microhardness of the plate amounts:

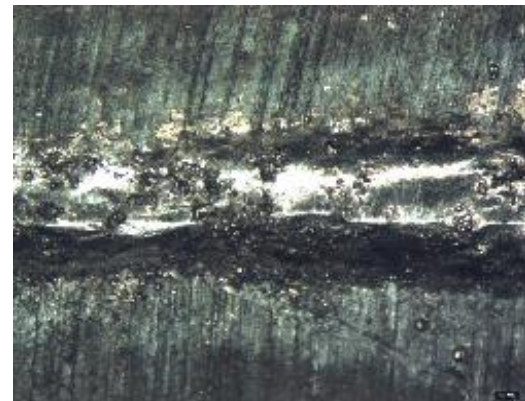
- ferrite in the main metal plate - 170 HV0.05;
- perlite plate-like in the base metal of the plate - 260 HV0.05;
- martensite in the HAZ - 670 - 702 HV0.05;
- welded seam - 524 - 570 HV0.05.

The effect of the inert gas consumption of argon can be observed from the surface roughness of the weld (Fig. 2.3). It can be seen from the figures that a violation of the nominal TP parameters leads to an increase in the roughness. This is because the increase in argon consumption leads to the formation of turbulent flows and mixing it with air. Hydrogen and oxygen lead to swelling of the welded joint [4-6]. The other technological parameters were the same.

In this case, there is an active interaction of metals with the surrounding gaseous medium present in the joint zone of the two metals because of the surface roughness. Laser welding of the samples was carried out on LTK, based on the ytterbium fiber laser "LS 2". Surface welds from oxidation were protected by a mixture of helium with argon in a ratio of 2: 1, fed through a special nozzle. To increase the absorption coefficient, Ni-Cr-B-Si-Fe metal powder was applied to the interface, BoroTec-Eutalloy® 10009 was a chromium-nickel alloy with an AN-43 flux, with an optimal content of manganese, silicon and other alloying elements, and also limited sulfur content and phosphorus.



**Figure 2.** Surface view of CGI plate weld 35 and CGI 30 at a nominal flow rate of argon, magnification x 75



**Figure 3.** Surface view of CGI plate weld 35 and CGI 30, with an increased flow rate of argon, an increase of x 75

To estimate the depth of penetration, one can use the formula (1):

$$h = \frac{P}{2\pi\lambda_T T_k} \ln \frac{r_{\text{л}} + a/v_{\text{св}}}{r_{\text{л}}}, \quad (1)$$

where  $\lambda_T$  - is the coefficient of thermal conductivity of the material, W / mK;  $T_k$  - is the boiling point, K;  $a$  - is the thermal diffusivity of the material [1].

With the initial LR interaction with the metal surface, the efficiency of the useful use of the LI energy depends on the ratio of the reflected and absorbed radiation [7]. The reflected part, as a rule, is irretrievably lost, the other part is almost completely absorbed by electrons in the near-surface layer  $10^{-6} \div 10^{-7}$  m thick. As a result, the electron temperature  $T_e$  increases sharply, and the temperature of the crystal lattice  $T_{cr}$  remains insignificant. With time, the intensity of energy transfer of free electrons of the crystal lattice increases. Beginning with the relaxation time (c):

$$\tau_p = 10^{-9} \div 10^{-11} \text{ c}$$

the temperature difference ( $T_e - T_{crp}$ ) becomes minimal and the thermal processes in the metal can be characterized by the total temperature. An integrated characteristic of the thermophysical properties of a metal is the coefficient of thermal diffusivity, which, on the whole, characterizes the rate of temperature equalization for nonstationary thermal conductivity. This coefficient determines the speed with which the energy is transferred to the metal. [8-9].

### 3. Conclusion

To exclude the "hot" cracks it is necessary to comply with the temperature conditions of heating and cooling of the welded parts, as well as the consumption of inert gas. One should not allow moisture and air to enter the weld seam but should use ultrasonic vibrations during welding [6].

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