PECULIARITIES OF INFLUENCE OF DEFECTS IN CAST BILLETS OF STEEL 110G13L ON MECHANICAL PROPERTIES OF JOINTS DURING FLASH-BUTT WELDING

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The features of defects formation in butt welds, made by flash-butt welding of cast billets of steel 110G13L (GOST 7432–87) with austenite rolled billets of steel 12Kh18N10T (GOST 5949–75), which are used in manufacture of welded railway frogs, were investigated. It was established that casting defects, being located in the butt weld zone, lead to formation of defects and, depending on conditions of their formation, affect the strength properties of welded joints in different ways.

Keywords: *pulsed flash-butt welding, high-manganese steel 110G13L, rail steel M76, austenite insert*

At the E.O. Paton Electric Welding Institute the technology and equipment for flash-butt welding of railway frogs [1] were developed, the main feature of which is the application of a pulsed flashing [2], which allows producing joints of high-manganese cast steel 110G13L with rail steel M76 through an insert of rolled chromium-nickel austenite steel 12Kh18N10T. The frog with welded-on rail ends is shown in Figure 1.

The actual task at the modern stage is the increase of reliability and life of operation of railway frogs. Its solution is closely connected with the development of rational methods of non-destructive testing both of a ready product (welds) and also incoming materials, which are used in producing of a welded frog.

The purpose of this work is the investigation of influence of weld defects, connected with available defects in initial materials before welding, on mechanical properties of the joints. This is especially important in welding of cast billets, as far as this problem practically was not investigated.

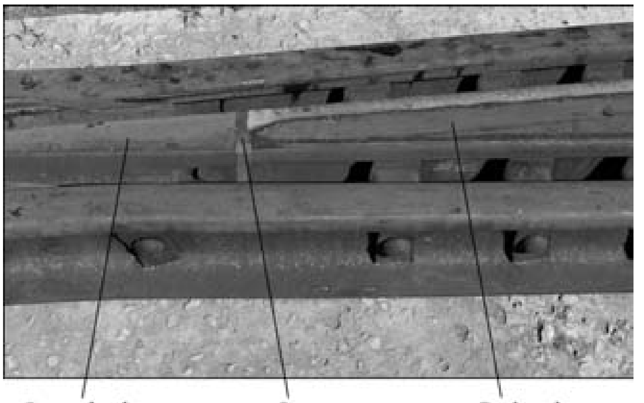

Figure 1. Frog with welded-on rail ends

The evaluation of influence of defects of butt welds, occurring as a result of getting the defects of casting (cavities, pores) into the zone of welded joint, on strength properties of the latter and their detection using radiographic method of inspection were conducted on specimens of a rail profile R65. For this purpose the batch of castings of steel 110G13L was cast with violation of casting technology which resulted in formation of cast defects. The ends of castings were subjected to radiographic inspection to the depth of up to 100 mm, from the results of which the sites of location of defects and their sizes were determined. After that the facing of specimens was carried out in such a way that during welding a defect could get into the zone of joining. In the specimens of castings, where natural defects were absent, the holes were drilled which simulated the hollows in the casting. The mechanical tests of specimens were carried out according to the TS U 27.3-26524137-1342:2006 [3]. Before the tests the radiographic inspection of welds on specimens was carried out to check up the presence of defects.

Having performed the mechanical tests of welded specimens on static bending in the areas, where defects of casting caused the fracture along the line of joint of 12Kh18N10T to 110G13L, the sections were cut out and metallographic examinations were carried out. The sections were also cut out from the defective sites, which were found in welds using radiographic inspection, though they did not lead to fracture of specimens along the joining line. The investigations of microstrucutre were performed using optical microscope «Neophot-32», and the analysis of chemical heteroge-

Chemical composition of melt in artificial defect, wt.%

Measuring zone	Mn	Cr	Ti	Ni
A	11.006	6.637	0.075	3.624
B	14.390	0.139	0	0.037
C	13.247	3.562	0	2.221
Matrix 110G13L	14.367	0.078	0	0.042
Matrix 12Kh18N10T	1.783	18.712	0.326	9.657

neity was made using the CAMEBAX microscope-microanalyzer SX-50.

In Figure 2 a macrosection is represented, cut out from specimen with an artificial flaw, which was fractured during the tests along the rail end (steel M76) at the force of 1100 kN and bending deflection of 21 mm. As is seen from the Figure, the hollow of an artificial flaw (horizontal hole of 8 mm diameter at the bottom of the casting 110G13L) was filled during flashing with a melt of steels 110G13L and 12Kh18N10T being welded. During upsetting the increase in defect area filled with a melt does not occur, and fusion line in defect zone preserves its straightness, characteristic for the zones without defect. Along the line of fusion even some decrease in defect area is occurred due to pressing in layers adjacent to the defect of layers 110G13L into the melt, lateral deforming of melt occurs which results in press welding of melt with base metal 110G13L along the lateral surface of an artificial defect. It is confirmed by tears formed in the steel 110G13L as a result of mechanical tests (Figure 3). Thus, the flaw in a form of a pore without slag inclusions is subjected during flash-butt welding to some «curing» and is not critical at static tests.

Filling of an artificial pore with melt occurs in the process of flashing. Therefore chemical composition of melt is interesting from the point of view of amount of metal which gets to the surface being flashed from the other surface being flashed during explosion of

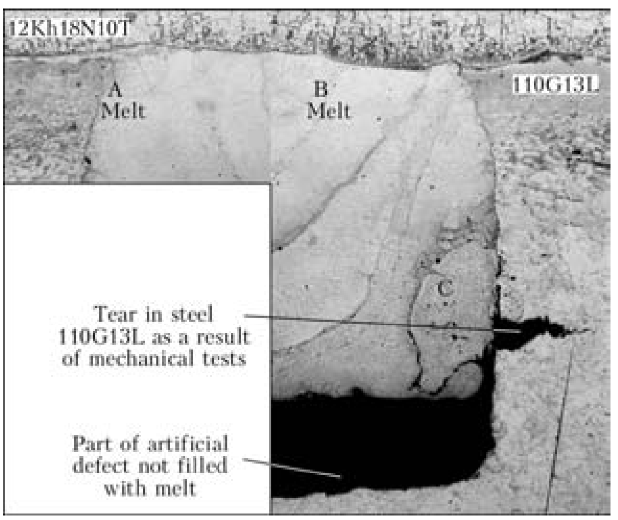

Figure 3. Microstructure (×25) of joint in the zone with artificial defect

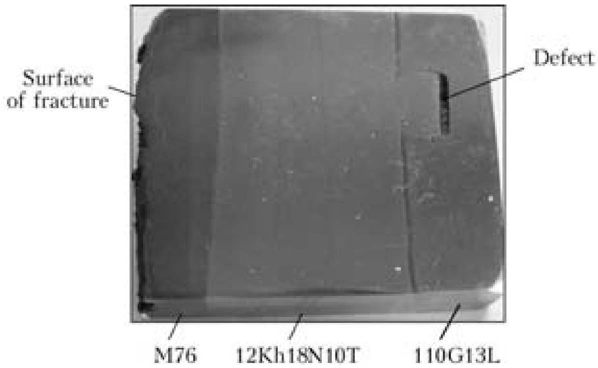

Figure 2. Macrosection of joint with artificial defect

bridges. According to the obtained results about 20 % of metal on the surface being flashed (in liquid layer) is the metal from the opposite flashed surface which gets there during explosion of bridges.

The results of analysis of chemical composition of melt in the zones A, B, C (Figure 3) are given in the Table. In microstructure of metal filling the hole the layers are observed delaminated by the chains of non-metallic inclusions. The formation of laminated structure is caused by a portion filling of a hole during explosion of bridges.

In Figure 4 a macrosection is represented, cut out from specimen with a real flaw, which was fractured during tests along the joining line of M76 to 12Kh18N10T at the force of 106 tf and bending deflection of 22 mm. This flaw was detected by radiographic inspection of the weld (Figure 5). Figure 6 shows microstructure of a joint in the zone of a real

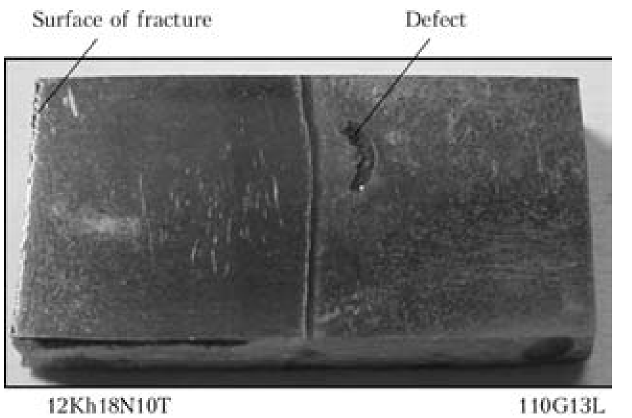

Figure 4. Macrosection of joint with natural defect

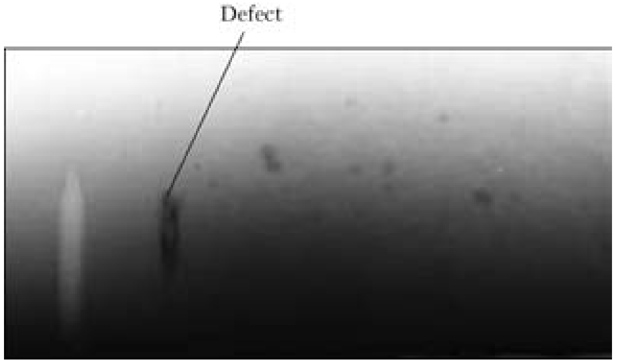

Figure 5. X-ray image of natural defect in the specimen

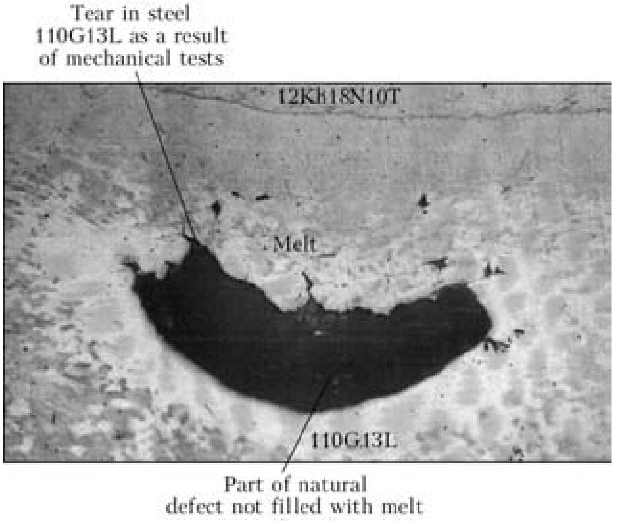

Figure 6. Microstructure (×25) of joint in the zone of natural defect

flaw (cast pore with slag inclusions). As is seen, the hollow of a flaw during flashing is filled with melt of steels 110G13L and 12Kh18N10T being welded. A slag of melt, being more fluid, is forced out to the periphery part of a pore and remains in a form of slag inclusions, a part of which gets to the metal melt. Though a defect was at the bottom of casting, the fracture of specimen along the defect did not occur. It is explained by the fact that during such formation of a joint the slag inclusions are forced out to the pore periphery and the zone of the joining line is formed from a melt where slag inclusions are absent. Thus, a defect of a pore type with slag inclusions behaves itself similarly to an artificial defect at the possibility of forcing out the slag melt from the zone of joining and does not considerably decrease the mechanical properties of specimens during static tests.

Figure 7 shows an appearance of natural defect in the specimen fracture surface. The fracture of specimen occurred along the joining line of 110G13L to 12Kh18N10T at the force of 800 kN and bending deflection of 12 mm. The main reason for fracture of specimen at low values of mechanical properties is the presence of defect of lack of penetration type [4]. The radiographic inspection performed before welding de-

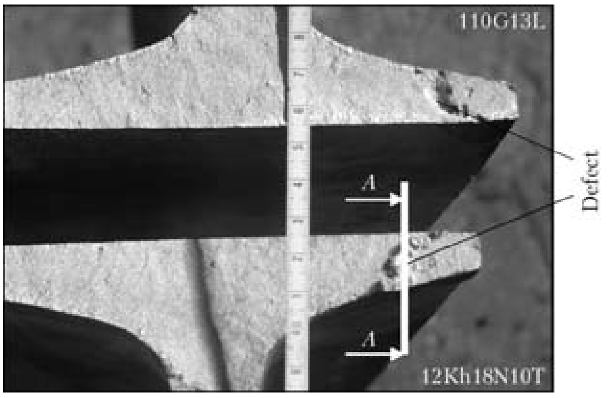

Figure 7. Appearance of defects in the fracture surface of specimen: *A*–*A* — scheme of cutting out of section from the specimen

tected a defect in the casting (cast pore). During flashing its filling with melt of steels 110G13L and 12Kh18N10T being welded occurred, as well as forcing out a slag melt to the periphery part of a pore. The deformation during upsetting due to lack of volume of a pore resulted in pressing in a slag melt and its dissolving in melt of metals being welded, and during solidification of a volume the shrinkage porosity was formed which is hard-to-detect during radiographic testing of joints, especially when thicknesses of metals being exposed to radiation are large.

Figure 8 represents microstructure of a joint in the zone of defect and in defectless area of a weld on the side of steel 12Kh18N10T. As is seen, the fracture occurs along the joining line of 110G13L to 12Kh18N10T and in the zone of defect the explosion along the bottom of initial pore occurs where maximal concentration of slag inclusions is observed.

In conclusion it should be noted that mentioned metallographic examinations of welded joints showed that casting defects (cavities, pores) do not almost increase their sizes during plastic deformation, that is a positive factor to conduct incoming radiographic testing of castings before welding. During testing of welded joint, the defects in castings, the sizes of which are less than limit of sensibility of radiographic inspection will not be detected, and after welding their sizes will not be increased.

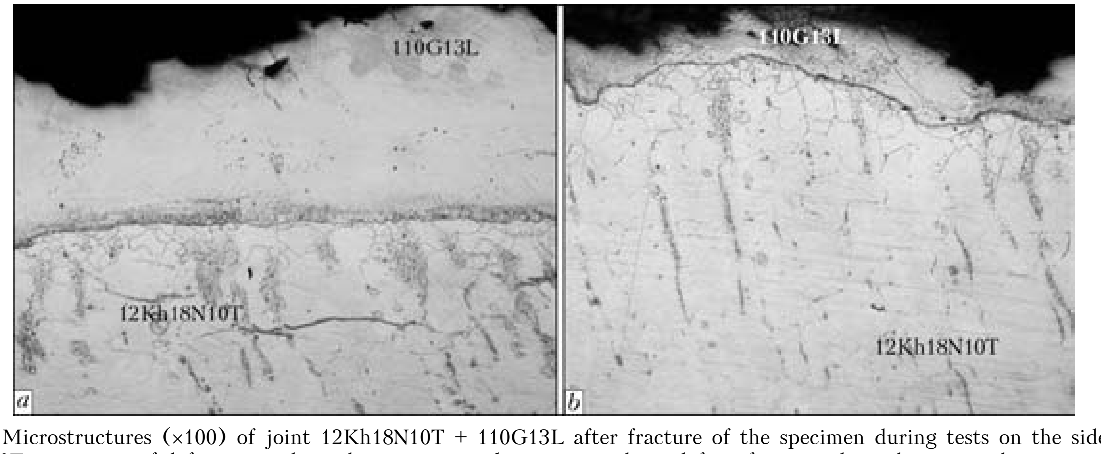

Figure 8. Microstructures (×100) of joint 12Kh18N10T + 110G13L after fracture of the specimen during tests on the side of steel 12Kh18N10T: *a* — zone of defect, tear along the cast cavity; *b* — zone without defect, fracture along the joining line

If cast defect (cavity or pore with slag inclusions) gets to the zone of welded joint, two variants of weld defect formation are possible:

• during the first one, when sizes of a defect allow forcing out slag inclusions in the form of a melt to the periphery of a pore, the zone of joining is formed from the melt where slag inclusions are absent. Such defects in a weld are good detected using radiographic inspection due to presence of slag hollows, but they do not decrease significantly the mechanical properties of specimens at static tests;

• during the second one, when sizes of defect do not allow forcing out slag inclusions in the form of a melt to the periphery of a pore, during deformation the pressing-in of a slag melt and its solution in melt of metals being welded occur due to lack of volume, which results in formation of shrinkage porosity during solidification of a volume, which are not detected during radiographic inspection of the joints. These defects lead to inadmissible reduction in mechanical properties of welded joints.

The radiographic inspection of ends of castings of frog cores, which are subjected to flash-butt welding, allows detecting casting defects, as well as their repairing before welding, which in combination with incoming ultrasonic testing of rail ends and an intermediate insert will provide guaranteed quality of incoming materials for welding. The system for control of welding condition parameters can guarantee the required quality of welded joints using inspection of incoming materials for welding. Therefore, the radiographic inspection of welds of the frogs after flash-butt welding is not reasonable.

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