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The Structure of Welded Austenitic and Non-austenitic Steel Joints

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The welding of austenitic and non-austenitic steels is recommended to carry out at the conditions giving minimal fusion of the base material and using austenitic electrodes. However the structural inhomogenity is observed in the fusion zone due to incomplete stirring in a weld pool and also due to the removal of carbon from the carbon steel to the austenitic weld. We researched fractograms of a fracture of welds, produced by welding low-carbon steel with austenitic-pearlitic and also austenitic electrodes. It was determined that the weld fraction has a complex ductile-brittle character in both cases. It shows that not only the right selection of welded materials influences on the quality of welded joints, but the choice of optimal technology of the welding is important, as well.
Keywords: austenitic and non-austenitic steels, welded joint.

1. INTRODUCTION

At the present time the main direction of welding of heterogeneous steels, is the application of welded materials, which give the austenitic steel in weld metal containing high level of nickel. Nickel is a rather expensive metal. In addition, it can influence the forming hot cracks in the weld. The amount of nickel must be optimal and chosen on the base of contradictory requirements. Larger amount is required to avoid a structure inhomogenity in the fusion zone and less amount – to get welds without cracks. Therefore the optimal amount of nickel in the weld metal of a welded joint of heterogeneous steels, which will operate in high temperature, must be chosen for each particular case, taken in the mind all factors, which give decisive influence on the structural inhomogenity, especially on the formation of martensite in the fusion zone. At the same time it is known, that the amount of nickel in the austenitic metal, which is necessary to avoid formation of structural inhomogenity, changes if the temperature of the fusion zone heating changes [1]. For welded joints, which operate at the temperature till 350 °C, this amount is below the limit, which must be in order to obtain the metal of an austenitic structure. Joints which can be heated till 450 °C must contain 19 % of nickel in the austenitic metal, in the case of heating till 550 °C – 31 % [1 – 3].

It is recommended to carry out the welding of different kind of steels by regimes, which guarantee minimal although reliable fusion of the base material. In the case of automatic submerged-arc welding austenitic steel with non-austenitic steel, the weld metal contains 40 – 45 % of the main metal and a part of the non-austenitic steel is twice less (20 – 25 %). In the case of welding using coated electrodes [1 – 10] the weld formation occurs analogically. With the aim to get the desirable austenitic structure in the weld metal and such fusioning of non-austenitic steel as was mentioned above, the composition of an electrode wire could be determined using the well-known Sheffler diagram.

Evaluating workability of welded joints is especially important to study the structure and properties of the fusion zone of heterogeneous metals. In joints obtained by fusion welding the crystalline type interlayer of the intersitial composition appears between the welded steels and the weld near the fusion boundary. The extent of the interlayer changes, depending on the manner and conditions of the welding.

Depending on the combination of welding steels and the weld, the structure and properties of the fusion zone will be different. In the case of welding steels of different alloying but of the same structural type (class), the presence of crystalline interlayers usually has no influence on the properties of the welded joint and they may not be valued. In the case of welding steels of various structural classes, e.g. pearlitic steel with austenitic steel, the forming of the welded joint is related with the conditions of simultaneous crystallization of materials with different structural lattices (of γ and α phases). In this case the interlayer is formed in the fusion zone. The biggest degree of the structural instability appears when crystalline layers of the compound are absent or they are of insignificant width. In the zone of variation of the composition of crystalline interlayers, their structure and properties can change significantly. In the fusion zone of the pearlitic steel with austenitic weld, the area of a crystalline interlayer containing Cr 3 – 12 % and Ni 2 – 7 % has the structure of a high alloyed martensite and is fragile. The width of a fragile martesitic interlayer depends on the degree of the austenitics of the weld metal.

The purpose of the work was to determine the character of the structure of joints of austenitic and nonaustenitic steels and to evaluate the joint reliability.

2. EXPERIMENTAL

We carried out comparative study of fractograms of surfaces failure of weld metal which was got by arc welding of an austenitic steel 20X23H18 plate with carbon steel Ст-3 plate without edges champering in the joint.

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Table 1. Chemical composition of the base metal and weld metal, %

Material	C	Mn	Si	Cr	Ni	Fe	Mo	P	S
20X23H18	0.088	1.610	0.364	23.680	17.410	56.300	0.146	0.027	0.011
Ст-3	0.151	0.537	0.068	0.043	0.15	98.54	0.031	0.021	0.045
Wire Cb - 07X25H13	≤ 0.09	1.00 ÷ 2.00	0.50 ÷ 1.00	23.0 ÷ 26.0	12.0 ÷ 14.0	57.0 ÷ 63.0	–	0.025	0.018
Wire Cb-08A	0.1	0.35 ÷ 0.6	0.03	0.15	0.3	98.7 – 99.0	–	0.03	0.03

The thickness of plates was 6mm. The welding was carried out by one run in the lower position using a direct current of an opposite polarity and electrodes ОЗЛ-6 and УОНИ-13/45 of 4.0 mm diameter, also using argon arc welding and direct current of a normal polarity. The current of welding was 130 A, the voltage of an arc 22 – 26 V.

The electrode ОЗЛ-6 is referred to the type Э-10Х25Н13Г2 and contains a rod of the wire Cb-07X25H13 and the basic coating.

An electrode УОНИ-13/45 is referred to the type Э-42 A and has a basic coating and a rod from the Cb-08A wire. Welded plates after cooling were broken along the weld (Fig. 1). Surfaces of the fracture were studied for structure homogeneity by the help of a scanning microscope XL 30 ESEM, PHILIPS.

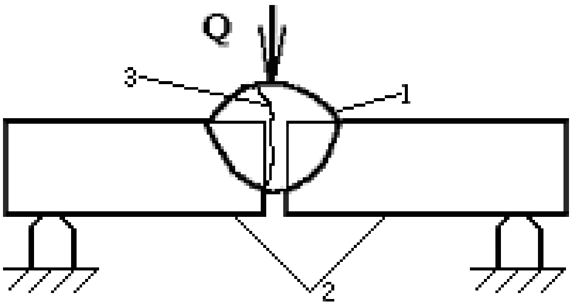


Fig. 1. Schematics of the fracturing of welded plates: 1 – weld, 2 – welded plates, 3 – damage area. *Q* – force, causing the fracture of a weld

A hydraulic jack type device was used for the destruction of welded plates. The fracture took the place all time through the welded seam. Value of the used force was not measured because the purpose of the testing was to determine the character of the fracture (fragile, ductile).

3. RESULTS AND ANALYSIS

The obtained weld fractures were examined in the presence of inclusions of different type, the character of the fracture of the weld metal was also established. The breaking mostly takes place in the middle of the weld. In the case of the welding by the help of austenitic and pearlitic electrodes the fracture has a complex ductile – brittle character. Fracturegrams of surfaces of a weld edge after breaking in the case of welding steels Ст-3 and 20X23H18 are shown in Fig. 2 – 7.

Mechanical (technological) and construction strength of welded joins is ensured when embrittle and friable areas disappears in various layers of the weld and in the zones of thermal influence. Regarding this in the case of welding heterogeneous steels it is necessary to evaluate the structure and properties of various layers when welded materials are selected.

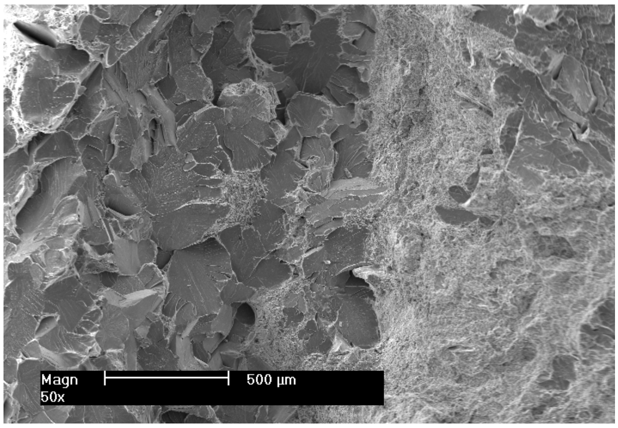


Fig. 2. Surfaces of fracture of the welded joint in the case of welding steel Ст-3 and steel 20X23H18 by the help of argon arc welding with noncomsumable electrode

The structure of a welded on metal can be determined by using the Sheffler diagram taken average values Ni and Cr.

Ni_{eq} = % Ni + 30% (C + N) + 0.5 % Mn + 3 % Cu.

Cr_{eq} = % Cr + 2% Si + 1.5% Mo + 5% V + 5.5% Al + + 1.75% Nb + 1.5% Ti.

Table 2. The structure of a welded on metal

Cr_{eq} / Ni_{eq}	Cr_{eq} + Ni_{eq}	weld structure
< 2,5	< 30 %	martensitic structure
> 2,5	< 30 %	martensitic - ferritic structure
< 2,5	> 30 %	ferritic structure
= 1,25 – 2,5	> 30 %	austenitic - ferritic structure
< 1,25	> 30 %	austenitic structure

Using the Sheffler diagram for the determination of the phase composition of the weld in the case of welding carbon steel with an austenitic one, we can see that the structure contains 90 % of an austenite and 10 % of α ferrite. The martensite in this case is entirely excluded. Therefore it may be expected that the formation of cracks in the weld metal is nearly impossible when the weld is formed by welding different metals using austenitic electrodes. By the way, in practice during the welding of an austenitic steel with carbon steel in the weld metal also in the fusion zone cracks sometimes appear.

In the case of welding steel Ст-3 and steel 20X23H18 using a noconsumable electrode the weld alloy has the Ni equivalent equal to 13.76 % and Cr equivalent equal to

12.394 %. Equivalents ratio $Cr_{eq.}/N_{eq.} = 0.9 < 2,5$ and $Cr_{eq.} + Ni_{eq.} = 26.155\ \% < 30\ \%$.

During analysis of structures presented in Figure 2 and Figure 5 we determined, that the large scale grain martensite takes about 90 % of the weld metal. The fracture of such weld will be sudden brittle that is such welds are inadmissible for important constructions. These results show that the weld metal has basically the martensitic structure with inclusions.

In the case of welding steel Ст-3 and steel 20Х23Н18 using an austenitic electrode ОЗЛ-6 equivalents are: $Cr_{eq} = 19.45\ \%$ and $Ni_{eq.} = 15.23\ \%$. The ratio of equivalents $Cr_{eq.}/Ni_{eq.} = 1.28$, which corresponds to the boundary value 1,25-2,5 and the sum, is equal to $Cr_{eq.} + Ni_{eq.} = 34.68\ \% > 30\ \%$ - these data show an austenitic–ferritic structure of the weld and also show the existence of the martensite in the weld (Fig. 3 and Fig. 6).

During analysis of structures presented in Figure 3 and Figure 6 we determined, that 90 % of the weld material are of an austenitic structure, The fracture of such welds is ductile and the reliability of the weld is high.

In the case of welding steel Ст-3 and steel 20Х23Н18 using pearlitic electrodes equivalents were found $Cr_{eq.} = 6.3\ \%$ and $Ni_{eq.} = 8.66\ \%$. The ratio in this case is equal to $Cr_{eq.}/Ni_{eq.} = 0.727 < 2.5$ and the sum is equal to $Cr_{eq.} + Ni_{eq.} = 14.96\ \% < 30\ \%$. It shows the martensitic structure of the weld.

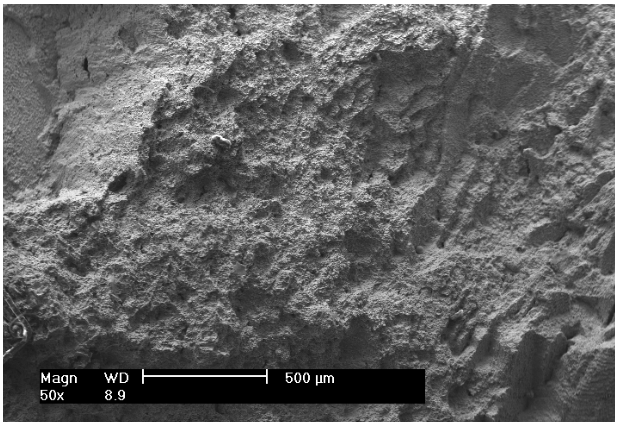


Fig. 3. Surfaces of fracture of the welded joint in the case of welding steel Ст-3 and steel 20Х23Н18 by the help of an austenitic electrode ОЗЛ-6

During analysis of structures presented in Figure 4 and Figure 7 we find, that the structure of the weld is martensitic. Such welds can be used in constructions which are not loaded by dynamic forces. If there are the martensitic structure of joint welds, the sudden fracture can occure under loading. The reliability of the construction is low in this case.

Theoretically the fracture of the weld of the martesitic structure must be brittle. In practice the ductile-brittle fracturing with some prevalence of the brittle one was got, it is illustrated in Fig. 4 and Fig. 7. It shows that the structure of the weld metal depends not only on the chemical composition of the weld metal, but also on the magnitude of the melt metal bath, its temperature, and especially on the weld cooling conditions. This is well illustrated in Fig. 2 and Fig. 5. This fact appears because the martensite has a brittle character of the fracture and the austenite – a ductile character.

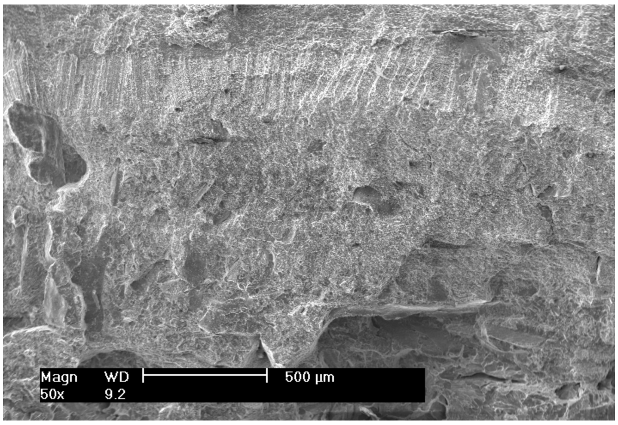
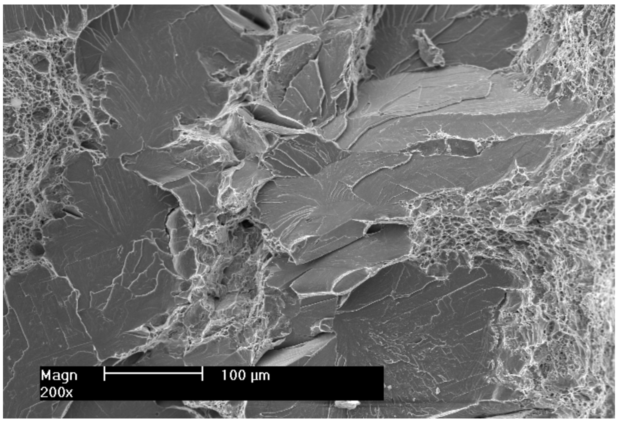


Fig. 4. Surfaces of fracture of the weld joint in the case of welding steel Ст-3 and steel 20Х23Н18 by the help of a pearlitic electrode УОНИ-13/45



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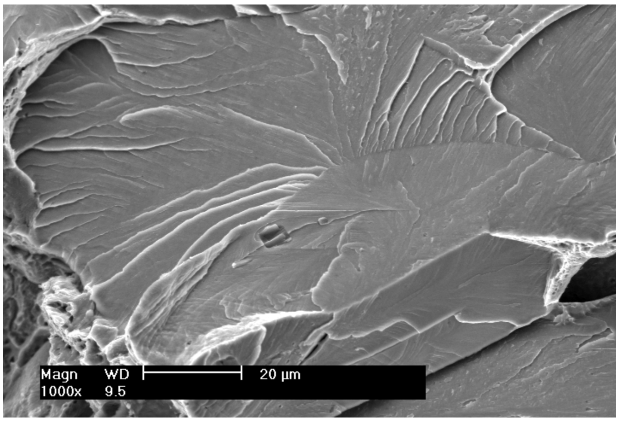
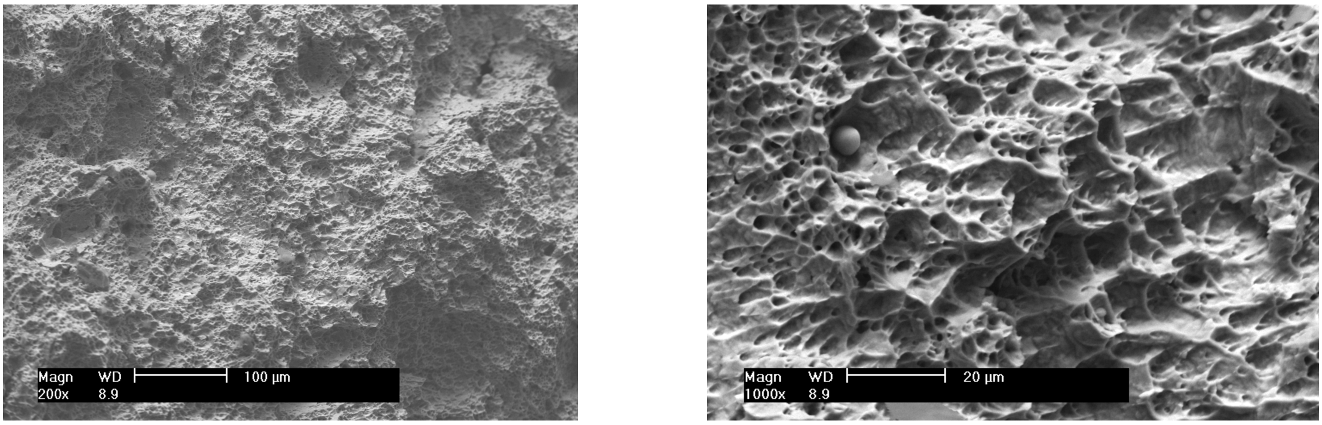


b

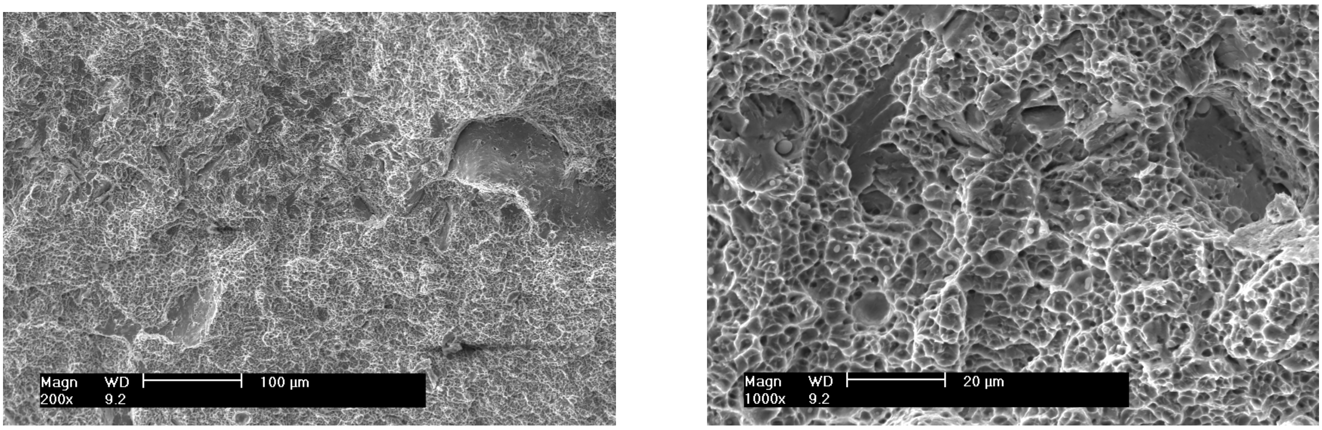
Fig. 5. The mostly typical place of a fracture of the weld in the case of an argon arc welding with noncomsumable electrode

If there are the austenitic structure of joint welds, the slow fracture can take place under loading. The reliability of the construction is high, because it can be detected in an early stage and stopped.



a b

Fig. 6. The mostly characteristic picture of fracture surface in the case of the welding steel Ст-3 and steel 20X23H18 by the help of an austenitic electrode ОЗЛ-6



a b

Fig. 7. The mostly characteristic picture of fracture surface in the case of the welding steel Ст-3 and steel 20X23H18 by the help of an pearlitic electrode УОНИ-13/45

4. CONCLUSIONS

1. The fracturing of the weld metal in the case of the welding of austenitic and non-austenitic steels has a complex ductile – brittle character.
2. In the case of austenitic electrodes the fracture of welded constructions is ductile, and in the case of non consumable electrodes without an additional metal used for welding the fracture is fragile, the latter case decreases the reliability of constructions.

REFERENCES

1. **Gotalskij, J. N.** Welding of Heterogenous Steels. Kiev, Technique, 1981: 184 p. (in Russian).
2. Weld Designs. Mechanics of Suitability **(V. A. Vinokurov, S. J. Kyrkin, G. A. Nikolaev,** Edited by **B.T. Paton).** Moscow, Machine Building, 1996: 576 p. (in Russian).
3. **Azbukin, V. G., Gorinin, V. I., Pavlov, V. N.** Perspective Corrosion-proof Materials for Nuclear Power Station Equipment. Moscow, "Prometej", 1997: 118 p. (in Russian).
4. Materials for Machine, Device and Apparatus Construction. German Publishing House for Industrial Materials, Leipzig, 1991 (in German).
5. **Shrier, L. L., Jarman, R. A., Burstein, G. T.** University of Cambridge *Corrosion ISBN 07506 1077 8* 2 Volumes 1994: pp. 1408.
6. Milsk. ASM Handbook. Metals Handbook. USA, 9 Vol., 2000: 775 p.
7. **Hercberg, R. V.** Deformation and Mechanics of Construction Materials. Moscow, Metallurgy, 1989: 575 p.
8. **Kovchik, S. E., Morozov, E. M.** Mechanics of Destruction and Durability of Materials. Vol. 1 – 4. Kiev, Nukova Dumka, 1988 (in Russian).
9. **Cottis, R. A., Markfield, A., Boukkerou, A., Haritopoulus, P.** Environment-induced Cracking of Metals, NACE 10. Edited by R.P. Gangloff and M.B. Ives, Houston, Texas, 1990: 223 p.
10. **Wishniakas, I., Lobanovski, E.** The Problem of Welding Heat-resisting and Low-carbon Steels among Themselves *Second International Congress "Mechanical Engineering Technologies'99", September 16 – 18, 1999, Sofia, Bulgaria* 1999: pp. 26 – 28 (in Russian).

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