ISSN 1392 - 1207. MECHANIKA. 2008. Nr.3(71)

Special features of breaking the welded connections of the ferritic steels

I. Vishniakas
Vilnius Gediminas Technical University, Basanavičiaus 28, 03324 Vilnius, Lithuania, E-mail: ivanas@me.vgtu.lt

1. Introduction

For the majority of materials utilized in welded constructions characteristic is the combination of the base and filler metal, when chemical composition of the weld material is different from the basics. It is not so strong so these metals belong to different structural classes. The reaction of many metals to the welding cycle is such that the zone near the weld becomes weak component of the welded joint. In it the weakening of the base metal, noticeable worsening in the viscous properties and appearance of cracks both during the welding and after it [1] occur.

Resistance to corrosion of ferritic steels like grade 08X25T steel, etc. is not inferior to chrome-nickel austenitic steels and considerably exceeds them on the resistance to corrosion cracking. The application of ferritic steels with the usual content of C and N prevents the cases of brittle failure in the welded joint zone (during manufacturing process, transport and the operation) [1].

The class of high-chromium ferritic steels inclines to the additional embrittlement under heating. Impact toughness and plasticity of the metal in heat-affected zone of welded joints approach to zero. It is impossible to avoid intensive grain growth during fusion welding in these steels. The coarsest grains are formed on the overheating zone where the temperature reaches T_{sol}. The embrittlement of the section near the weld expands to the layer, directly adjoining the like of fusion and heated above 1000°C. Due to refinement impossibility of the structure of ferritic steels by the methods of heat working, the brittleness of their welded joints is irreversible [1-11].

For the ductile fracture the multistage nature of the process is characteristic, which includes the appearance of times in the particles of the second phase, the formation of cups as a result of growth and merging the adjacent microspaces around the times, plastic deformation of the material around the microspaces and its break.

Reduction in temperature, passage from the state of plane stress to the plane-deformed contributes to the replacement of viscous mechanism of destruction by the brittleness. The destruction of welded constructions more often occurs on the welds; therefore the estimation of the reliability of welded joints is very important [1-9].

Structural failure occurs most frequently, when several unfavorable phenomena appear simultaneously. For example, in the weld and the zone near the weld brittle tempering structure was formed, and also there are microscopic cracks and its destruction occurs with the large load on this construction. Destruction can be rapid or slow. Rapid destruction usually leads to emergencies. Slow destruction can be noticed and exploitation of the construction can be stopped without emergency. So for slow destruction to occur weld material must have high plasticity and have no defects.

To avoid crack formation welding should be conducted with the preheating up to 150 - 200°C. However, preheating with the welding adversely affects plasticity of the metal with the ferrite structure, so the rate of decrease cooling and endurance duration increase are in the range of temperatures, close to 475°C.

Basic difficulty during high-alloy ferritic steels welding is its tendency toward the formation of cracks near the weld and the zone of heating and cooling. Hot cracks usually are of crystalic nature. They can be micro or seen. The formation of hot cracks is usually connected to the formation with welding of the coarse-grained microstructure of weld and the presence of shrinkage stresses.

When using austenitic electrodes and wires the welded joints weld material of steels pure on the admixtures is characterized by high plasticity and impact toughness. If for the welding uniform electrodes and wires with the usual impurity content are used, then plasticity and impact toughness of the metal are extremely low and any requirements for these characteristics are not presented [1-9].

2. Experimental

Grade 08X25T steel GOST 5632-72 (X8CrTi25 EN100027-1) relates to difficult welded. In the case of manual welding a good plasticity of the weld must ensure perlitic (brand P48M), ferritic (brand Cromarod 430) and austenitic (brand Cromarod 310) electrodes. Before the welding it is necessary to preheat up to 150-200°C and subsequent heat treatment - leave at 600°C.

Materials for the realization of complex researches in metal science field were templets, which were cut out from the welds of welded plates. A comparative metalographics researches of a weld metal and metal of the heat affected zone obtained by manual arc welding (111 EN 24063) of plates (200 x 100 x 6 mm) from grade 08X25T steel, were done. Pearlitic electrodes P48M (EN 499 − E46 3 B4H10), austenitic electrodes Cromarod 310 (EN 1600-97: E 25 20 R12), ferritic electrodes Cromarod 430 (EN 1600-97: E 25 R12) were applied. The welding was conducted on a constant current of return polarity in one pass by electrodes of the diameter 3.25 mm. The current of welding was 110; 140; 160 A, voltage of an arch was 22 - 24 V. Welding was conducted without preheating and subsequent heat working. Welding conditions of models made from grade 08X25T steel are presented in Table 1.

The structure of a weld was investigated using microscope LEICA MEF 4M and scanning microscope XL 30 ESEM, PHILIPS. Chemical composition was determined by microscope Spectro LAB 05 3/N 45/263. The chemical structure of the basic and weld materials is presented in the Table 2, and chemical structure of weld − in the Table 3.

Table 1

Welding regimes during grade 08X25T steel welding by the different electrodes

Type of the electrode	P48M		Cromarod 430		Cromarod 310	
Designation of the models	1A	1B	2A	2B	3A	3B
1 weld	110 A	110 A	110 A	110 A	110 A	110 A
2 weld	110 A	160 A	110 A	140 A	110 A	140 A

Table 2

Chemical structure of the basic and welding materials, %

Material	C	Mn	Si	Cr	Ni	Fe	The note
08X25T	0.08	0.63	0.41	26.71	037	71.34	Ti = 0.83
P48M	0.05	1.2-1.4	0.3-0.5	0.15	0.30	97.6-98.0	S = 0.01
Cromarod 310	0.10	2.0-3.0	0.5-1.2	25.0-27.0	20.0-22.0	46.2-52.3	Mo = 0.1-0.5
Cromarod 430	0.10	0.3-0.5	0.7-1.0	24.0-25.0	0.10	73.3-74.8	S = 0.01

Table 3

Chemical structure of welds, %

Material	Electrode	C	Cr	Ni	Mn	Si	Fe
08X25T	P48M	0.072	14.11	0.32	0.82	0.36	84.35
08X25T	Cromarod 310	0.086	25.85	10.76	1.92	0.70	60.68
08X25T	Cromarod 430	0.084	24.80	0.18	0.42	0.61	73.90

3. Results and analysis

The comparative studies of microstructure of the weld material and the zone near the weld were done. The mechanism of destruction by a study also was determined.

The diagram of testing welding models is presented in Fig. 1. Possible diagrams of the formation of flex cracking of model are presented in Fig. 2.

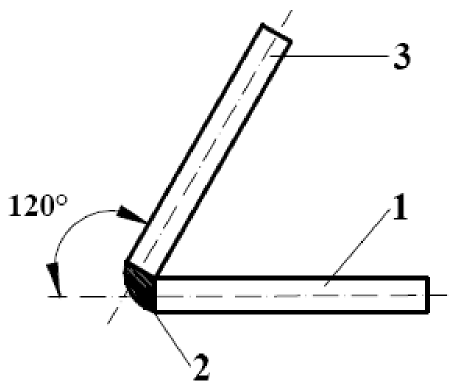


Fig. 1 Diagram of testing the welding models: *1*, *3* - base-metal, *2* - the weld

Connection breaking obtained by welding grade 08X25T steel by pearlitic P48M and by ferritic Cromarod 430 electrodes has quasi-brittle nature, according to the type both in the middle of weld and the dilution zone (Fig. 3). Connection breaking obtained by welding grade 08X25T steel by austenitic Cromarod 310 electrodes usually is viscous (with the separate starts of brittle).

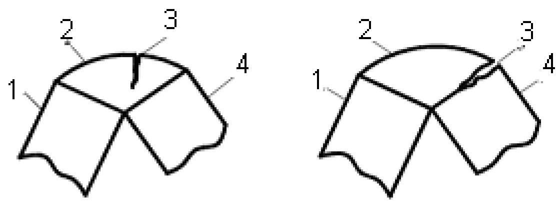


Fig. 2 Possible formation of flex cracking of the model: a - crack in the welde, b - crack in the heat-affected zone; *1*, *4* - base metal, *2* - weld, *3* - crack

Moreover when welding using copper electrodes microscopic cracks in the base metal are observed, and with the welding by ferritic Cromarod 430 electrodes in the weld material (Fig. 4) breaking the welded connection it became grade 08X25T steel by austenitic Cromarod 310 electrodes usually viscous (with the separate starts of brittle) according to the type in the dilution zone.

The comparative researches of microstructure of the weld metal and of the zone near to the weld were carried out at welding of heat-resistant steels.

For reliability estimating of a welded connection it is very important to know its strength and the character of a possible destruction. Martensite has high hardness and durability, also low plasticity. In the case of a martensitic structure of a welded joint, and when the upper limit of loading takes place, there can be fast fragile destruction. It is especially dangerous at shock or variable loading. In this case the reliability of a construction will be low and it can be used only at static loading. An austenite has lower durability and high plasticity. At presence of an austenitic structure in a welded joint and when the upper limit of loading is used, a slow (viscous) destruction takes place more often. The reliability of the construction in this case is much higher, as the beginning of destruction can be noticed in time and operation of the structure can be stopped without accident. It was considered, that the longer destruction takes, the reliability of it is higher.

Microstructures of the fusion zone and fracturegrams of the surface of destroyed weld obtained by welding steels grade 08X25T steel using various electrodes are presented in Figs. 3 - 6. **S**tructure of the welded metal can be determined using the Sheffler diagram taking average values of Ni and Cr.

$$Ni_{eq} = \text{of } \%\ Ni + 30\% \times (C + N) + 0.5\% \times Mn. \quad (1)$$

$$Cr_{eq} = \text{of } \%\ Cr + \%\ Mo + 1.5\% \times Si + 0.5\% \times Nb \quad (2)$$

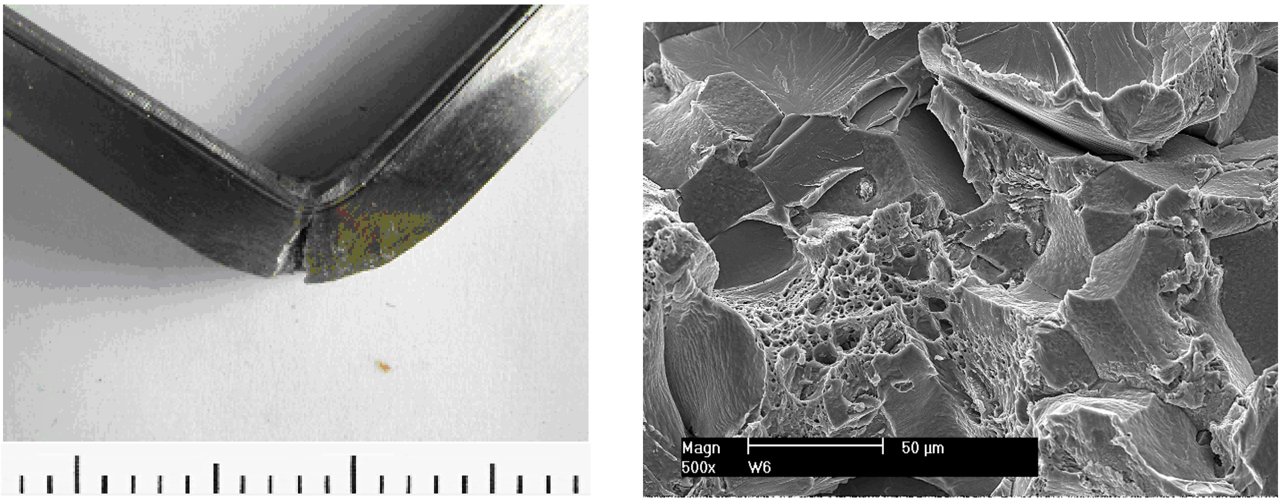
At welding grade 08X25T steel by electrodes P48M we have received Cr_{eq} = 14.65%; Ni_{eq} = 2.89%; Cr_{eq} / Ni_{eq} = 5.14; Cr_{eq} + Ni_{eq} = 17.50% < 30%. The received data shows, that structure of the weld should be martensitic-ferritic (under the Sheffler diagram, Fig. 7. – martensitic -ferritic).

Table 4

Structure of a welded on metal

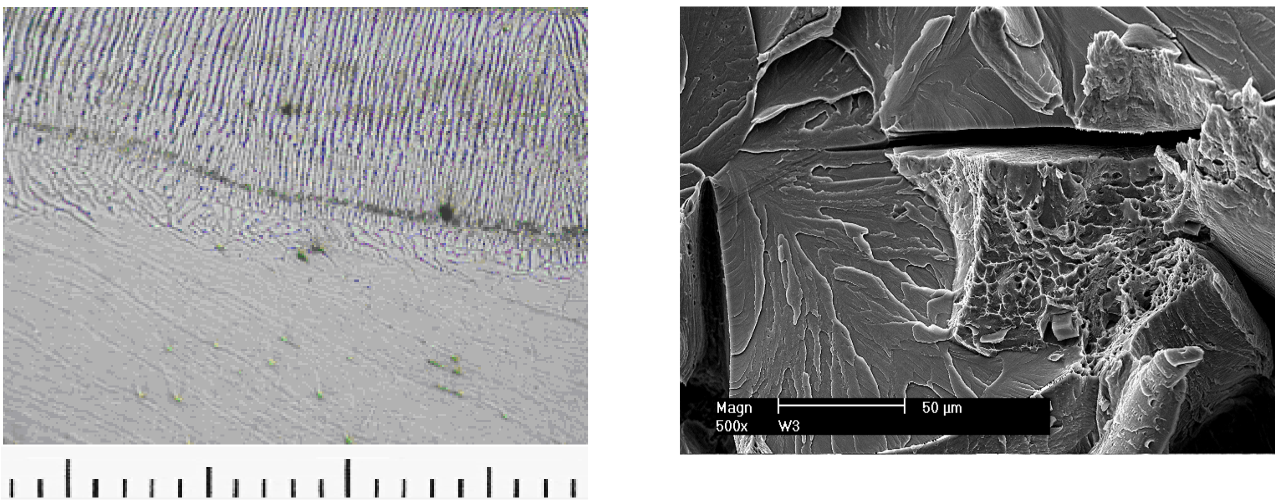
Cr_{eq}/ Ni_{eq}	Cr_{eq} + Ni_{eq}	Weld structure
< 2.5	< 30%	martensitic structure
> 2.5	< 30%	martensitic - ferritic structure
< 2.5	> 30%	ferritic structure
1.25-2.5	> 30%	austenitic - ferritic structure
< 1.25	> 30%	austenitic structure

At welding grade 08X25T steel by electrodes Cromarod 430 we have received Cr_{eq} = 25.72%; Ni_{eq} = = 2.95%; Cr_{eq} / Ni_{eq} = 8.84; Cr_{eq} + Ni_{eq} = 28.63% < 30%. The received data shows, that structure of the weld should be ferritic (under the Sheffler diagram, Fig. 7 – ferritic).



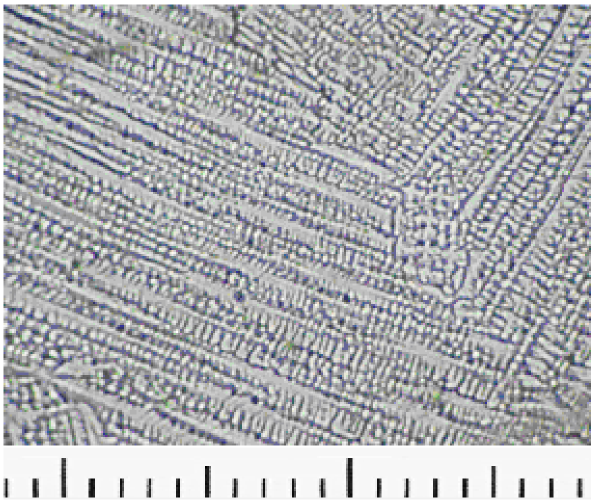
a b

Fig. 3 Fracture the welded connections obtained during the welding of grade 08X25T steel by perlitic electrodes P48M (a, mark size – 18 mm) and fracturegram (b) of breaking electrodes

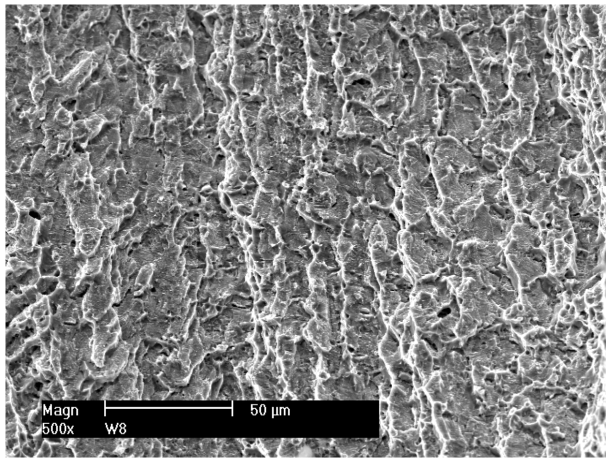


a b

Fig. 4 Dilution zone (a, mark size – 1 mm) and fracturegram (b) the welded connection in the heat-affected zone with the welding of grade 08X25T steel by the ferrite electrodes Cromarod 430

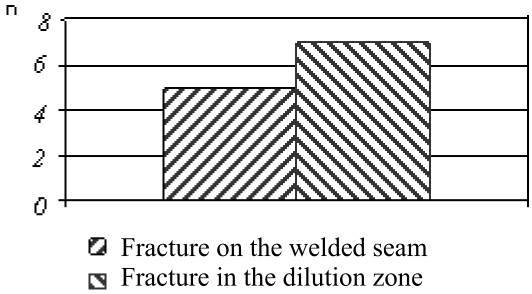


a

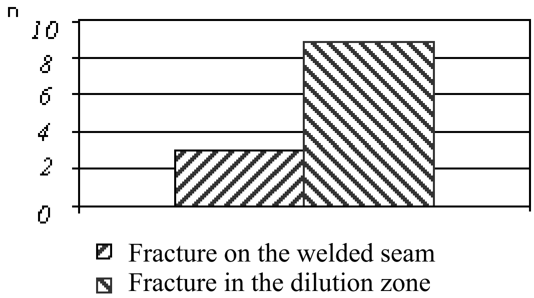


b

Fig. 5 The microstructure of weld metal (a, mark size – 1 mm) and the fracturegram of the weld (b) obtained during the welding of grade 08X25T steel by the austenitic electrodes Cromarod 310



a



b

Fig. 6 Types of fracture of models made from grade 08X25T steel welded by electrodes P48M and Cromarod 430 (a) or Cromarod 310 (b)

At welding grade 08X25T steel by electrodes Cromarod 310 we have received Cr_{eq} = 26.90%; Ni_{eq} = = 14.34%; Cr_{eq} / Ni_{eq} = 1.88; Cr_{eq} + Ni_{eq} = 41.20% > 30%. The received data shows, that structure of the weld should be austenitic-ferritic (under the Sheffler diagram, Fig. 7 – austenitic-ferritic, with 15% ferrite).

In the dilution zone, and also in the zone of overlap of the rollers, the microscopic cracks sometimes are observed with the presence of flux contaminations. When there are no welding defects, microscopic cracks are not observed.

When welding grade 08X25T steel with austenitic Cromarod 310 electrodes the weld hardness is 190 - 195 HV, dilution zone − 165 - 170 HV, base metal − 200 - 210 HV. When welding grade 08X25T steel with ferrite Cromarod 430 electrodes it is observed approximately the identical hardness of the weld material and zone − 180 - 185 HV near the weld, dilution zone − 180 - 190 HV. When welding grade 08X25T steel with pearlitic P48M electrodes the weld hardness is 195 - 220 HV, dilution zone − 240 - 270 HV, base metal − 200 - 210 HV. In the dilution zone, and also in the zone of overlap of the rollers, microscopic cracks sometimes are observed with the presence of flux contaminations. When there are no welding defects, microscopic cracks are not observed.

In Fig. 6 destruction frequency of the weld and in the heat-affected zone is shown. From the figure one can see that with the welding by ferrite and pearlitic electrodes the fracture equally is observed both in the heat-affected zone and on the weld. With the welding by austenitic electrodes the fracture most frequently is observed in the heat-affected zone.

Tables 5-7 shown the lengths of flex cracking of the welded model made from grade 08X25T steel by different electrodes. It is established also, that the formation of noticeable cracks (1 mm) begins with the angle of curvature 30 - 45° for all types of the electrodes and it reaches critical dimensions (4 - 5 mm) with the angle of 80 - 90° for the ferrite and pearlitic electrodes; for the austenitic electrodes – 100 - 120°.

Table 5

Length of crack and angle of curvature of the model

Designation of the models	1A					1B				
Angle of curvature	30°	45°	60°	90°	120°	30°	45°	60°	90°	120°
Length of crack, mm	1.5	2.2	3.5	5.8	-	1.0	1.6	3.0	5.6	7.5

Table 6

Length of crack and angle of curvature of the model

Designation of the models	2A					2B				
Angle of curvature	30°	45°	60°	90°	120°	30°	45°	60°	90°	120°
Length of crack, mm	-	1.1	2.5	5.0	7.2	-	1.3	2.5	4.8	7.0

Table 7

Length of crack and angle of curvature of the model

Designation of the models	3A					3B				
Angle of curvature	30°	45°	60°	90°	120°	30°	45°	60°	90°	120°
Length of crack, mm	-	1.0	2.0	3.8	6.0	-	1.1	2.2	4.5	6.3

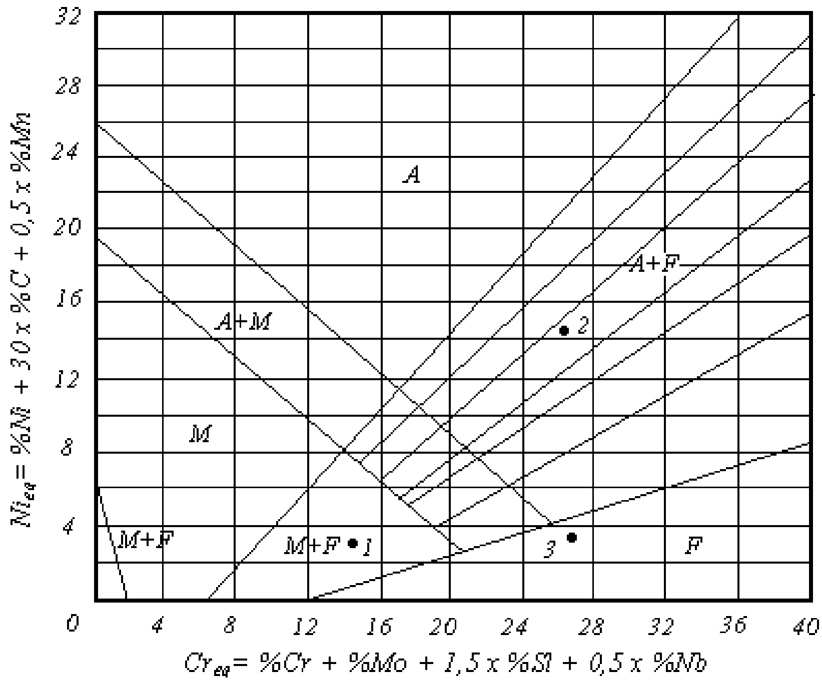


Fig. 7 Structures of weld metal on Sheffler diagram; *1* – structure of a weld at welding grade 08X25T steel by pearlitic electrodes P48M; *2* – structure of a weld at welding grade 08X25T steel by austenitic Cromarod 310 electrodes; *3* – structure of a weld at welding grade 08X25T steel by ferritic Cromarod 430 electrode

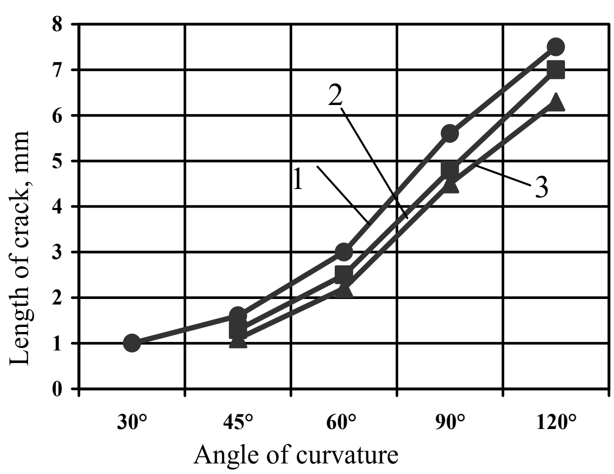


Fig. 8 The dependence of the length of crack on the angle of curvature of welding models when welding by grade 08X25T steel by the different electrodes: *1* - P48M electrodes; *2* - Cromarod 430 electrodes; *3* - Cromarod 310 electrodes

Fig. 8 shown the dependence of the curvature angle of the model on the value of the crack generation. It is established that crack length is the largest with the welding by pearlitic and ferrite electrodes.

4. Conclusions

1. Destruction of the welds welded by austenitic electrodes has viscous nature with the individual sections of quasi-brittle destruction, and the welds welded by ferritic and pearlitic electrodes – intermediate nature.

2. With the bend of the welded joint of grade 08X25T steel the destruction more frequently is observed in the heat-affected zone and it is thinner in the weld itself.

3. The formation of noticeable cracks (1 mm) begins with the angle of curvature 30 - 45° for all types of the electrodes and it reaches critical dimensions (4 - 5 mm) with the angle of 80 - 90° for the ferrite and pearlitic electrodes; for the austenitic electrodes – 100 - 120°.

References

1. **Akulov, A.I.** Technology and the Equipment for Fusion Welding and Thermal Cutting.-Moscow: Machinostroenie, 2003.-560p. (in Russian).
2. **Anderson, T.L.** Fracture Mechanics. Fundamentals and Applications.-London: CRC Press. I nc., 1993. -693p.
3. **Jankauskas, V., Kreivaitis, R., Stonkus, D., Andriušis, A.** Research of strengthening plough parts by welding. -Mechanika. -Kaunas: Technologija, 2008. Nr.1(69), p.80-84.
4. **Meadows, C., Fritz, J.D.** Understanding stainless steel heat-affected zones. -Welding Journal, 2005, v.84(7), p.26-30.
5. New Materials. Under the scientific editorial staff of U.S. Karabasova. **-**Moscow: Misis, 2002.-736p. (in Russian).
6. **Chromichenko, F.A.** Reference Benefit of the Electrowelder. -Moscow: Machinostroenie, 2003.-416p. (in Russian).
7. **Neimitz, A.** Cracks Mechanics. Scientific Publishing House PWN SA Warsaw, 1998.-436p. (in Polish).
8. Weld Designs. Mechanics of Suitability/ Vinokurov, V.A., Kurkin, S.J., Nikolaev, G.A. / Edited by Paton, B.T.-Moscow: Machinostroenie, 1996.-576p. (in Russian).
9. **Vaičiulis, D., Braženas, A.** Stress strain state of mechanically heterogeneneous welded joint with mild sguare butt weld subjected to elastic pure bending. -Mechanika. -Kaunas: Technologija, 2007, Nr.1(63), p.5-10.
10. **Vishniakas, I., Lobanovski, J.** Reliability estimation of the dissimilar welded joints. -Materials and Technologies, 2005, No3, p.291-297.
11. **Vishniakas, I.** Reliability estimation of the ferritic steels welded joints. -Mechanika. -Kaunas: Technologija, 2006, Nr.6(62), p.68-72.

I. Višniakas

FERITINIŲ PLIENŲ SUVIRINTŲJŲ JUNGČIŲ SUIRIMO YPATUMŲ TYRIMAS

R e z i u m ė

Atlikti karščiui atsparaus (iki 1100°C) feritinės klasės plieno 08X25T (X8CrTi25, EN 10028-2) jungčių, suvirintų rankiniu lankiniu būdu (111 LST EN 24063) perlitinės, feritinės ir austenitinės klasių elektrodais, tyrimai. Nustatyta, kad tiriamieji sujungimai dažniausiai suyra terminio poveikio srityje, rečiau suyra pati siūlė. Jungtys suvirintos perlitinės klasės elektrodais, dažniausiai suyra trapiai, rečiau suirimas būna tarpinio pobūdžio. Austenitiniais elektrodais suvirintų jungčių suirimas dažniausiai būna plastiškas, rečiau – tarpinio pobūdžio.

I. Vishniakas

STUDY OF THE SPECIAL FEATURES OF BREAKING THE WELDED CONNECTIONS OF THE FERRITIC STEELS

S u m m a r y

Were investigated the special features of breaking the welded joints of the high-temperature (oxidation-resistant) (up to 1100°C) of the ferrite class of steel grade 08X25T steel (X8CrTi25, EN 10028-2) by the executed manual arc welding (111 LST EN 24063) by the electrodes of pearlitic, ferrite and austenitic classes. It is established that in the joints being investigated destruction more frequently is observed in the heat-affected zone and it is thinner in the weld itself. Breaking of the welded connections executed by the electrodes of pearlitic class more frequently had brittle character, is thinner intermediate. Breaking the welded connections executed by austenitic electrodes more frequently had plastic nature, thinner - intermediate.

И. Вишнякас

ИССЛЕДОВАНИЕ ОСОБЕННОСТЕЙ РАЗРУШЕНИЯ СВАРНЫХ СОЕДИНЕНИЙ ФЕРРИТНЫХ СТАЛЕЙ

Р е з ю м е

Исследовались особенности разрушения сварных соединений жаростойкой (до 1100°C) ферритного класса стали 08X25T (X8CrTi25, EN 10028-2), выполненных ручной дуговой сваркой (111 LST EN 24063) электродами перлитного, ферритного и аустенитного классов. Установлено, что в исследуемых соединениях разрушение чаще наблюдалась в зоне термического влияния и реже в самом шве. Разрушение сварных соединений, выполненных электродами перлитного класса, чаще имело хрупкий характер, реже промежуточный. Разрушение сварных соединений, выполненных аустенитными электродами, чаще имело пластический характер, реже – промежуточный.

Received March 19, 2008