

NEW GENERATION ELECTRIC-WELDED PIPES FOR METALLIC BUILDING STRUCTURES

ЭЛЕКТРОСВАРНЫЕ ТРУБЫ НОВОГО ПОКОЛЕНИЯ ДЛЯ МЕТАЛЛИЧЕСКИХ СТРОИТЕЛЬНЫХ КОНСТРУКЦИЙ

Prof., Dr Sc. Vedyakov I.I.¹, Prof., Dr Sc. Odesskiy P.D.¹, Sc. Ass. Gurov S.V.¹, Sen. Sc., PhD Arsenkin A.M.²

V.A. Kucherenko Central Research Institute of Building Structures of JSC «Research Center «Building»¹,

A.A. Baikov Institute of Metallurgy and Materials Science of Russian Academy of Sciences²

E-mail: tsnisk@rambler.ru, odesskiy@tsniisk.ru, x25xe@mail.ru, alex_arsenkin@yahoo.com

Abstract:

Investigation of low carbon microalloyed API 5L X80 steels for electric-welded pipes applied in building of metallic structures of different complexity. Problems of weldability of these steels and effect of technological and structural factors on mechanical properties of weld seams have been considered. Also mechanical characteristics at cyclic loading of the steels are considered.

KEY WORDS: LOW CARBON MICROALLOYED API 5L X80 PIPE STEELS, WELDABILITY, WELD SEAMS, MICROSTRUCTURE, IMPACT TOUGHNESS, FRACTURE RESISTANCE.

1. Introduction

Circular section pipes as a building structure element has several essential advantages compared with shaped or thick sheet rolled metal both in reduction of steel intensity of building structure and in the case of such specific actions to building structure as corrosion, high temperature at fire and wind [1-3]. Moreover constructions made of pipes have high architectural expression. Pipes of large diameters milled on metallic construction works were applied in erection of unique constructions for a long time [4]. Roof structures of covered skating center in Moscow are supported by pipe \wedge -bearing with height 50 m and outer diameter 2,5 m and pipe wall thickness 20-50 mm with cable-stayed structure. The pipe was made of 0.1C-Cr-Si-Ni-Cu steel, contained low concentrations of S and P (0.010 and 0.012%, respectively) and had $\sigma_{0.2} = 390\text{MPa}$ and $KCV^{60} = 60\text{J/sm}^2$.

Wide usage of pipes in building industry appeared to be possible due to adoption of technology of massive pipe production.

At building of stadiums and the other unique constructions pipes with large diameters (530-1420mm) and high strength grade are widely used (table 1).

Table 1 – Mechanical properties of steels for building structures

Mechanical properties	Strength grade		Temperature, °C
	C390	C440	
σ_b , MPa	540-730	590-770	+25
$\sigma_{0.2}$, MPa	390	480	+25
δ_5 , %	20	20	+25
KCV, J/sm ²	34	34	-40

2. Preconditions and means for resolving the problem

For building of stadium in Kazan pipes $\varnothing 1420 \times 45,8$ mm (1) with $\sigma_{0.2} = 480\text{MPa}$, $\varnothing 1220 \times 30\text{mm}$ (2) with $\sigma_{0.2} = 390\text{MPa}$, $\varnothing 820 \times 40\text{mm}$ (3) with $\sigma_{0.2} = 480\text{MPa}$ were investigated. Table 2 presents chemical composition of steels under the study.

Table 2 – Chemical composition pipe steels according to the results of control tests

Pipe	Element content, %						
	C	Mn	Mo	Nb	V	S	P
1	0.07	1.55	0.1	0.05	0.08	0.002	0.01
2	0.08	1.51	0.01	0.04	0.05	0.003	0.01
3	0.07	1.39	0.22	0.05	0.03	0.004	0.01

It should be noticed that hydrogen content was on snowflake nonhazardous level. Table 3 presents mechanical properties of steels under the study.

Table 3 – Mechanical properties of pipe steels under the study

#	Mechanical properties						
	$\sigma_{0.2}$	σ_b	δ_5	Ψ_z	KCV-40	KCV-60	HV
	MPa		%		J/sm ²		
1	520-670	610-700	20-28	60-70	>300	175-300	219-254
2	480-560	570-620	20-30	70-81	>300	275-300	138-183
3	520-600	610-710	22-27	72-76	>300	180-325	193-230

Investigation of mechanical properties of pipe steels under cyclic elastic-plastic deformation has been conducted with cylindrical samples with size $\varnothing 12 \times 60$ mm under tension-compression on "soft" cycle (at constant swing of stress) at asymmetry coefficient $R = -1$. Extremely high impact toughness of the steels is caused by thermo-mechanical treatment during rolling in γ -area near A_{r3} -point with accelerated cooling to $(\gamma + \alpha)$ - area, low concentrations of harmful impurities and gas elements that provide formation of fine microstructure evaluated by transmission electron microscopy [5]. Microstructure represents grains of quasipolygonal ferrite with size $1-2 \mu\text{m}$ possessing developed substructure and lathlike bainite (fig. 1, 2) [6].

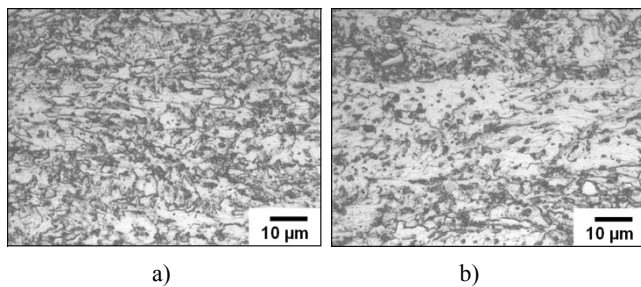


Figure 1 – Microstructure of the steels under the study: quasipolygonal ferrite (a) and lathlike bainite (b) (light microscopy)

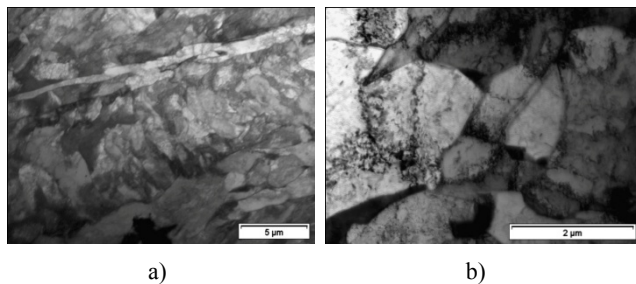


Figure 2 – Images of lathlike bainite (a) and quasipolygonal ferrite (b) obtained by transmission electron microscopy

Weldability of the C440 steels has been investigated in details. Analysis of heat-affected zone, seam zone has been conducted where seam structure has lowest properties. Kinetics of phase transformation of austenite in a range of cooling rates, mechanical properties of seam zone material, propensity to forming of cold cracks have been studied. At making of TTT-diagram simulated structure of seam zone has been obtained by induction heating of billets $6 \times 10 \times 55$ mm up to temperature 1300°C and subsequent cooling with rates $0.1-300^\circ\text{C/s}$.

Hard martensite constituent responsible for formation of cold cracks, appears at the cooling rate after $> 100^\circ\text{C/s}$, which is higher than cooling rate at welding of root technological seams and essentially higher than cooling rate of seam zone at construction welding. Criterion of exclusion of cold cracks is hardness $\leq 320\text{HV}$.

In this case absence of cold cracks can be guaranteed at any type of welding applied in making of steel constructions including welding of root seam without of preliminary, accompanying and sequential heating.

Dependence of impact toughness on considered cooling conditions has been studied. The results of tests showed that in cooling rate range $2-8^\circ\text{C/s}$ dip of impact toughness happened, associated with formation of ferrite and bainite mixture.

Strength of welds at testing of the samples cut from joint has been evaluated. At tension testing the samples were fractured on base metal, out of heat affected zone, showing typical mechanical properties for base metal. Bending test showed that on expanded side there was no cracks up to 180° bending angle.

Results of impact bending test are presented in table 4.

Table 4 – Results of impact bending test

	Impact toughness, J/sm^2 at $t^\circ\text{C}$		
	-20	-40	-60
KCV	97	55	28
KCU	-	69	76

Next aspect which we investigated in this work was behavior of pipe steel at cyclic loading. After first cycle of loading hysteresis loop is disconnected that is associated with Bauschinger effect i.e. action of compressing loading induces decreasing of resistance to small plastic deformation, so reaching of stress level corresponding to tension stress deformation value has to exceed value reached at a tension (fig.3).

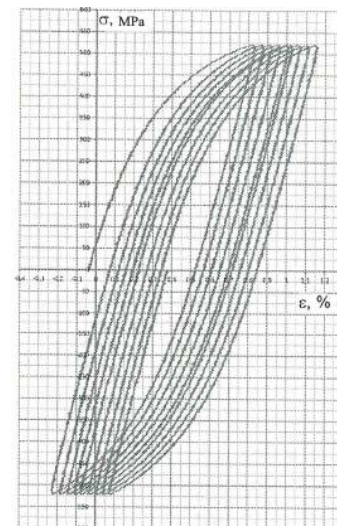


Figure 3 – Typical mechanical hysteresis loop of the steels under cyclic loading "tension-compression"

Analysis of tests results under repetitive "soft" loading showed that width of plastic hysteresis loop stabilizes in first loading cycles i.e. materials under the study are cyclically stable. Cyclic stability of the materials is caused by firstly developed subgrain structure. Effect of disordered dislocation nets is nonessential since such

material is normally cyclically softened. Secondly cyclic ductility of these materials and particularly plastic hysteresis loop width are twice higher than plastic steels for building structures have. This effect can be explained by not only high ductility but microstructure and properties inhomogeneity which enhance damping ability of these steels.

3. Conclusion

The steel under the study possesses wide favorable range of cooling rates, in which high resistance of brittle fracture at electric welding is provided.

Weldability completely corresponds to standard requirements. Considered steels have very good weldability that making of constructions has confirmed.

Application of steels under the study is reasonable in seismic active regions building since seismic oscillations are naturally low frequent.

4. Literature

1. F.C. Feher, A.K. De and M. Manohar: Value-added Nb microalloyed construction steels. Symp. Proc. Singapore, 2012, pp. 45-54.
2. L.M. Silvestre, R.J. Pimenta, M. A. Stuart Nogueira et al.: Value-added Nb microalloyed construction steels symp. Proc. Singapore, 2012, pp. 89-102.
3. M. King, W. Whitby, G. Hanshaw: Value-added Nb microalloyed construction steels symp. Proc. Singapore, 2012, pp. 3-40.
4. K.S. Sivakumaran: Value-added Nb microalloyed construction steels symp. Proc. Singapore, 2012, pp. 103-114.
5. G. Krauss: Steels Processing Structure and Performance, ASM International Materials Park, Ohio, 2005, pp 230-32.
6. A. B. Arabei, V. M. Farber, I. Yu. Pyshmintsev, A. G. Glebov, O. V. Selivanova, N. V. Lezhnin, and V. E. Bazhenov: Steel in Translation, 2012, Vol. 42, No. 1, pp. 14–21.

Acknowledgment

This work was financially supported by Russian Foundation of Basic Research, grant # 14-03-31291.