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REASONS FOR LOW TECHNOLOGICAL PLASTICITY ABOUT THE PROBLEMS OF LOW TECHNOLOGICAL PLASTICITY OF STEEL 04H14T3R1F USED IN THE PRODUCTION OF PIPES FOR NUCLEAR ENERGY

ПРИЧИНИ НИЗЬКОЇ ТЕХНОЛОГІЧНОЇ ПЛАСТИЧНОСТІ СТАЛІ 04Х14Т3Р1Ф, ЩО ВИКОРИСТОВУЄТЬСЯ ПРИ ВИРОБНИЦТВІ ТРУБ ДЛЯ АТОМНОЇ ЕНЕРГЕТИКИ

Gubenko S.I.,
DSc (Engineering), Professor, Iron and Steel Institute of Z.I. Nekrasov of the National Academy of Sciences of Ukraine; Ukrainian State University of Science and Technologies: ESI Prydniprovska Academia of Civil Engineering and Architecture, Dnipro, Ukraine

Губенко С.І.,
д.т.н., професор, с.н.с., Інститут чорної металургії імені З.І. Некрасова Національної академії наук України; Український державний університет науки і технологій: ННІ Придніпровська академія будівництва та архітектури, м. Дніпро, Україна

Bespalko V.M.,
PhD (Engineering), Senior Researcher

Беспалько В.М.,
к.т.н., с.н.с

Introduction. When boron is introduced into steel, a large quantity of borides is formed, which negatively affects its mechanical properties and technological ductility during the production of hot-rolled pipes [1]. The **goal of the work** was to study the influence of boride inclusions on the mechanical and technological properties of 04H14T3R1F steel.

Materials and Procedures. The studies were carried out on the samples taken from pipe blanks, as well as from hot-rolled pipes made of steel 04H14T3R1F. Deformation by oblique rolling was carried out in the temperature range 850...1150 ºC (feed angle 5º30', roll rotation speed – 40 rpm). Tensile tests were carried out according to GOST 1497, in addition, tensile tests were carried out at elevated temperatures (Instron 1195). The microstructure of steel was studied using an optical microscope "Neophot – 31" and a scanning electron microscope JSM 35.

Results of investigation. Steel 04H14T3R1F contains a large amount of boride phases of the two types: light and dark inclusions, the latter being heterophase. The volume fraction of dark and light borides in the steel structure was 2.7 and 3.5% (vol.), respectively. Large borides were brittlely destroyed during hot deformation; due to the localization of stresses near inclusions, microcracks arose and the destruction of borides was facilitated.

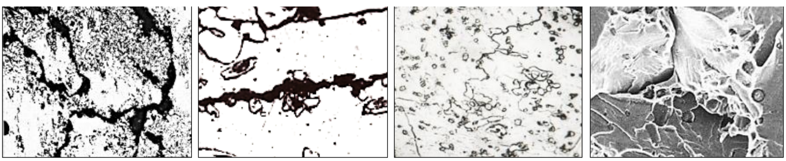
The content of elements in borides of various types and in the ferrite matrix after deformation at temperatures of 1100, 1150°C was analyzed. Dark borides are heterophase inclusions of complex composition, their base is a complex boride $(Ti,Fe,Cr,V)_2B$, and the shell is a boride $(Ti,Cr,V)_2B$, in which there is a phase containing V. Analysis of the content of alloying elements in light borides at a temperature of 1100 °C showed that they are inclusions based on Fe, Cr – $(Fe,Cr)_2B$. When the deformation temperature increases to 1150°C, a change in the composition, structure and shape of borides occurs, which is associated with the diffusion redistribution of chemical elements in the borides. The study of thermogravimetric analysis curves indicates transformations in the boride inclusions themselves. DTA curves are due to transformations in borides. Perhaps, at a higher deformation temperature, the boride transformation $(Ti,Fe,Cr)_2B \rightarrow (Fe,Cr)_2B$ occurs. Boride transformation is also possible during the heating process of 04H14T3R1F steel under deformation, or during cooling after deformation

The mechanical and technological properties of 04H14T3R1F steel are largely determined by the initial structure of the pipe blank, as well as the possibilities of its transformation during the process of plastic deformation (Fig. 1). In the samples taken from the workpiece and sleeves after the first piercing, large borides of both types are present. A significant change in mechanical characteristics, especially ductility, occurs during the process of piercing a pipe blank into a sleeve, where the main deformation of the metal occurs (Table 1).

Table 1

Mechanical characteristics of steel 04H14T3R1F

Metal condition	**ultimate strength, MPa**	**yield point, MPa**	**specific elongation, δ %**	**Impact strength, KCU, J/cm²**
Initial workpiece	435…452	320…372	8,2…10.3	5,1…6,2
sleeve	480…510	310…330	16,0…18,5	6,3…7,4
Hot rolled pipe	550…586	410…445	13,0…15,5	10,2…19,2



a b c d

Fig. 1. Microstructure of steel 04H14T3R1F after hot deformation at temperatures of 1150 (a), 1050 (b) and 950 °C (c), as well as fracture after dynamic tests (d); a, c – x 200, b – x600, d – x500

Mechanical tensile tests were carried out to determine the mechanical characteristics of 04H14T3R1F steel at elevated temperatures (Table 2). Thus, the test results showed that the use of elevated temperatures during piercing (1150 °C) and rolling pipes on an automatic TPA 350 installation (1050 °C) is undesirable. Research was carried out to determine the optimal temperatures and degrees of deformation during rolling on an automatic installation and the influence of temperature-deformation parameters of rolling on the development of destruction processes in steel 04H14T3R1F under dynamic loading (Table 3).

Table 2

Mechanical characteristics of steel 04H14T3R1F at elevated temperatures

property	test temperature, °C							
	850	**900**	**950**	**1000**	**1050**	**1100**	**1150**	**1200**
ultimate strength, MPa	92,3	78,1	56,4	46,2	38,5	35,6	29,3	23.2
yield point, MPa	81,2	62,4	51,3	39,3	32,4	29,6	25,4	22,4
specific elongation, δ, %	61,4	64,0	71,8	76,3	62,3	66,4	46,2	18,7
contraction ratio, ,ψ %	68,3	72,1	75,4	81,2	87,2	92,5	69,1	33,4

Table 3

Values of impact strength of steel 04H14T3R1F after deformation at various rolling parameters

Deformation degree, ε, %	Impact strength, KCU, J/cm², after deformation at temperatures				
	850 °C	**900 °C**	**950 °C**	**1000 °C**	**1050 °C**
20	4,7	7,3	5,0	5,0	5,0
34	4,4	20,8	10,4	5,0	5,0
50	4,7	5,0	5,0	5,0	5,0

In the process of hot deformation, phase and structural transformations occur: a change in the composition of borides due to the redistribution of elements, dynamic diffusion crushing and separation of "satellite" particles, brittle destruction of borides, boride transformation, as well as melting of inclusions. Boride inclusions in the process of hot deformation are not plastic and are the sources of the appearance of cracks, which contributes to a decrease in the technological plasticity of 04H14T3R1F steel. The study of the behavior of boride inclusions during hot pressure treatment of steel and their influence on the formation of the structure of the deformed matrix, the development of destruction near the inclusions, as well as the mechanical properties made it possible to determine the treatment regimes (temperature and degree of deformation) that contribute to obtaining an optimal structure that provides increased impact *strength* of 04H14T3R1F steel.

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