PECULIARITIES OF THE PROPERTIES OF HIGH-NITROGEN STAINLESS STEEL WELDS

St .Christov, V. Ushev, Z. Manilov *

Using nitrogen to replace nickel in stainless austenitic steels creates a number of problems in their welding. One of them is the lower strength of the weld metal than this of the base metal. To this end the results of the studies aiming creation of a suitable system of electrode metal alloying are presented in the paper. The optimum contents of the elements Cr, Ni, Mn in relation to the strength parameters of the electrode metal as well as in relation to its phase content is established. Strength parameters of welds of Cr18NMn12 steel obtained by welding with the optimum electrode material are estimated.

INTRODUCTION

High nitrogen austenitic steels represent a new and perspective structural material (1). However now they are hardly used for welded joints and structures because of their low weldability. The main reasons are the lower mechanical properties of the weld as compared to those of the base metal.

The low weld strength is due to the reduced nitrogen contents in the welded seam. For example, Cr18NMn12 steel contains about 0.7% of nitrogen. But that steel is produced under special conditions:pressure of 1,0 to 1,5 MPa, pouring temperature of about 1600°C, crystallization under pressure.

Under normal (atmospheric) pressure equilibrium concentration of nitrogen in the molten metal at 1600°C is within 0,3 to 0,5 % depending on the chemical composition (2). Welding pool is characterized by a small volume, high heating and cooling rates and high thermodynamic non-equilibrium of the processes. Results of our investigations show that in

* Institute for Metal Science and Technology,
Bulgarian Academy of Sciences

manual arc welding nitrogen concentration in weld deposited material, i. e. weld metal, can be maintained within the range of 0,3 to 0,45 %. In welding under atmospheric pressure of 0,1 MPa nitrogen releases in the form of vapour. The results of this phenomenon are ferritizing of the weld metal, pore formation and decrease of weld metal strength characteristics. In order to prevent denitration two approaches are possible - controlled atmosphere and pressure welding (3) and selection of an optimal system for weld metal alloying (4). The first method is more effective, but it is expensive and can be used only for small size joints. Advantages of the second method are versatility and convenience, and although it is not as effective as the first one it can lead to possitive results (5).

EXPERIMENTAL PROCEDURE AND RESULTS

The objective of our investigations is to find a system for weld metal alloying in Cr18NMn12 steel welding which can give optimal ferritizing of the weld metal with maximum strength parameters and absence of pores in it. To achieve this objective a planned experiment has been carried out (6) with varying Cr, Mn and Ni contents.

For comparison we have to say that Cr18NMn12 steel, as quenched from 1150°C and water cooled, has a conventional yield strength Re of 450-750 MPa and Brinell hardness of 210-310 HB. From about 0,4% N every 0,1% of N increases Re by approximately 36 MPa and HB by 12,2. The steel plasticity is over 40 % for the whole N-range from 0,3 to 1,0 %.

Based on really obtained values for Cr, Mn and Ni regression equation have been derived. The form of the equation is:

$$Y_i = A + BX_1 + CX_2 + DX_3 + EX_1X_3$$

where Yi (i = 1 to 4) is one of the four characteristics Re, Rm, A, ferrite number; X1 to X3 are concentrations of Cr, Mn and Ni in the all-weld metal; A, B, C, D, E are coefficients given in Table 1.

Cromium in the all-weld metal varies from 21,70 to 26,76 %, manganese from 3,44 to 4,50 % and nickel from 7,53 to 8,90. These values determine the domain of definition of factors variation. Within the

TABLE 1. COEFFICIENT OF REGRESSION EQUATIONS

Coefficient of regression Measure	Y_1 - Yield strength [MPa]	Y_2 - Tensile strength [MPa]	Y_3 - Relative elongation [%]	Y_4 - Ferrite number [%]
A	602,6	927,5	60,7	-68,9
B	1,25	1,01	-2,5	4,25
C	0,477	2,56	-1,98	3,35
D	-3,14	-4,07	1,96	-4,86
E	-	-	0,14	-
F	8,19	1,36	89,6	8,92
R	0,96	0,819	0,998	0.98

it by 5,98. Together with that all-weld metal plasticity is within the ranges of 24,33% to 35,45% and tensile strength within the ranges of 930,7 to 976,7 MPa, respectively. It is obvious that plasticity is within acceptable limits, while tensile strength is not substantially influenced by the variation of chemical composition in that range. Based on the results the conclusion can be drawn that the basic elements influencing yield strength and ferritic number are chromium and nickel. Any substantial changing of electrode metal parameters can be observed only through varying the contents of these elements.

Strength parameters of welded joints, made by means of that set of electrodes do not substantially differ from those of the all-weld metal. Tensile strengths of V-prepared weld joints having 12 mm thick plates for the eight types of electrodes, are within the range of 850 to 930 MPa. These values are approximately 10 % lower than those of the all-weld metal.

Ferrite contents in the weld depending on Cr, Mn and Ni contents in the electrode metal can be describe by the regression equation:

$$Y = 1073 + 0{,}24X_1 - 26{,}74X_2 - 240X_3 - 8{,}7X_1X_2 + 4{,}4X_1X_3 + 30X_2X_3$$

where Y - ferritic number of weld metal; X_1 - Cr content in electrode metal; X_2 - Mn content in electrode metal; X_3 - Ni content in electrode metal.

Coefficient of multiple correlation of this equation is 0,96. The equation is adequate. Nickel has a very strong possitive effect on the ferrite decrease while Cr and Mn effects are less substantial. Nitrogen influence can be seen through the negative correlation coefficient (N,ferrite) = -0,676 although N is not included in the equation as a factor. Precipitation of ferrite in the heat affected zone in the proximity of the fusion line has been established for all weld joints and varies within the range of 1,1 to 4,75 %. Most probably this is due to metal denitriogenization near the fusion line.

CONCLUSION

Qantitative estimation of Cr, Mn and Ni effects on the strength parameters of the electrode metal and its ferrite contents has been obtained. The quality of Cr18NMn12 steel weld joints made by means of above mentioned electrodes has been evaluated. The presence of ferrite in the head affected zone has been established, most probably due to the redistribution of nitrogen under the influence of the welding thermal cycle.

SYMBOLS USED

Re = Yield strength (MPa)
Rm = Tensile strength (Mpa)
A = Relative elongation (%)
F = Fisher coefficient
R = Coefficient of multiple correlation

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