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CHEMICAL COMPOSITION AND STRUCTURE OF THE WELD METAL STAINLESS STEELS DEPENDING ON THE SHIELDING GAS COMPOSITION

Behar Alić
Metalurški institut "Kemal Kapetanović"
Zenica
BiH

Sead Pašić, Edin Džiho
Mašinski fakultet Mostar
Mostar
BiH

Sead Avdić
"Institute Of Welding" d.o.o. Tuzla
Ul. Tušanj br. 66, 75000 Tuzla
Bosnia and Herzegovina

ABSTRACT
Thanks to the processes that may occur due to the high temperatures prevailing in the electric arc, in welding processes with gas protection enabled the introduction of nitrogen from the inert gas in the weld metal, or alloying of the weld metal with nitrogen. The consequence of alloying with nitrogen is a change of chemical and structural composition, ie changes characteristics of the weld metal and welded joint at large. This paper presents the results of testing the chemical composition and delta ferrite content depending on the nitrogen content in the shielding gas.
Keywords: *stainless steel, nitrogen, structure, austenite, ferrite, ferrite number*

1. INTRODUCTION
Since in the pillar of arc temperatures exceed 5000 K, it is possible to reeling processes of dissociation of molecular gases (H2, O2, N2) into the atomic gases (H, O, N). In liquid metal gases are easier to dissolve into their atomic than in the molecular form, which in liquid weld metal can be achieved by a higher content of nitrogen than in liquid metal in which nitrogen dissolves under equilibrium conditions. In this case, dissolution of nitrogen in liquid metal (weld metal) does not obey the so-called square root law, or Sivert's law, but its content in the weld metal is more proportionate to its partial pressure in the atmosphere above the liquid metal. As strong gamagenous element, nitrogen contributes to increasing the stability of austenite, ie to reducing the content of delta-ferrite. The presence of delta ferrite, in principle, is not desirable in the austenitic stainless steels, however, due to the decreased tendency of the steel to occurrence of hot cracks, the presence of delta ferrite in a small volume is desirable. In literary sources different data can be found on the limits in which the content of delta ferrite is desirable, however, most of the authors agree to the minimum content of 3%.

2. EXPERIMENTAL PROCEDURE
The experiment was carried out welding stainless steel sample sheets 6 mm thick, with the tag X5CrNi 18 and 10 in accordance to EN 10088-2. The samples were prepared with a "V" groove, with

the angle of the groove opening of 60º, a space in the roots groove of 2,4 mm and the height of the root portion of the groove of 2 mm.

Table 1. Comparative chemical composition of welded steel with the standards prescribed chemical composition

Designation	Chemical elements [$\%_{mas.}$]								
	C	Si	Mn	P	S	Cr	Ni	Mo	N
X5CrNi 18 10 (EN 10088-2)	max. 0,07	max. 1,00	max. 2,00	max. 0,045	max. 0,030	17,5÷19,5	8,0÷10,5	---	max. 0,11
Shavings from plates	0,04	0,34	1,20	0,007	0,006	18,8	9,5	0,22	0,05

Welding sample was conducted as mechanized, using the devices for TIG welding device equipped with an automatic supply of filler material (wires) and the mechanized moving carrier with a given sample rate, with a stationary torch. For samples welding filler material marked as ER 308 L Si, according to AWS A 5.9. is used. Chemical composition of filler material was tested and compared to catalog values of the manufacturer. The results are given in Table 2.

Table 2. Comparative chemical composition of the sample wires and catalog value manufacturers

Designation	Chemical elements [$\%_{mas.}$]								
	C	Si	Mn	P	S	Cr	Ni	Mo	N
ER 308 L Si (Catalog)	< 0,03	0,85	1,70	P + S <0,035		20,00	10,00	0,15	-
A sample of wire	0,03	0,80	1,90	0,007	0,007	20,10	9,90	0,07	0,06

As a the shielding gas the pure argon and argon gas mixtures with 1.25 and 2.50% nitrogen by volume is used. Welding parameters are determined on the basis of preliminary welding samples, and are given in Table 3.

Table 3. Welding parameters

Designation of the sample	Current [A]	The nitrogen content in the argon [%]	Voltage (to the layers) [V]			The speed of the wires (to the layers) [m/min]			Speed welding [cm/min]
			I	II	III	I	II	III	5
11AN0	110	0,00	11,20	10,40	11,60	0,30	0,26	0,18	5
11AN1	110	1,25	9,80	10,90	10,69	0,30	0,26	0,18	5
11AN2	110	2,50	9,50	11,30	12,87	0,30	0,26	0,18	5
13AN0	130	0,00	9,90	12,35	12,73	0,30	0,26	0,18	5
13AN1	130	1,25	10,67	13,02	14,07	0,30	0,26	0,18	5
13AN2	130	2,50	10,46	12,68	14,90	0,30	0,26	0,18	5
15AN0	150	0,00	11,20	13,90	14,90	0,30	0,26	0,18	5
15AN1	150	1,25	11,50	13,40	14,90	0,30	0,26	0,18	5
15AN2	150	2,50	11,40	13,40	15,20	0,30	0,26	0,18	5

3. TESTS RESULTS

After welding, the measuring of the content of delta-ferrite at the center line seam of each of the samples was performed and scrapings are taken for chemical analysis of the weld metal of the same samples. Based on the chemical analysis results the values of the equivalent content of chromium and nickel is calculated, using the following forms:

$$Cr_{eq.} = Cr + Mo + 0{,}7\ Nb \ldots\ldots \quad (1)$$
$$Ni_{eq.} = Ni + 35\ C + 20\ Ni + 0{,}25\ Cu \ldots\ldots \quad (2)$$

The results of these measurements of delta-ferrite, chemical analysis and calculation of equivalent content of chromium and nickel are given in Table 4.

Table 4. Chemical composition of weld metal, the equivalent chromium and nickel content and delta ferrite content

Desig-nation of the sample	Chemical elements [$\%_{mas.}$]						Equivalent		$FN_{dia.}$	$FN_{me.}$
	C	Mn	Cr	Ni	Mo	N	$Cr_{eq.}$	$Ni_{eq.}$		
11AN0	0,030	1,65	19,00	9,00	0,14	0,028	19,14	10,61	10,7	9,17
11AN1	0,027	1,52	18,50	8,50	0,17	0,120	18,67	11,85	4,0	3,12
11AN2	0,044	1,52	18,40	8,80	0,17	0,160	18,57	13,54	0,9	1,24
13AN0	0,023	1,50	18,50	8,60	0,16	0,056	18,66	10,88	7,6	9,25
13AN1	0,042	1,48	18,40	8,60	0,18	0,130	18,58	12,67	2,2	2,97
13AN2	0,029	1,43	19,00	8,40	0,19	0,190	19,19	13,22	2,6	0,82
15AN0	0,039	1,42	18,20	8,40	0,18	0,042	18,38	10,61	7,6	9,66
15AN1	0,027	1,40	18,10	8,10	0,17	0,140	18,24	11,85	2,5	3,17
15AN2	0,050	1,42	18,50	8,50	0,18	0,180	18,68	13,85	0,6	1,79

Changing the content of nitrogen in the weld metal, depending on its content in the shielding gas is shown in Figure 1.

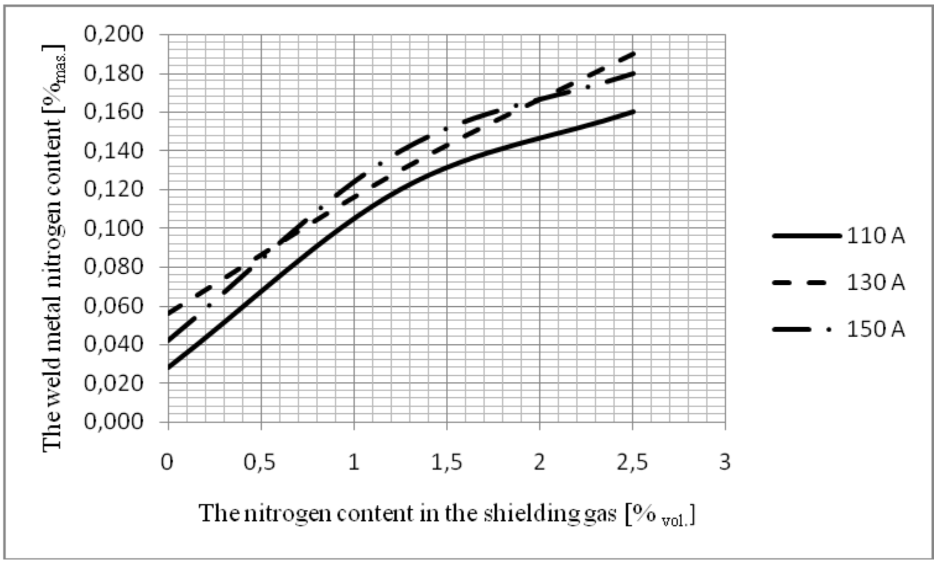

Figure 1. The dependence of the nitrogen content in weld metal on the content of nitrogen in the shielding gas

With the WRC-1992 diagram (Figure 2), using the data on the equivalent content of chromium and nickel, the delta ferrite in the weld metal of each welded sample is determined, whose values are given in the Table 4. Change in structural system, or the content of ferrite-ferrite in the weld metal is shown in Figure 2.

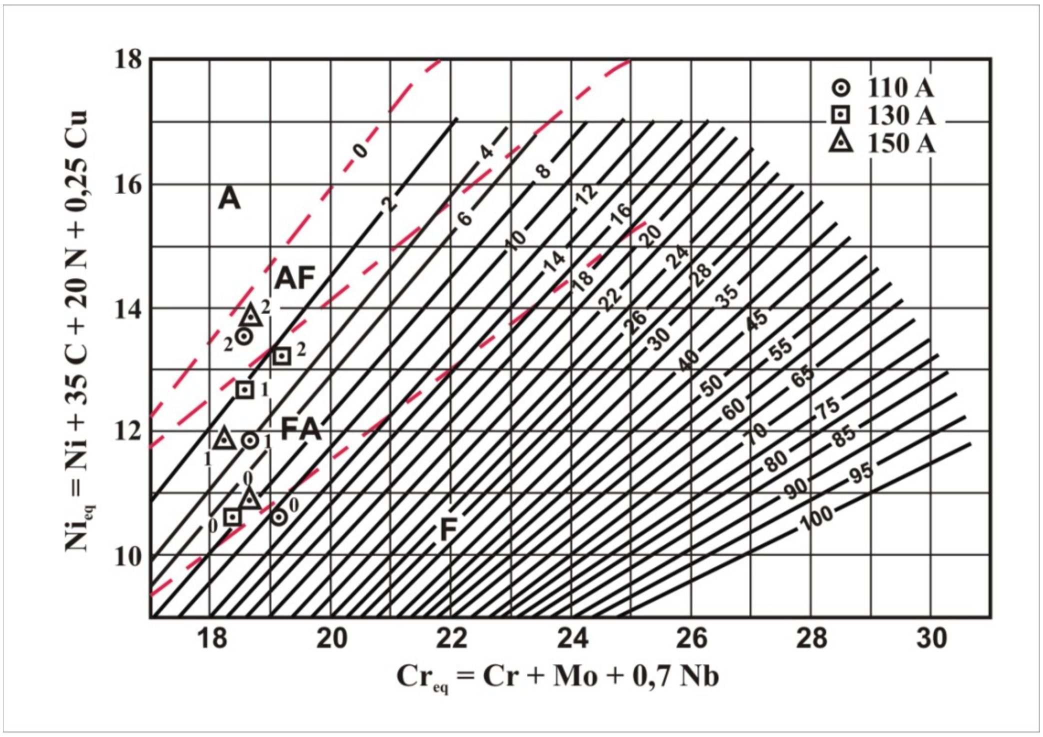

Figure 2. WRC 1992 diagram with specified the weld metal composition of welded samples 0,1 and 2 - the nitrogen content in the argon: 0%, 1.25% and 2.50%, respectively

4. CONCLUSIONS

Based on the results of the examination, the following conclusions can be carried out:

- With the nitrogen addition in the argon shielding gas, the nitrogen content in the weld metal increases,
- At low nitrogen content in the shielding gas, the dependence between the content of nitrogen in the weld metal and in the shielding gas is approximately linear,
- The nitrogen content in the weld metal increases with the increase of the welding current
- There is a relatively good agreement between the measured of delta ferrite (ferrite number) values and the values of delta ferrite determined by WRC-1992 diagram

5. REFERENCES

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