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DETERMINATION OF THE CONTENT OF DELTA FERRITE IN AUSTENITIC STAINLESS STEEL NITRONIC 60

Dr. Sc. Almaida Gigović-Gekić[1], Dr.Sc. Mirsada Oruč[2], Dr. Sc. Mirko Gojić[3]
[1] University of Zenica, Faculty of Metallurgy and Materials Science, Zenica
[2] University of Zenica, Metallurgical Institute „Kemal Kapetanović"
[3] University of Zagreb, Faculty of Metallurgy in Sisak
Contact e-mail: almaida.gigovic@famm.unze.ba

ABSTRACT
Microstructure of austenitic stainless steel Nitronic 60 is primarily monophasic ie. austenitic. However, the chemical composition can affect on precipitation of delta ferrite. The presence of delta ferrite decrease grain growth and increases strength properties of steel. It is known that, the delta ferrite has a very important role in welding of austenitic steels to prevent the occurrence of hot cracks. This paper presents the results of determining the content of delta ferrite in steel Nitronic 60 using the Schaeffler's diagram, metallographic methods and method of magnetic induction. Analysis of results showed no significant differences in the content of delta ferrite in relation to different methods of determining the delta ferrite.
Keywords: Austenitic stainless steel, delta ferrite, Schaeffler's diagram, method of magnetic induction, metallographic method

1. INTRODUCTION

The beginnings of the production of austenitic stainless steel are dating from the early 20 century. Today, 2/3 of the total production of stainless steel in the world belong to the production of austenitic stainless steel. These materials are widely used in automotive, petroleum, chemical, construction and other applications due to their excellent properties such as a corrosion resistance in different conditions, good mechanical properties, attractive layout of the final product, long service life etc [1].
Microstructure of austenitic stainless steel Nitronic 60 is primarily monophasic ie. austenitic. However, it is possible precipitation of the delta ferrite depending on the chemical composition.The delta ferrite occurs during solidification and remains in the microstructure at room temperature. The presence of delta ferrite, which has a BCC crystalline structure slows a grain growth and increases strength properties of the steel. The interphases boundaries are a strong barrier to dislocation motion.
The delta ferrite is ductile at room and elevated temperature but brittle at cryogenic temperatures. However, the delta ferrite has a very important role in welding of the austenitic steel because it protects from the appearance of hot cracks [2]. For this reason it is recommended that the content of the delta ferrite in the weld of austenitic steel is 5 to 10%. The content of delta ferrite should not exceed 10% because at higher contents could occur secondary phase, ie. sigma phase at higher temperatures. This paper presents the results of determining the content of delta ferrite in steel Nitronic 60 using the Schaeffler's diagram, metallographic method and magnetic induction method.

2. EXPERIMENTAL PART

To determine the delta ferrite content the samples from Ø15 mm rods obtained from austenitic stainless steel Nitronic 60 have used. The chemical composition of the investigated steel is given in Table 1. The melts with a different chemical composition, was tested. The chemical composition of melts was within the limits prescribed by ASTM A276-96 standard [3]. The content of alphagenic and gamagenic elements are changed in order to determine their effect on the content of delta ferrite.

Table 1. The chemical composition of melts for steel Nitronic 60.

Melts	Chemical composition / wt.%							
	C	Si	Mn	Cr	Ni	P	S	N
ASTM A276	≤0.10	3.5-4.5	7-9	16-18	8-9	≤0.006	≤0.03	0.08-0.18
V1692	0.04	4.41	7.4	18.0	8.1	0.007	0.005	0.183
V1693	0.08	3.81	7.0	18.0	8.0	0.008	0.015	0.162
V1694	0.04	3.74	8.6	18.0	8.0	0.007	0.005	0.160
V1696	0.05	3.5	7.9	16.9	8.6	0.005	0.005	0.120
V1701	0.05	4.54	7.5	16.0	9.0	0.005	0.011	0.126
V1717	0.05	3.8	8.9	17.0	9.0	0.007	0.005	0.161
V1718	0.05	3.7	7.9	17.7	8.6	0.006	0.005	0.178
V1720	0.05	3.9	9.0	16.0	8.7	0.007	0.006	0.179

The delta ferrite content was determined using three methods: Schaeffler's diagram, metallographic method and magnetic induction method. Analysis of delta ferrite content by Schaeffler's diagram was made on the basis of known chemical composition and empirical formula (Figure 1):

$$Cr_{eq}=\%Cr+\%Mo+1{,}5\%Si+0{,}5\%Nb \qquad ...(1)$$
$$Ni_{eq}=\%Ni+0{,}5\%Mn+30\%C+30\%N \qquad ...(2)$$

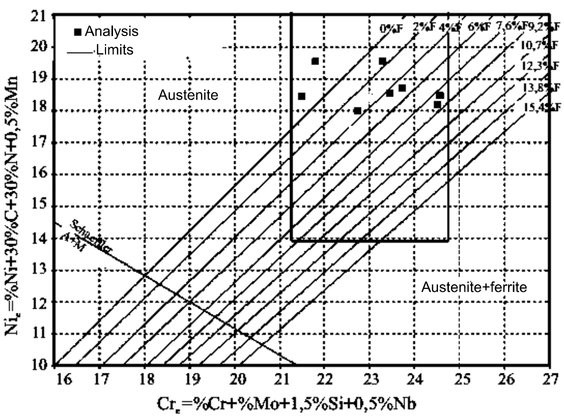


Figure 1. Analysis of delta ferrite content by the modified Schaeffler's diagram [4]

Figure 2. Feritscope MP 30E-S probe EGAB 1.3 Fe [5]

The determination of the delta ferrite on base material by the magnetic method was carried out at the Faculty of Metallurgy in Sisak, Croatia using Feritscope MP 30E-S probe EGAB 1.3 Fe (Figure 2). Testing was done on samples Ø15x100 mm. The five tests was carried out at each sample and taken the mean value. This test is based on the fact that the austenite is nonmagnetic and the delta ferite is magnetic.

The metallographic examination was performed on Olympus optical microscope with magnification 100x using Olympus software for phase analysis. The samples were previously prepared (grinding and polishing) and etched in the Kalling's solution.

3. RESULTS AND DISCUSSION

The results of determining of the delta ferrite content are given in Table 2

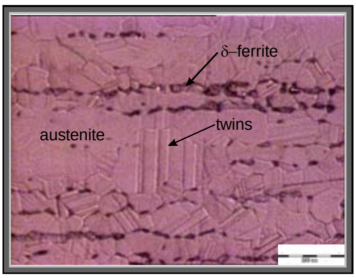
Table 2. The delta ferrite content for steel Nitronic 60.

Melt	Ni_{ekv}	Cr_{ekv}	Delta ferrite content [%]		
			Schaeffler's diagram	Magnetic induction method.	Metallographic method
V1692	18.49	24.62	7.6-9.2	10.25	cca 8.86
V1693	18.76	23.72	7.6-9.2	9.55	cca 10.56%
V1694	18.30	24.61	4-6	4.3	cca 5.32%
V1696	17.65	22.15	2-4	1.4	cca 2.6%
V1701	18.03	22.81	2-4	0.12	cca 0.33%
V1717	20.48	22.7	0	0.11	cca 0.15%
V1718	19.39	23.25	0-2	0.15	cca 0.25%
V1720	19.57	21.85	0	0.145	cca 0.31%

On the base of the obtained values for Cr_{eq} and Ni_{eq} and using a modified Schaeffler's diagram can be estimated that the content of delta ferrite is in the range from 0 to 9.2 %. The delta ferrite content depends on the chemical composition of the melts. The disadvantage of this method is that it can only estimate the interval of the delta ferrite content. Also, in practice for steels for which the diagram predicts delta ferrite content of 0-5%, the actual content is usually lower [6].

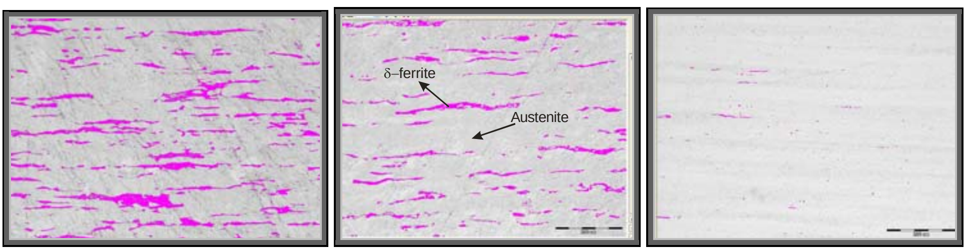
The metallographic analysis showed that Nitronic 60 is an austenitic steel with a characteristic twins and delta ferrite (Figure 3).

Example of the metallographic method for determining the delta ferrite content is shown in Figure 4 for three melts with different delta ferrite content. During the analysis, ten visual fields at the sample photographed and determined the mean value. The software evaluates the share of the ferrite phase on the basis of differences in color.



100x

Figure 3. Microstructure of steel Nitronic 60[4]



Kalling 100x Kalling 100x Kalling 100x

a) b) c)

Figure 4. Analysis of the delta ferrite content using an optical microscope with Olympus software for the phase analysis for the melts: a) V1693, b) V1694 and c) V1720.[4]

The analysis showed that the delta ferrite content ranging from 0.15 to 10.56%. The tested samples by this method have to be well prepare because the presence of any form of surface errors affect the accuracy of the data.
Testing by feritscope showed that the delta ferrite content ranging from 0.11 to 10.25%. The analysis of obtained results showed that with increasing alphagenic and decreasing of gamagenic elements content, the content of delta ferrite increases which is consistent with the literature data [6,7].

4. CONCLUSIONS

The delta ferrite content was determined for eight melts with different chemical composition. Three methods were used for testing: Schaeffler's diagram, metallographic method and magnetic induction method.
The analysis of results showed that the delta ferrite content was from 0 to 10.56% depending on the chemical composition and test methods.
The method of magnetic induction showed as the best method of testing. This method uses a device feritscope that is easy to work, do not require special preparation of samples and results are accurate.
The analysis of delta ferrite content by Schaeffler's diagram is a simple but requires knowledge of chemical composition is not precise and is intended primarily for welding.
The metallographic method is simple, requires careful preparation of samples but no reliable. However, comparing of results it can be concluded that there are not wide deviations in the content of delta ferrite for different test methods.

5. LITERATURE

[1] A.F. Padilha, P.R. Rios: Decomposition of Austenite in Austenitic Stainless Steels, ISIJ International, vol.42, no.4, 2002.,p. 325-337
[2] M.Gojić, S. Kožuh, L. Kosec, D.Pinotić: Properties of Austenitic Steel AISI 321 after Welding with TIG Procedure, MNM 2008, Zenica, p.295-300, 2008
[3] ASTM A276-96 Standard
[4] A.Gigović-Gekić: Quantification of the effects of alpha-gamma elements on mechanical properties and presence of delta ferrite in austenitic stainless steel Nitronic 60, University of Zenica, Faculty of Metallurgy and Materials Science, Doctoral thesis, 2010
[5] http://www.gardco.com/pages/filmthickness/df/fischer_feritscope.cfm
[6] http://www.outokumpu.com/files/Group/HR/Documents/STAINLESS20.pdf, B. Leffler: Stainless-stainless steel and their properties
[7] R.A. Lula : Stainless Steel, American Society for Metals, Ohio, 1986.