Journal of Chemical Technology and Metallurgy, 50, 6, 2015, 581-584

ON THE PROBLEM OF LIQUATION OF ALLOYING ELEMENTS IN THE STRUCTURE OF SINGLE-PHASE AUSTENITIC STEEL

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Received 14 February 2015
Accepted 05 September 2015

ABSTRACT

The results of study on the chemical composition of austenitic steel for 12 elements in standard parts, obtained by casting, and used for critical parts of machines and mechanisms at elevated temperatures of operation, are discussed. Anomalous segregation of some elements set the practical limits of the instability of the chemical composition of austenitic cast steel structure.

Keywords: steel, elements, liquation, austenite.

INTRODUCTION

It is known that the 12X18H9T steel and its analogs (e.g., 12X18H10T, 10H14G14N4T, 12H17G9AN4 and even 12H18N9TL, 10H18N9L) are used in welded structures, working in contact with nitric acid and organic acids of average concentration, organic solvents, corrosive atmospheric conditions. 12X18H9T structural cryogenic steel is mainly used as a corrosion-resistant material, sometimes as heat-resistant and high-temperature steel. Capacitive, heat-exchange equipment, parts of the furnace accessories, heat exchangers, muffles, exhaust systems parts, sheet and bar details are made from it, as well as apparatuses and vessels operating at temperatures from -196 to 600°C under pressure, and to 350°C in the presence of corrosive media. The microstructure of the steel is single-phase, austenitic. The chemical composition of the steel follows GOST 5632 - 72 “Steels high-alloy and alloys corrosion-resistant, heat-resistant and high-temperature grades” (Table 1).

EXPERIMENTAL

The casting grade of austenitic steel is different in its average content of nickel, chromium, wider tolerances on the range of concentrations of manganese and silicon; it possesses less significant performance characteristics compared to the classical 12X18H9T and 12X18H10T grades.

The complex of austenitic steel properties is achieved by the right choice of the regime of heat treatment (tempering, hardening and tempering, etc.), which stabilizes the austenite grain size and prevents if necessary the formation of complex carbides. Nickel serves as an austenite stabilizer in the normal conditions of exploiting steel, while chrome adds a high resistance to aggressive media and slows down the growth of grains at high temperatures.

There are 5 - 6 methods of smelting high alloy steel, but they all come to obtaining a homogeneous melt of nickel and chromium in the iron melt before tapping. In the molten state due to a large amount of chromium steel is aggressive to the main lining of steel making units and ladles. Manganese is present in the grade because it is present in the metallic part of the charge and may be used in primary steel deoxidation at tapping. Silicon is also used for deoxidation of the melt and/or is inherited from metal stock in the production of steel by the refining method, followed by mixing the melts in ladles. Titanium stabilizes the microstructure properties during a prolonged use of steel in aggressive media, offsetting the effect of the structure’s aging. In

Table 1. Chemical composition of the steels.

Grade	C at most	Si at most	Mn at most	S at most	P at most	Ni	Cr	Ti	Cu at most
12X18H9T	0,12	0,8	2,0	0,02	0,035	8-9,5	17-19	0,2-0,8	0,3
12X18H10T	0,12	0,8	2,0	0,02	0,035	9-11	17-19	0,2-0,8	0,3
12X18H9TЛ	0,12	0,2-1,0	1-2	0,02	0,035	8-11	16-20	at most 0,6	0,25

some grades of stainless steel, aluminum and vanadium are present, but the presence of the former threatens with the pinhole effect even when casting in molds of cold-hardening mixtures, with vanadium being inferior to titanium in binding dissolved nitrogen into stable nitrides. However, this method can significantly reduce the cost of steel, even at concentrations of titanium of 0.2 (0.5*C, %) to 0.8 % mass.

The Department of Metallurgy at Lipetsk State Technical University has studied the chemical composition of the 12X18H10T, 12X18H9T and 12H18N9TL steels, as well as the small-sized parts made of it (with the weight of 140 - 160 g) in the Acrolein-100 atomic emission spectrometer. All the samples were divided into two sets (10 samples in each set, in the first set 2 samples were randomly selected, in the second set - 4 typical samples) with different conditions of smelting and alloying with the release of melt from the furnace. Spectral analysis was performed by the method of chromium-nickel alloys, iron-based, provided in the software of the spectrometer. The results of a series of measurements of the chemical composition of the steels is shown in Tables 2 and 3.

RESULTS AND DISCUSSION

The titanium content in all the samples was less than 0.01 %, and we have not taken it into account. It should be noted that some samples of different sets of melts contain a sufficiently large tungsten content (up to 0.0077 %), which can be regarded as a “process” impurity residue of a complex alloy steel smelting in the same furnace (furnace linings, ladle). An unstable but increased content of aluminum testifies to it being used as a deoxidizer in the furnace and on tapping, without the use of out-of- furnace melt-refining operations.

The vanadium content in the samples of the melt set 2 is relatively stable, and the use of “remelting” technologies in the case of induction furnaces with a basic or neutral lining indicates the introduction of ferrovanadium into the furnace just before tapping [1 - 5]. Tungsten samples in set 2 were not found. Grounding

Table 2. The average chemical composition of austenitic steel (Set 1).

Element	Sample №1	Sample №2	Average concentration, %	SD, unit.	Relat. SD, %
Al	0,01583	0,00121	0,01583	0,0061	18,9
C	0,0713	0,09846	0,08488	0,01921	22,6
Cr	17,62	17,16	17,39	0,33	1,9
Cu	0,1296	0,1362	0,1329	0,0047	3,5
Mn	1,003	1,044	1,024	0,029	2,8
Mo	0,0536	0,05189	0,05274	0,00121	2,3
Ni	9,178	9,319	9,249	0,1	1,1
P	0,0398	0,03119	0,03549	0,00609	17,2
S	0,008832	0,008833	0,008833	0,000001	0,0
Si	0,8044	1,078	0,9412	0,1935	20,6
V	0,07879	0,07415	0,07647	0,00328	4,3
W	0,02097	<0,01	0,02097	0	0

Table 3. The average chemical composition of austenitic steel (Set 2).

Element	Sample №1	Sample №2	Sample №3	Sample №4	Average concentration, %	SD, unit	Relat. SD, %
Al	0,0202	0,0217	0,03052	0,0194	**0,02403**	0,00812	39,0
C	0,0801	0,08093	0,06619	0,07813	**0,07508**	0,00783	10,4
Cr	16,39	17,02	17,06	17,26	**16,93**	0,38	2,2
Cu	0,1099	0,1273	0,1281	0,1198	**0,1213**	0,0085	7,0
Mn	0,9321	1,003	1,04	1,134	**1,027**	0,084	8,2
Mo	0,06463	0,06208	0,08444	0,1133	**0,08111**	0,02367	29,2
Ni	8,99	9,538	9,512	9,792	**9,41**	0,623	6,7
P	0,02883	0,03294	0,03151	0,03363	**0,03173**	0,00212	6,7
S	0,01152	0,009022	0,009406	0,008912	**0,009715**	0,001222	12,6
Si	0,8696	0,7107	0,6544	0,746	**0,7452**	0,0911	12,2
V	0,06879	0,07697	0,07366	0,07556	**0,07375**	0,00357	4,8

on this analysis we have identified the austenitic steel as that of the 10H18N9L grade (without titanium, but with aluminum and vanadium). This may be acceptable if the company which uses the components of the steel negotiates the content of major elements with the manufacturer.

The draft of sample parts made of austenitic steel is shown in Fig. 1. The changes in the average coefficient of conditional liquation of elements are shown in the diagrams of Figs. 2 and 3. The greatest deviation of the concentration from the average content in the steel is observed for aluminum, phosphorus and molybdenum. The most unstable chemical composition of the steel was observed in set 2 for aluminum, molybdenum, sulfur, carbon and silicon. Two different samples from set 2 demonstrate a significant content deviation of aluminum

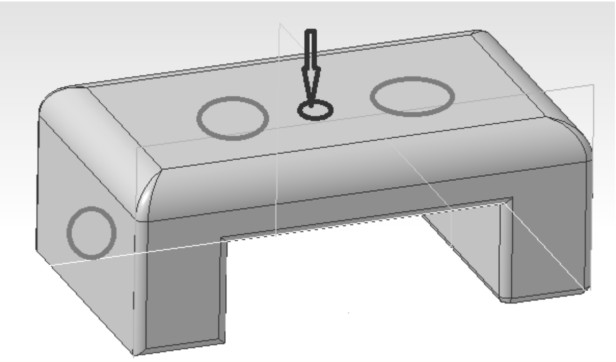

Fig. 1. Draft of sample parts of austenitic steel: red circles mark the spectral analysis area, the black arrow indicates the place of feed-casting (feeder).

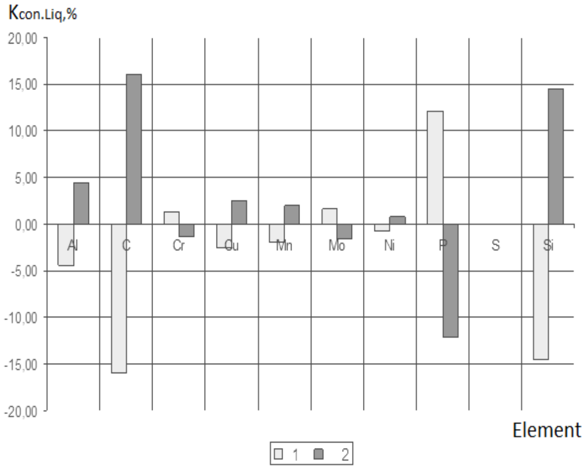

Fig. 2. Values for elements in set 1.

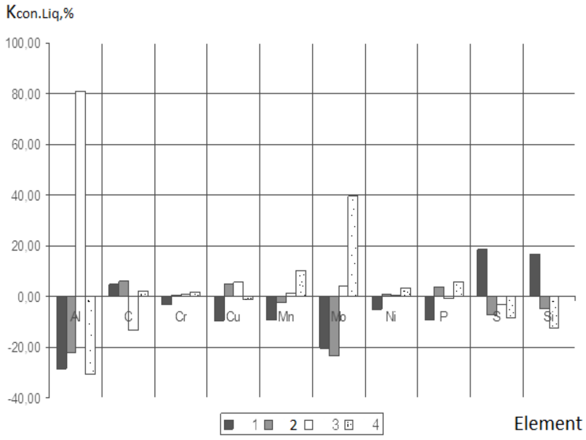

Fig. 3. Values for elements in set 2.

(up to 80 % rel.) and molybdenum (up to 22 % rel.), Fig. 3. Despite the significant nickel content (up to 10 % wt.) and chromium (up to 19 % wt.) their relative liquation ratios were not more than 5 % rel. in both the sets (Figs. 2 and 3).

CONCLUSIONS

The obtained values of the coefficients indicate an uniform distribution of alloying elements in the austenitic structure, and significant fluctuations in the concentrations of other elements are explained by the peculiarities of the smelting process (melt burdening) and/or technology of the production of castings (e.g. in the area of the probable feeder on top of the sample part the nickel and aluminum content is somewhat higher than on the sides (see Fig. 1).

Such fluctuations in the chemical composition of steel occur due to the instability of the metallurgical production technologies, namely by the use of aluminum as the main deoxidizer and the use of the remelting technology to a charge of an unstable quality.

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