STUDY THE INFLUENCE OF ALLOYING ELEMENTS ON THE STRUCTURE OF IRON-BASED ALLOYS WITH HIGH CONTENT OF CARBON, MANGANESE AND CHROMIUM IN MODES OF HEAT TREATMENT

ПРОУЧВАНЕ НА ВЛИЯНИЕТО НА ЛЕГИРАЩИТЕ ЕЛЕМЕНТИ ВЪРХУ СТРУКТУРАТА НА СПЛАВИ НА ЖЕЛЯЗНА ОСНОВА С ВИСОКО СЪДЪРЖАНИЕ НА ВЪГЛЕРОД, МАНГАН И ХРОМ ПРИ РЕЖИМИ НА ТЕРМИЧНО ОБРАБОТВАНЕ

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Abstract: *Demand for alloys with high mechanical performance and optimum qualities in the service conditions require new studies regarding thermal stability, wear resistance and corrosion resistance to them. Of interest are materials in which the deficient and expensive Ni is partially or completely substituted with Mn, such as the alloys of the systems Fe-Cr-Mn-C or Fe-Cr-Mn-Ni. To build an accurate picture of the structural features, properties and their behavior in the operating conditions need to be carried out relevant studies. The objectives of the study are related to clarify the processes of structure formation in heating and cooling of this type of austenitic alloys. Object models are cast with an increased concentration of carbon and constant chromium and manganese in the starting composition, as well as those supplemented with vanadium and nickel.*

KEYWORDS: ALLOYING, VANADIUM, NICKEL, HEAT TREATMENT, MICROSTRUCTURE

1. *Introduction*

The aim of this study are materials in which the deficient and expensive Ni is partially or completely substituted with Mn, such as the alloys of the systems Fe-Cr-Mn-C or Fe-Cr-Mn-Ni, [1-3]. To an accurate picture of the structural features, properties and their behavior in terms of their exploitation, we made the investigation plan and carried out the relevant studies. The objectives of these investigation are related to clarify the processes of structure formation at heating and cooling of this type austenitic alloys. A starting composition of the alloys include a high concentration of C, constant content of Cr and Mn, as well as supplemented with V and Ni.

Major contribution to the systematization of the results have previous studies of the team on the alloys of the system Fe-Cr-Mn with carbon content more than eutectic . Novelty is the further enriched with vanadium and nickel, the mechanisms of structure formation during the casting process and changes after heating and cooling of this type alloys that still contain unknown and should be fully investigated.

2. *Preparation of starting materials*

The starting materials are prepared in an induction autoclave with basic lining of crucible. The melting is effected in the closed position of the machine and under pressure of about 12.10^{-5} Pa. Raw materials are St. 3, electrolytic manganese, chromium electrolyte, electrode graphite, technically pure aluminium and ferrosilicon. Melt is treated in the atmosphere with molecular nitrogen, ferroalloys are imported under pressure. The nitrogen is present in the composition of the alloys by the addition of ferro-nitride and chromium as additives. The temperature of the casting is in the range of 1480-1500^{o}C. Control over the temperature changes during the process is carried out by W-Re thermocouple and recording device “Servogor”. Alloys are pouring into dry sand forms with a rectangular section. After crystallization of cast shapes are cut specimens on abrasive machine with special cooling, preventing strain hardening of the surface layer. Samples are shaped with an area of study 15÷20mm^2, suitable for metallographic and X-Ray structural analysis.

3. *Chemical composition*

The percentage of chemical elements in resulting alloys is pre-determined by separation of filings according to standard technology and spectral analysis of Spectrolab, Germany. To specify the nitrogen content of the samples is made a gas analysis in Institute of Metal Science, equipment, and technologies “Acad. A. Balevski” with Center for Hydro- and Aerodynamics at the Bulgarian Academy of Sciences, (IMSETHAC-BAS). The exact chemical composition of materials is presented in Table 1.

Table 1. Chemical composition of the studied alloys

Alloys	**C, %**	**Mn, %**	**Si, %**	**Cr, %**	**V, %**	**Ni, %**	**N, %**
1 (300)	1,38	22,6	0,45	4,0	-	-	0,442
2 (310)	1,38	22,2	0,42	4,0	1,52	-	0,451
3 (320)	1,38	22,2	0,10	3,8	-	2,2	0,348

4. *Heat treatment (HT) of the alloys*

❑ *Homogenization*

Thermal treatment of samples was conducted in two stages. The first stage of research is homogenization at 1150^{o}C for 2 hours. The aim is dissolving of the compounds at high temperatures (carbides, nitrides, etc.) in the solid solution matrix which is homogeneous. Hardening after homogenization is in water for the purpose of fixing the high temperature state, i.e. in order to avoid disintegration of the solid solution and separation of the second phase from him. A greatest rate of absorption of carbon and nitrogen at high temperatures of homogenization is carried out at crumbling of carbide, nitride and carbo-nitride phases. This heat treatment is implemented in a furnace type Ks-400. The specimens are bombarded with corundum to be protected of the oxidation atmosphere of the furnace and reduce the surface diffusion processes. All samples are simultaneously placed in the furnace and after reaching the 1150^{o}C the retention is two hours. After removing from furnace, the samples are immediately cooled in water.

❑ *Aging*

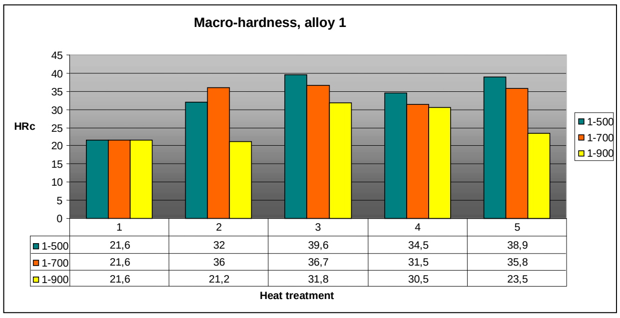
At the next stage of heat treatment the samples are put on aging at temperatures 500°C, 700^{o}C and 900^{o}C and times of retention 1, 5, 10 and 20 hours followed by rapid cooling in water. The modes are presented in Table 2.

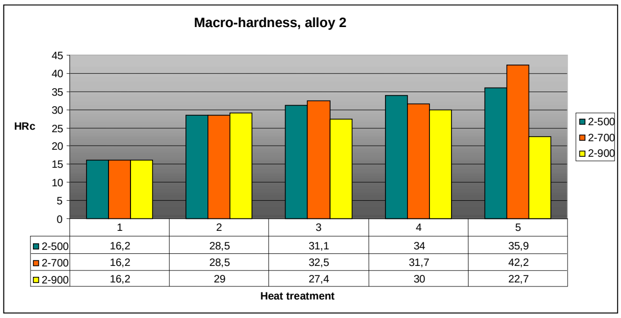
Table 2. Modes of heat treatment

Spesimens	Modes of HT	T [°C]	Time, [h]	Cooling
1 (300) 2 (310) 3 (320)	Homogeni zation	1150	2	H_2O
	Aging	500 700 900	1, 5, 10, 20; 1, 5, 10, 20; 1, 5, 10, 20;	H_2O

5. *Measurement of hardness of samples*

Device for measuring of hardness is combined device HP-250. A standard method of Rockwell with load 1471N is attached. Reporting is done on scale 1Rc=0,002mm depth of penetration. The results are summarized in Fig. 1÷3.





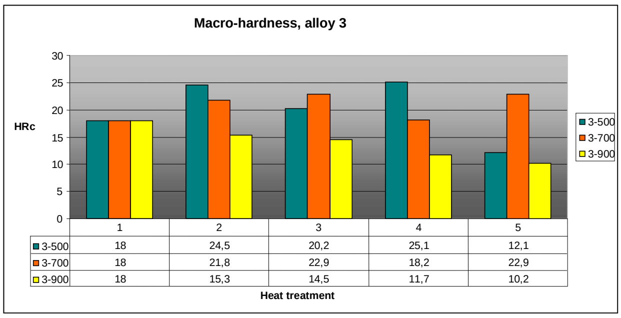


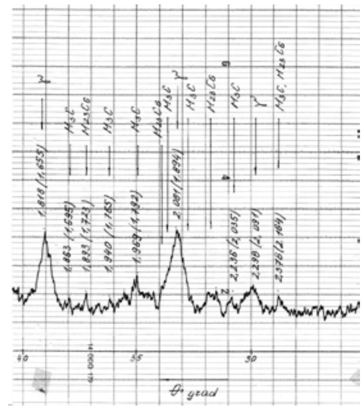
Figure 1÷3 Data for hardness of the alloys

6. *X-Ray structural analyse*

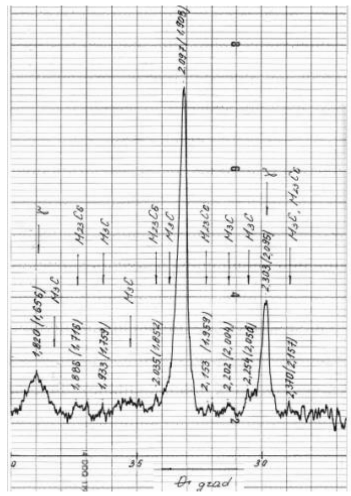
As a result of that analyse the facts are obtained for the distribution of elements at the alloys in the form of different phases and compounds. This is based on the fact that each phase has its own crystal lattice, and this affects the X-ray as a specific system of lines. The phase composition is determined by the data, calculated from formulas and compared with standards. The results are compared with existing datas for the lines of carbides and solid solution phases α and γ. According to the serial numbers of the elements from the research system in this analysis is used Cr-radiation because it has the greatest wavelength α = 2,29092 Å, [4].

Roentgenograms are made of some specimens and are shown in Figure 4.

Alloy 1



Alloy 2



Alloy 3

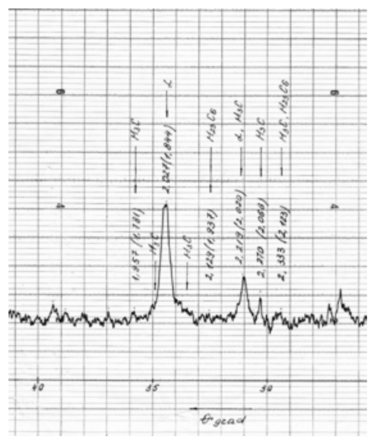


Figure 4. X-ray diffraction of the alloys after homogenization

7. *Microstructure metallographic analysis*

Samples are prepared for analysis by standard methods [5, 6]. The structure is developed with Nital (3% solution of HNO_3 in ethyl alcohol) and 10% solution of $(NH_4)_2S_2O_8$ in water. Metallographic images are made at 300x magnification. Fig. 5 shows only part of them.

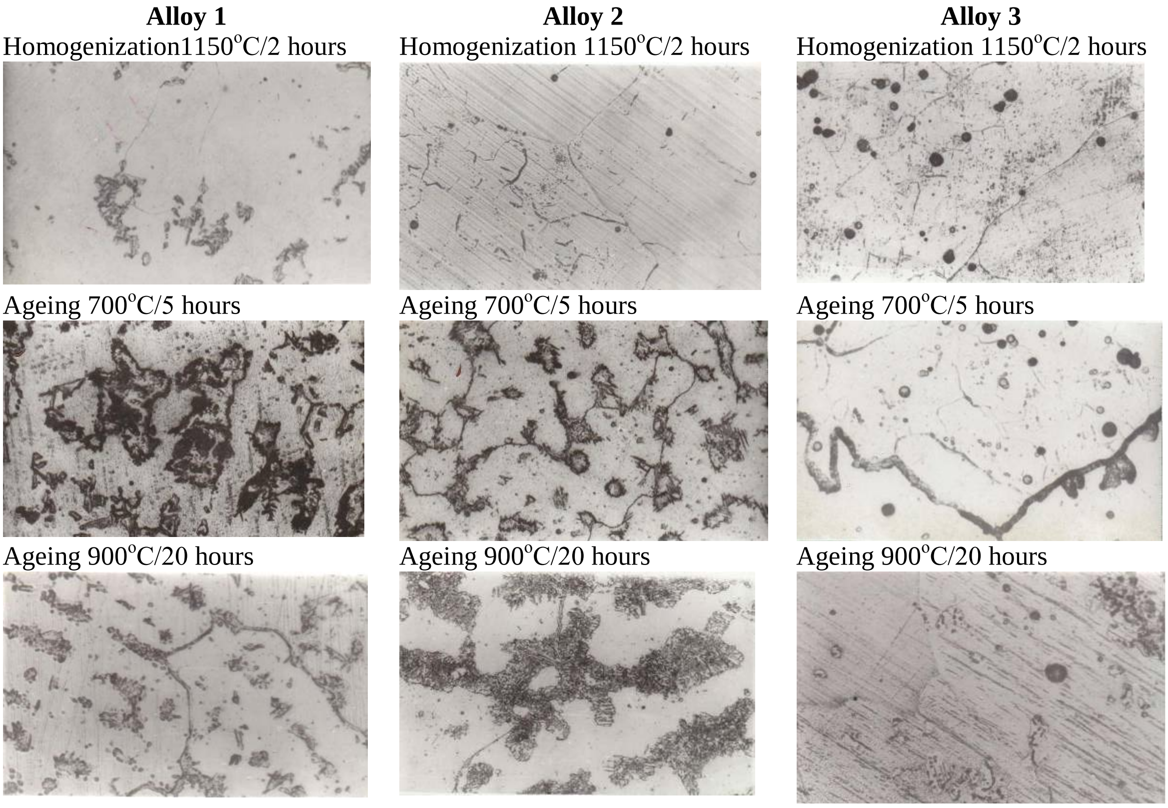


Fig. 5. Microstructures of the alloys after heat treatment (HT)

8. Conclusions

Alloy 1: In a homogenized state structure consists an austenitic phase and undissolved carbide of type Me_3C and $Me_{23}C_6$ - probably complex carbides $(Cr, Mn, Fe)_{23}C_6$. The aging process starts separating the finely dispersed second phase of type Me_7CN_3, as we conclude about this in accordance with variation of makrohardness. Upon aging 700°C/5 hours was observed maximum depositions and maximum in hardness. With longer retention disintegration takes place in the interrupted precipitation mechanism. Than are observed formation of sections of pseudo-eutektoid (γ+carbides), which quantity gradually decreases and is at least of prolonged retention of 20 hours. Upon aging 900°C/20 hours pass a dissolving the second phase (solid solution is saturated with the alloying elements and the amount of precipitates decrease).

Alloy 2: This composition has the greatest content of vanadium. According to X-ray structural analysis in homogenized condition are observed homogeneous austenitic grain and carbide phases type Me_3C and $Me_{23}C_6$. Aging occurred with a change of microstructure. At low temperatures can be seen isolated grains, like teardrops, in austenite structure, around some non-metallic inclusions (HT at 500°C). With consolidation of the second phase at 700 and 900°C the hardness increase. The mechanism of precipitation under these temperatures is different from that at 500°C and with increasing of retention time leads to formation of colonies with analogy of eutektoid - γ + carbides.

Alloy 3: The composition has added Ni and missing V. Regularities, observed in aging are: absence of suspended eutectic carbides in a homogenized condition and correspondingly low values for HRc compared to the base alloy. At low temperature of aging there is not deposition from second phase in volume and over the grain boundaries**.** In 900°C and short retention are observed partial precipitates of the eutectoid type, and at 10 and 20 hours is observed the process of their dissolving in the austenite and consequently reducing in macro-hardness. The amount of second phase in any mode of aging is significantly less than the amount in the same mode, separated in the base alloy. This affects the absolute HRc, but the austenitic structure is more stable.

9. Literature

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