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Cr - Ni SYSTEM ALLOYS COMPOSITION IMPACT ON DURABILITY VALUE

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Preliminary Note – Prethodno priopćenje

There are considered the alloys of the Cr – Ni system with addition of iron, molybdenum and other alloying elements. In the alloys there varied chrome content from 35 to 55 %. The alloys were subjected to various types of heat treatment.

There were measured mechanical properties at the room temperature, then the alloys were studied for the durability limit. There was additionally studied the impact of chrome content in the alloy and operation temperatures on the value of rupture stress. All the indicators studied were compared with similar parameters of the ХН77ТЮР alloy. It was established that in terms of heat resistance with the present combination of alloying elements the most optimal chrome content is 40…45 %.

Key words: the Cr – Ni system, durability, temperature, annealing and ageing, rupture stress

INTRODUCTION

With the development of technologies the growing number of machine parts and mechanisms are working at high temperatures (turbine blades, airplane fuselage and wing skin, loaded valves of powerful motors, atomic reactor units). Their operation reliability is defined by heat resistance of metal materials they are made of.

It is worth noting that heat resistant materials operate in various loading patterns: static tensile, bending or twisting loads, dynamic variable loads of different frequency and amplitude, thermal loads due to temperature changes, dynamic impact of high-speed gas flows onto the surface.

As a result of this there are used multiple types of testing for heat resistance: tests for creeping and durability under static loading, tests for high-temperature and thermal fatigue, tests for gaseous corrosion in differ-rent media, tests in high - speed gas flows, etc. However, the most important in terms of heat resistance are tests for creeping and durability.

Resistance to loads at high temperatures of metals and alloys is strongly connected with their temperature of recrystallizing. Metals and alloys can be highly resistible to strains only when heated to the temperature that does not exceed the temperature of this metal or alloy recrystallization.

The temperature of recrystallizing being exceeded, there increases sharply the atoms mobility and decreases strain resistance. That's why for the purpose of increasing materials heat resistance it is necessary to increase the temperature of its recrystallization [1]. Alloying heat resistant alloys based on iron permits to obtain materials with recrystallizing temperature about 800 °C. Alloys based on nickel and chrome show a higher recrystallizing temperature. The ХН77ТЮР alloy is especially widely spread. It contains about 20 % Cr. In the last decades the subject of studies as heat resistant alloys became alloys with higher chrome content.

A large part of these works appeared to be unsuccessful in term of practical use, i.e. the materials studied possessed but very low ductility or impact viscosity at the room temperature. The alloys with iron and molybdenum additives [2, 3] showed their availability when tested for durability, but the presence of a significant quantity of the σ – phase in them worsened significantly these alloys properties. The presence of the σ – phase is a cause of the significant reducing of impact viscosity, especially in the process of long-term keeping at 760 ^{0}C and higher [4].

EXPERIMENTAL STADIES

In the present work there were studied the alloys based on the chrome-nickel system with chrome content from 20 % and more. When selecting the metallic system composition based on chrome and nickel for studying as heat resistant materials, there were taken into consideration three factors:

- the absence of the σ – phase in the chrome-nickel system (Figure 1);
- the possibility to develop an alloy composition in wide limits that are subject to ageing;
- changing the structure owing to heat treatment.

The laboratory experiments show that chrome-nickel alloys containing 60…85 % Cr, are interesting in

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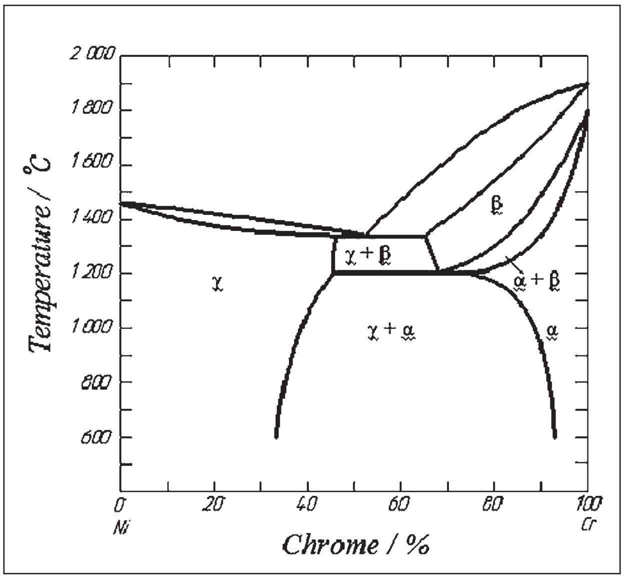

Figure 1 Cr – Ni state diagram

terms of increasing their hardness from 45 HRC in the annealed state up to 65…68 HRC with hardening from 1 230 ^{0}C. However, because of high ability to hardening these alloys are very sensitive to thermal impacts and cuts. besides, these alloys treatment presents large difficulties as they are not ductile practically, the obtaining of precision casting due to high melting temperature is almost impossible.

To avoid these difficulties in using alloys with high chrome content there were studied alloys with 35 – 55 % Cr.

As we can see from Figure 1, these alloys can be hardened owing to separating α – and γ – phases and can be thermally treated with forming various structures. The alloys that contain over 50 % Cr are characterized by forming in the cast form a continuous network of the α – phase that, if distributed incorrectly, leads to reducing ductility and impact viscosity.

For studying the were made specimens with different chrome and nickel content and minor additives of Fe, Mo, Nb, Ti and Al. These elements content was constant as there was posed the problem of studying chrome content increase impact on the alloys properties. In case of alloying a chrome-nickel alloy with these elements when ageing a hardened alloy there forms an intermetallic g$^/$ - phase of Ni_3(Ti, Al) type connected coherently with basic solution and increasing hardness at high temperatures. Molybdenum and niobium additives increase the temperature of recrystallization and hamper the diffusion process that is needed for excessive phases and recrystallization coagulation.

The experimental specimens were cast in the form of rods of 30 mm length and 6 mm diameter. All the melts were carried out in an arc electric furnace with the side location of coal electrodes, without protection from polluting the melts with nitrogen or oxygen, as there was posed the problem of obtaining alloys by the simplest methods. In Table 1 there are presented the experimental melts compositions.

Table 1 **Studied specimens compositions /mass %**

Alloy No	Cr	Ni	Fe	Mo	Nb	Ti	Al
1	35	50	10	2	1	1	1
2	40	45	10	2	1	1	1
3	45	40	10	2	1	1	1
4	50	35	10	2	1	1	1
5	55	30	10	2	1	1	1

The first stage of the study was studying the alloys mechanical properties at the room temperature. All measurements were made in accordance with the known methodologies [1]. The results are presented in Table 2.

Table 2 **Mechanical properties of the alloys studied at the room temperatures**

Alloy No	Yield point / MPa	Fracture stress / MPa	Relative elongation / %	Relative contraction / %
ХН77ТЮР	400	550	3,5	4,0
1	350	539	3,9	4,0
2	553	585	7,5	10,6
3	525	623	6,0	5,6
4	-	546	1,2	1,8
5	490	630	0,7	0,9

The ready specimens were subject to various types of heat treatment: ageing; ageing followed by hardening and ageing immediately after casting. For comparison there were used the indicators of the ХН77ТЮР alloy after hardening and ageing.

The treated specimens were subject to testing for durability in accordance with the methodologies of SS 10145-81. The testing temperature was 870 ^{0}C. The period of testing was 100 hours. The testing results for durability are presented in Table 3.

Table 3 **Durability limit depending on chrome content and type of heat treatment**

Specimen No	Chrome content / %	Durability limit, MPa		
		After cast-ing	Ageing at 470 ^{0}C 4 hours	Ageing at 470 ^{0}C 4 hours, hardening at 1 220 ^{0}C, ageing at 470 ^{0}C 2 hours
ХН77ТЮР	20	-	-	200
1	35	100	120	160
2	40	105	155	240
3	45	105	150	240
4	50	107	140	220
5	55	102	140	205

As it is seen from the data of Table 3, chrome content in the alloy does not practically affect the value of the alloy durability after casting. The introducing of the hardening treatment has a more significant effect. The alloy ageing within 4 hours at 470 ^{0}C leads to durability increase within the limits from 20 to 50 %. The introducing of a complicated hardening heat treatment (ageing, annealing, ageing) leads to durability significant increase. Chrome content increasing up to 45 % acts positively, however, the further chrome content increase leads to some decreasing in indicators.

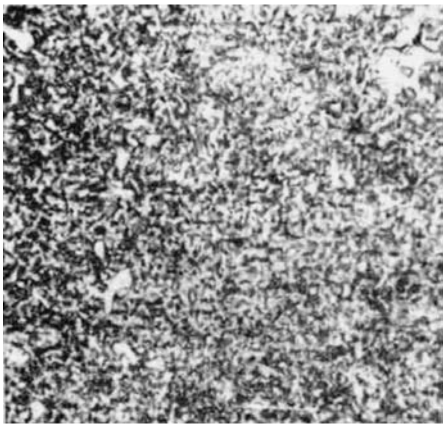

Figure 2 Microstructure of alloy 2 after annealing at 1 220 ^{0}C and ageing at 470 ^{0}C within 2 hours. X500 magnification, HCl etching

As it can be seen from the data of Cr – Ni state diagram, up to temperature 1 200 ^{0}C the system alloys structure within 30 – 85% Cr remains two-phase and is presented by the structural components α and γ. Chrome content increase leads to increasing α component.

The next step in the study was the studying of the operation temperature impact on the value of rupture stress in the constant period of 100 hours. The testing results are presented in Table 4.

From the data of the Table it is seen that the tested alloys have better indicators of the rupture stress value as compared with the XH77TЮP alloy at all temperatures. The testing temperature increase leads to reducing the value of rupture stress for the tested alloys similarly to that of the XH77TЮP alloy. However, this value reducing is not so critical, especially for alloys 2 and 3. If for XH77TЮP rupture stress at 800^0 makes 270 MPa, and at 1 020 ^{0}C only 80 MPa (3.4 times), for alloy 2 these indicators are respectively 300 and 160 MPa (1.8 times).

Table 4 **Temperature impact on the value of rupture stress**

Alloy No	Rupture stress value / MPa				
	Testing temperature / ^{0}C				
	800	870	920	970	1 020
XH77TЮP	270	200	160	120	80
1	250	160	160	120	100
2	300	240	220	205	160
3	320	240	220	210	145
4	310	220	216	180	65
5	305	205	200	160	65

RESULTS AND DISCUSSION

If we carry out the general analysis of the obtained results, there will be observed a tendency of increasing durability indicators and rupture stress value with the increase of chrome content up to 50 %. The further increase will lead to some reducing of the results.

However, taking into consideration indicators of strength and plasticity at the room temperature it is, perhaps, necessary to limit chrome content in the alloy to 40…45 %. Chrome content increase over 45 % leads to plasticity reducing. Plasticity is known to be of great importance in alloys operation at high temperatures, especially when there forms a body-centered cubic phase [1, 2]. In the presence of other body-centered cubic alloying elements the alloys can be particularly sensitive to cutting due to large quantities of the chrome α - phase.

The work carried out is an initial stage of studying the system alloys properties. It is obvious that reducing impurities in the alloy will be of great importance, therefore the vacuum impact studying will be prospective. In the present work iron, molybdenum and other alloying additives content was kept constant owing to the components deficit and the difficulty of carrying out the experiment, however, it is obvious that these elements content changing also affects the composition of the forming phases and structure.

The studies carried out showed the possibility of the further increasing chrome content in the chrome-nickel system alloys and availability of their use as heat resistant materials.

CONCLUSIONS

1. There was established the optimal chrome content (40…45%) in the alloys of the chrome - nickel system with addition of molybdenum, titanium, aluminum in terms of durability indicators.
2. There were established the dependences of chrome content impact on the value of rupture stress at different temperatures.
3. There was established the impact of heat treatment on the value of durability of some alloys of the chrome-nickel system.

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