SCIENCE AND TECHNOLOGY, Vol.31, No.1(2002), pp.59~62

The Relationship Between Chromium Content and Erosion-Corrosion Resistance of Fe-Cr-C Alloy System

Nguyen Viet Hue, Doan Dinh Phuong, Nguyen Van Tich, and Hoang Thi Binh

The Institute of Materials Science
Hoang Quoc Viet Rd., Caugiay Dist., Hanoi, Vietnam.

In order to determine the influence of chromium on erosion-corrosion coefficient of alloy in acid media, experiments were performed with chromium content in the range of 12-33% in different typical erosion-corrosion environments such as solution of sand, solution of sand with free acid in pH 2-7. The erosion-corrosion coefficient was evaluated by Apparatus for abrasion-corrosion testing. Wear coefficient, K, was calculated by formula: K= $\Delta M_{etalon} / \Delta M_{alloy}$ Testing results were showed that the alloy with composition (%): Cr=28-30; C=1.8-2.0; Mn=2.5 - 3.0; is the optimum for manufacturing details resistant erosion-corrosion in media upto pH=2-3.

This alloy is used successfully to produce details for sand-pumps, minerals processing cyclones.

Keywords *: Erosion-corrosion coefficient, acid media, chromium content, alloy, composition*

1. Introduction

Erosion - corrosion resistant alloy system based on Fe-Cr-C, has been widely used in industry. Depending on environments, the different compositions of alloy were established. Most important factor which accompanies the erosion-corrosion resistance of alloy is chromium content. The content of chromium in alloy determines not only the composition and phase structure of carbide - a component formed solid grains resistant against erosion, but also forms by thermal treatment process martensitic matrix phase promoting the passivity of alloy in acid media.

In order to determine the influence of chromium on erosion-corrosion coefficient of alloy in acid media, experiments were performed with chromium content in the range of 12-33% in different typical erosion-corrosion environments such as solution of sand, solution of sand with free acid in pH 2-7. The erosion-corrosion coefficient was evaluated by Apparatus for abrasion-corrosion testing. Wear coefficient, K, was calculated by formula: K= $\Delta M_{etalon} / \Delta M_{alloy}$ Testing results were showed that the alloy with composition (%): Cr=28-30; C=1.8-2.0; Mn=2.5 - 3.0; is the optimum for manufacturing details resistant erosion-corrosion in media upto pH=2-3.

This alloy is used successfully to produce details for sand-pumps, minerals processing cyclones.

2. Experimental

2.1 Choosing the compositions of alloys

Two groups of Fe-Cr-C alloys with different crystal structures were chosen according to the phase-diagram of Fe-Cr-C system. Annealed steel SAE 1020 sample was used as Etalon.

2.2 Method of alloy making:

Materials for alloy making were ferrochromium (high and middle carbon), ferromanganese, cast iron, ferromolypdenum, copper. Alloying was done in electric induction smelting furnace with middle frequency. After alloying and casting, all the ingots were thermally treated by the same regime in the electric resistance furnace. Thermal treatment was important process to achieve expected crystal structure.

2.3 Methods for measurements:

- The chemical composition - by Spectrometer, Type ARL - 3460.
- The microstructures - by X- ray diffractometer, Type SIEMENS D-500.
- The size and distribution of crystal phases - by SEM , Type Jeol - 5000.
- The passivation of alloy - by PRINCETON Potentiostat,

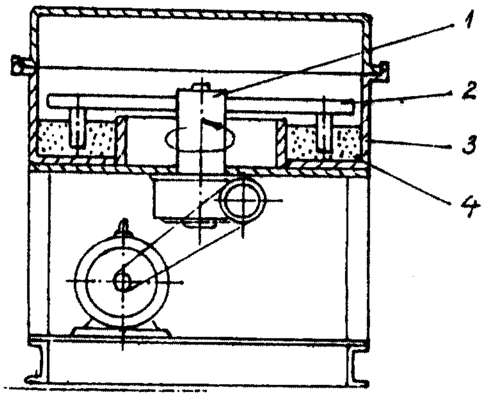


Fig. 1. Mechanical outline of apparatus for abrasion-corrosion testing

1- Rotary mechanism
2- Arms for holding the specimens
3- Trough for abrasive suspension
4- Abrasive - corrosion suspension

Table 1. Composition and microstructure of studied alloys

Samples	Composition (%) and microstructure							Hardness (HRC)
	C	*Cr*	*Si*	*Ni*	*Mn*	*Cu*	*Structure*	
SAE1020 Steel	0.28	-	0.41	-	0.45	-	100% ferrite	130HB
HKC-15	2.7	15.8	0.7	-	-	1.0 Cu 1.5Mo	Cr_7C_3 + M +A	61
HKC-20	2.32	21.49	0.71	-	1.60	1.5	Cr_7C_3+ M+A	56.5
HKC-25	2.18	26.52	1.1	-	2.57	1.50	$Cr_{23}C_6$+ Cr_7C_3+ M+A	53.4
HKC-30	2.01	30.16	0.82	-	3.1	-	$Cr_{23}C_6$+ Cr_7C_3+ M+A	51.6

Type CMS - 100.

- Corrosion and abrasion resistance of the alloys by apparatus for abrasion-corrosion testing (figure 1), here,

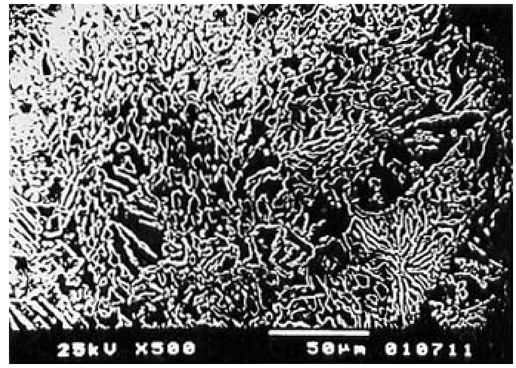


Fig. 3. Microstructure of the HKC-30 alloy

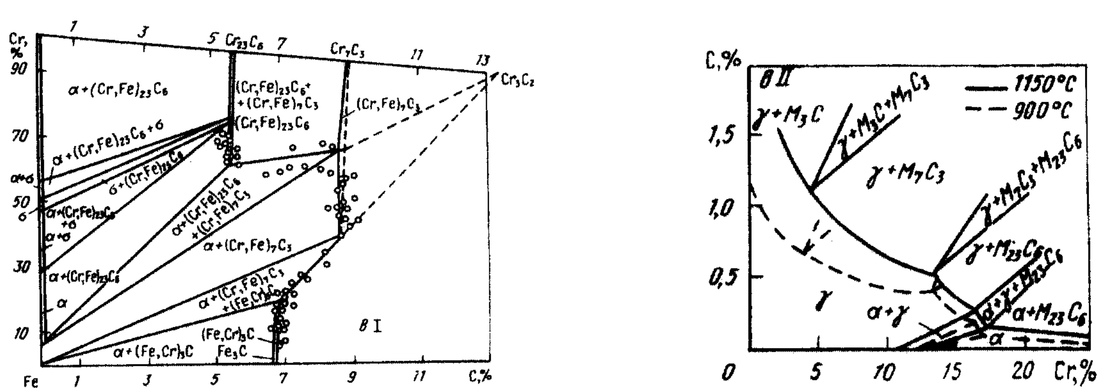
the wear coefficient was calculated as follow:
K= ΔM_{etalon} / ΔM_{alloy} (ΔM is weight loss of specimen)

3. Results and Discusion

The chemical composition of the alloys was shown in table 1. Manganese, copper and molypdenum had been added to achieved martensitic matrix after quenching in the air. The crystal structures were foreseen from phase-diagram of Fe-Cr-C system and shown on figure 2.

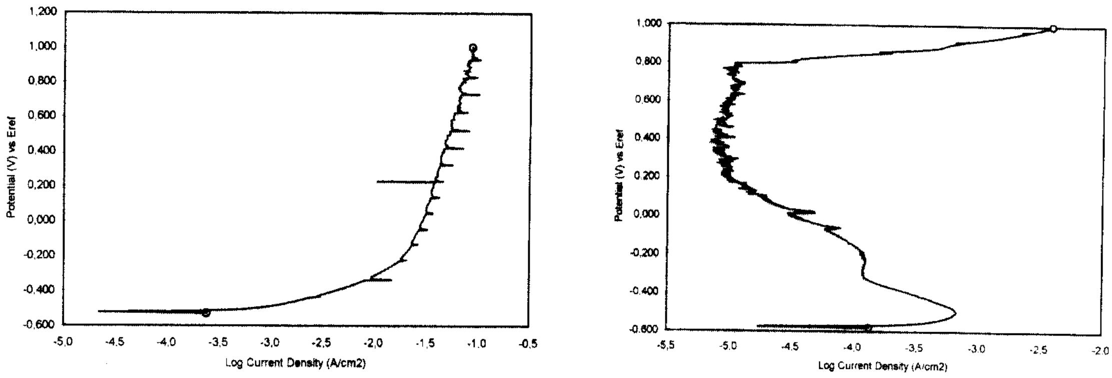
The alloys with Cr < 15% were specified with carbide grains type M_7C_3 (M-Metal) and martensitic + austenistic matrix, whereas the alloys with Cr > 25% specified with $M_{23}C_7$ + M_7C_3 grains and martensite + austenite matrix. It was shown in[1-3] that the matrix phase with martensite structure has minimum elastic micro-deformation, it would strongistly hold carbide grains and then the alloy has the best abrasive resistance. The hardness of M_7C_3 carbide grains is the highest, while M_3C- the lowest. On the evidence of these, it can confirm that the alloy with martensitic matrix and carbide $M_{23}C_6$ + M_7C_3 has the best corrosion-abrasive resistance.

The chromium content in the alloy was divided into both matrix phase and carbide grains. When the chromium



(a) (b)

Fig. 2. Phase diagram of Fe - Cr - C system at 25°C (a), 900°C and 1150°C (b)



(a) (b)

Fig. 4. Potentiodynamic anodic polarization curves of HKC-20(a) and HKC-30(b) samples, in H_2SO_4 solution, pH=2

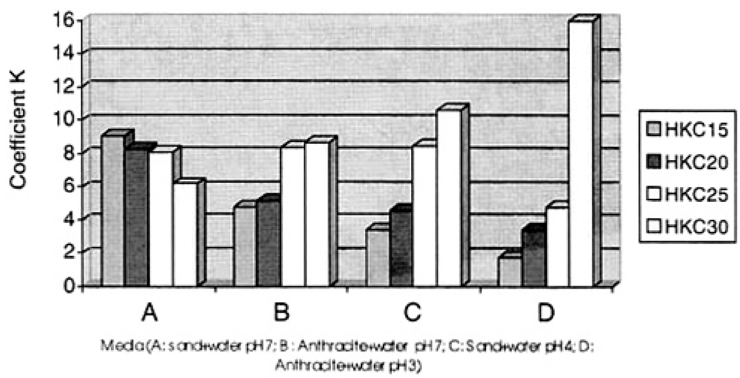


Fig. 5. Abrasive - corrosion coefficients of alloys in different media

content increases, the quantity of carbide grains would increase parallelly with chromium concentration in the matrix phase. Authors[2,3] have shown that the optimal weight proportion of carbide grains for the best abrasive-resistance alloy is 30%. The alloy HKC-30 with 30.16% Cr is satisfied this condition, therefore its crystal structure was likely similar to this of composite materials, as seen in figure 3.

By the ability of forming the passive film, the chromium dissolved in matrix phase will determine the corrosion resistance of the alloy. The increasing of chromium content in alloy leads to increasing the corrosion resistance. This relationship was demonstrated by potentiodynamic anodic polarization curves in H_2SO_4 solution of samples HKC-20 and HKC-30 in figure 4. The alloys with less 20% Cr had no passivation, all the range of polarization potentials from E_{cor} = -525 mV/SCE to E = +800 mV, the alloy was still active. The alloy HKC-30 with Cr = 30,16% had clearly passive action. The passivation appeared at E_p = 505 mV and I_p = 6.93 10^{-4} A/cm^2 and ended at E_{pp} = +100 mV and I_{pp} = 1. 10^{-5} A/cm^2. These data proved strong passive film of HKC-30 alloy in studied solution (H_2SO_4, pH =2).

The results of abrasive - corrosion measuring in different media were shown in figure 5. It was seen that in the neutral medium sample with 21.45% chromium has abrasive - corrosion coefficient K = 8.1, and the similar with 30.16% chromium sample. In acid medium, their coefficients were different, K of sample HKC-30 was strongly increased, whereas K of sample HKC-20 was decreased. It was proved that the alloy HKC-30 was the best in abrasive and corrosion resistance.

4. Conclusion

In the present work, erosion-corrosion resistance of some kinds of high chromium cast alloy has been studied. It was shown that alloy of 30.0% chromium and 2.0% carbon with structure consisting of $M_{23}C_7$ + M_7C_3 crystals in martensite matrix, had low weight loss in weak corrosion suspension of abrasive. This percentage is an essential condition for the alloys to have both corrosion and abrasive resistance.

This alloy has proved very good for mining and mineral processing machinery parts such as sand-pumps, cyclones.

Acknowledgement

Authors would like to express their thanks to Fundermental Research Program of Vietnam for financial suppot.

References

1. Scientific Report of National Programme KHCN.03 *"Improving the Quality of Metallic Products"* Hanoi, December (2000).
2. Xypin I. I. *Belye iznosostoikie chuguny*, Metallurgia, Moskva (1983).
3. Cihal V. *Mezikrystalova koroze oceli a slitin*, SNTL, Praha (1978).
4. Avery H. S. *Surface Protection Against Wear and Corrosion*. Published by the ASM Cleveland, Ohio (1953).