The Structure of Resistant Surface Layer in High-Entropy Alloys of System $VCrMnFeCoNi_x$

Karpets M.V[1], Myslyvchenko O.M[2], Rokitska O.A[1],
Krapivka M.O[1], Marchenko S.V.[3]

[1]*Institute for Problems of Materials Science, NAS of Ukraine*
[2]*National Technical University os Ukraine "KPI", Kyiv,* Ukraine
[3]*Sumy State University (SumSU), Sumy, Ukraine*

In 2007 J.W.Yeh worked out the scientific fundamentals and proposed the formal criteria of material adequacy to new class of alloys, which were names as high-entropy alloys (HEA) [1]. According to these criteria such alloys which contain not less than 5 elements are referred to HEA, though the amount of every element mustn't exceed 35 at. % mustn't be less than 5 at. %. This class of alloys is new; because the processes of phase formation and the mechanism of mechanical characteristics are considerably differ from the similar processes in traditional alloys. The latter alloys are those where the main elements are Fe, Al, Cu and others, which defined the crystal lattice of the material. The goal of this work is to research the surface layers of friction zone of HEA of system $VCrMnFeCoNi_x$ (where x= 1; 1,5; 2 in molar correlation (in the text they will be named as Ni_1, $Ni_{1,5}$, Ni_2).

Table1. The results of X-ray diffraction analysis and mechanical characteristics of alloys of system $VCrMnFeCoNi_x$.

Alloy	Phase compos.		Lattice period, nm	Inside the friction zone		Outside the friction zone	
	Struct.	Mass.,		H^*, GPa	E^{**}, GPa	H^*, GPa	E^{**}, GPa
Ni	σ	68	a = 0,8787 c = 0,4664	15±0,7	175±9	9,1±0,5	140±4,2
	FCC	32	a = 0,3599				
$Ni_{1,5}$	σ	16	a = 0,8841 c = 0,4603	6,5±0,3	160±8	5,4±0,3	134±4,1
	FCC	84	a = 0,3625				
Ni_2	FCC	100	a = 0,3603	5,4±0,3	148±7	3,6±0,2	131±3,9

* microhardness, ** Young modulus

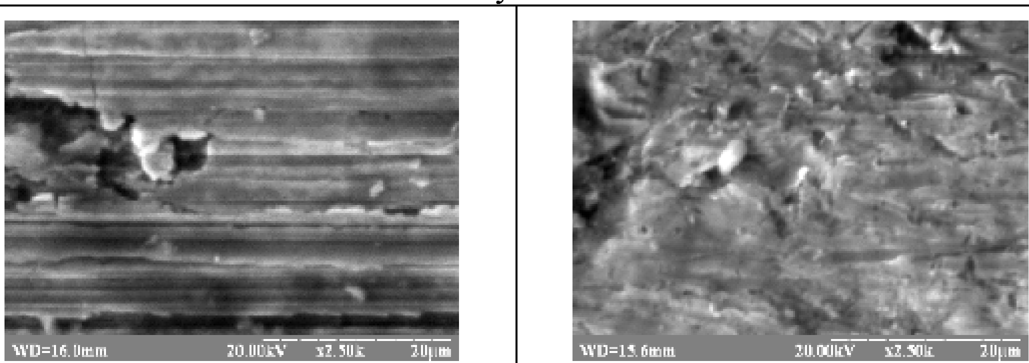
These alloys gained by the method of argon-arc melting, some plates were cut from them to do the test on resistance for abrasive wear. The determination of wear resistance was done according to State Standard 23.208-79 (Material test method for wear resistance at friction on flexible fastened abrasive particles). An arithmetical mean loss of weight of the pieces was: g_{Ni1}=0,0204 g; $g_{Ni1,5}$=0,037 g; g_{Ni2}=0,0412 g, relative resistance was: K_{Ni1}= 3,03; $K_{Ni1,5}$= 1,69;

K_{Ni2}= 1,54 properly. This test showed, that alloy Ni_1 had the highest level of abrasive resistance.

The phase composition of researched alloys in initial condition is marked in table 1. In all investigated concentration interval of content changes of Ni the number of phases are changed from two (solid solution with structure FCC+ σ-phase of type CrFe) to one (solid solution with structure FCC). That is for the increasing of amount of Ni in system the amount of solid solution with structure FCC is also increased. The ratio of lattice spacing c/a, for σ-phases in formed HEA is in the interval 0,517-0,518, that is practically coincided with the correlation c/a (~0,517) for the double and triple σ-phases.

The morphology of surface layers of friction space was investigated with a help of Scanning Electron Microscopy and is shown on the picture 1.

The intensive nicks are formed in alloy Ni_1, oriented to the way of friction. it should be noted, that abrasive particles in pointed zones-lines are not matched. In alloy Ni_2 the considerable changes are caused on the friction surface. It has the flat surface with fine and chaotically distributed scratches.



а б

Picture1. – The Friction Surface in Secondary electrons (SEI) of alloys: a) $VCrMnFeCoNi_1$, × 2500; b) $VCrMnFeCoNi_2$, × 2500

The mechanical characteristics of materials in and out of friction zones are changed (table 1.). As the results of X-ray diffraction analysis showed, qualitative and quantitative changes of phase compound in the friction zone were not occurred. The increasing of micro hardness in the process of friction on the surface of the material is explained of formation of nanosrtuctural components. During hardness measuring by Rokvel method (HRC) the difference in and out of friction zone was not occurred, that indicated the small thickness of nanostructures layer.

1. Yeh J.W., Chen Y.L., Lin S.J. High-entropy alloys – a new era of exploitation // *Materials Science Forum.* 560, (2007), 1.