Study on wear resistance FeNiCrMnAl high entropy alloy. Mechanical properties.

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Abstract. Traditional alloys are based on a single element called matrix and to improve some mechanical properties (strength, ductility) are added and other metallic elements in the system. High entropy alloys have become a field of increasingly explored in the world of materials. Excellent mechanical properties obtained of the high entropy alloys recommend them to be from year to year as investigated. In the last decade more than 500 high entropy alloys journal and conference papers have been published [1]. High entropy alloys are alloys who have in their composition 5 to 13 metal elements and the concentration of each component is between 5% and 35%. These elements in the composition of high entropy alloys are divided into elements of minority and majority elements. They are called minority elements because their molar fraction is less than 5%. High entropy alloys have mixing entropy higher than traditional alloys, $\Delta S_{cons} \geq 1.61R$ (R = 8.314 J / (mol • K)) [1]. High entropy alloy have been obtained in the laboratory of Science and Materials Engineering faculty from Iasi using a medium frequency induction furnace with 8000 Hz. Because they have excellent mechanical properties high entropy alloys can be used in various fields with high wear and corrosion degree or electronic, magnetic applications [1]. In this work we selected pure metallic elements like: Fe, Ni, Cr, Mn and Al. The quantity of alloy developed varied between 0.5 and 1.5 kg. Metal load necessary for the preparation of metal alloys were formed technical grade, industrial accessible prices and satisfying. Friction and wear rezistance were studies by using a reciprocating sliding test machine, in a pin on disk configuration, using aluminum as counter face.

In this paper it investigated the wear resistance of high entropy alloys obtained, microstructure and their mechanical properties.

Introduction:

Since the early ages of time the universe of alloys was mainly based on the sole concept that they are made of only one component or singular element [2]. That concept was the ground for developing the more practical alloys used today in everyday life in order to help the human civilization. All that being said, this notion was frequently blamed for the fact that it limits the chemical composition of the alloy and was being restrictive with the manufacturing of certain structures and special microstructures that could have had varied applications and properties [3-4]. Unlike the traditional way of making alloys, that used to contain only two or three metallic elements, this notion was able to make alloys that could contain up to five, six or even seven chemical elements but only contained in equal proportions. Keeping that in mind, all of the alloys that were made had to respect this condition and based on that certain tests were conducted (regarding density, hardness, resistance to impact, ductility, resistance to abrasion and finally resistance to oxidation in different environment such as air and liquid) [6-9]. The new concept, called high entropy alloy, was exposed and explored and it made scientists to be really excited. An alloy that has "high-entropy" (HEA) it's an alloy that is made from at least five metallic elements in equal atomic percent (at. %) [9]. This alloy has high blending entropy that conducts to forming a solid solution. The concentration of each element isn't necessarily equi-molar but it can be between 5% and 35% which allows the possibility of the number of high-entropy alloys systems to grow [10, 11].

2. Materials and methods

FeNiCrMnAl high entropy alloy investigated was obtained in the laboratory using an induction furnace.

In order to obtain the FeNiCrMnAl, high entropy alloy, we used metallic materials, with high purity level that were industrial accessible and with reasonable prices, to make the chemical composition. The metallic load calculation was made taking into account losses of certain elements, due to association with othersor specific to an induction furnace and a controlled atmosphere, the percentage and the difference between melting temperature of each chemical element.

After all the components were melted, the resulted high entropy alloy was casted into molds made out of furan resin.

3. Experimental methods

To investigate mechanical properties and wear resistance FeNiCrMnAl high entropy alloys we used different modern methods like: SEM (scanning electron microscope SEM Vega Tescan LMH II, structural analysis 2D and 3D), optical microscope (Optical Microscope Microphot FXA with a camera Hitachi HV-C201A 3CCD), chemical analysis EDAX (Equipment Bruker), value hardness high entropy alloys FeNiCrMnAl (hardness tester Vickers Tukon 2100 B, hardness tester Brinell (Wolpert Dia Testor 3b, hardness tester Rockwell (Roc 4JR, Instron B2000, X-ray diffraction (X'Pert Pro MPD) and reciprocating sliding test machine Pin-on-disc contact.

Friction coefficient monitored continuously during testing and wear of the disk measured after the disk with 3D topography analysis (confocal microscope ALICONA FOCUS G4).

4. Results and discussion

The chemical composition (at%) and (m%)for FeNiCrMnAl high entropy alloys is given in table 1, determined using EDAX.

Table 1. Chemical composition for FeNiCrMnAl high entropy alloy.

Element	(at%)	(m%)
Iron	30	32.3
Nickel	10	11.3
Chromium	30	30.0
Manganese	20	21.2
Aluminum	10	5.2
Total	100%	100%

4.1 Microstructural characterization

The Figure 1 shows the structure to FeNiCrMnAl high entropy alloy. The analyzes performed show that the high entropy alloy studied has a dendritic structure. Well obviously limits are the primary grains. This alloy is very close to a structure type solid solution but probably due to low aluminum content, the volume is lower secondary phases.

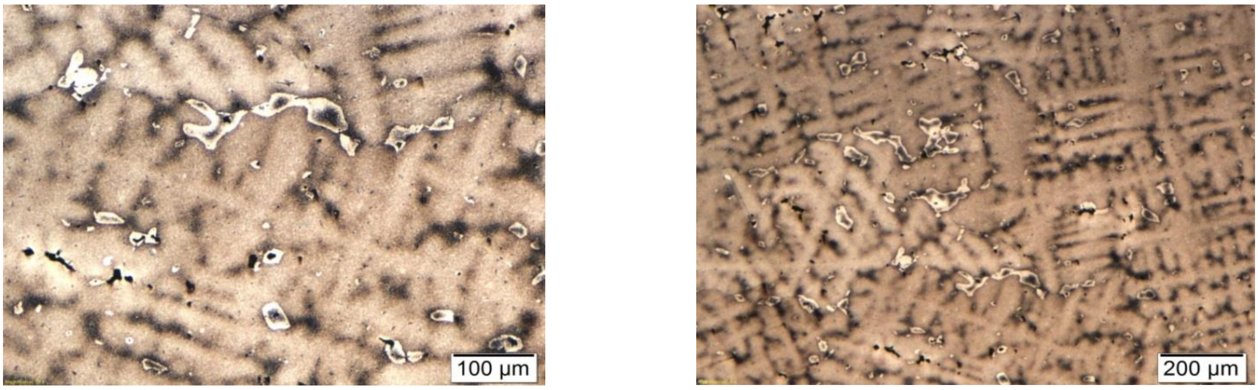

Fig 1. Optical micrograph of experimental FeNiCrMnAl high entropy alloys.

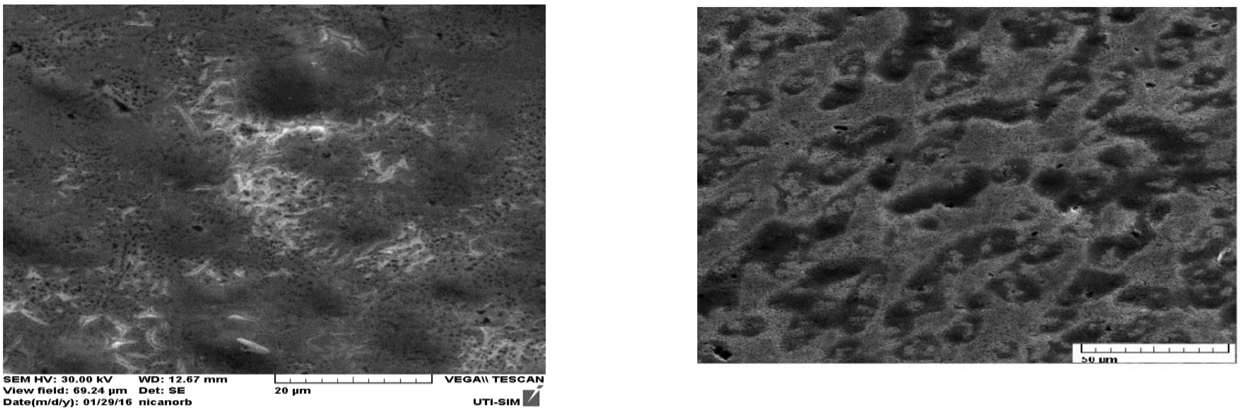

Fig 2. SEM image of experimental FeNiCrMnAl high entropy alloy.

4.2 Hardness Test

Hardness is the property of a material that shows the ability to oppose to an action of permanent shape change when a compressive force is applied. The representative values as the results of the hardness of the high entropy alloy, FeNiCrMnAl, are shown in table no. 1.

Table 2. Hardness value for FeNiCrMnAl high entropy alloy.

	High entropy alloys	Parameters		Vickers Hardness HV	Rockwell Hardness HRC	Brinell Hardness HB
		F, [kgf]	t, [s]			
1.	FeNiCrMnAl	1	15	475	47	450

4.3 Wear resistance high entroy alloys FeNiCrMnAl

To determine the wear resistance we used reciprocading sliding test machine pin-on-disc contact, framework laboratory of Institute of Metals and Technology, Ljubljana, Slovenia. The parameters used was: F_N (normal load) =30 N, a (amplitude)=4mm, f(frequency)=15 Hz, p_H (contact pressure)=1GPa, t (timeof test)=1667 s, v_s(average sliding speed)=0.12 m/s, counter body Al_2O_3= 20 mm, disc ball.

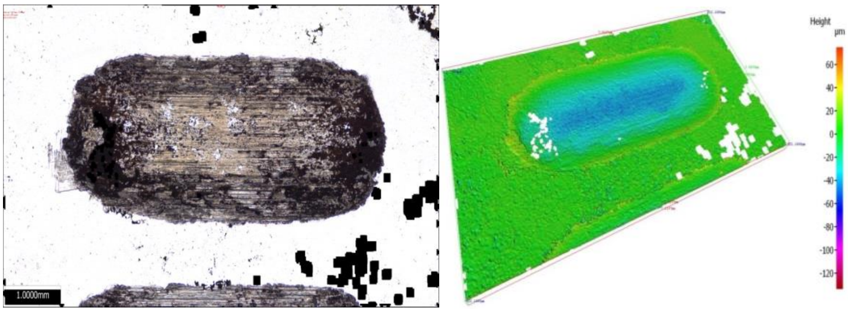

Fig 3. Trace on the surface test wear resistance of high entropy alloys FeNiCrMnAl.

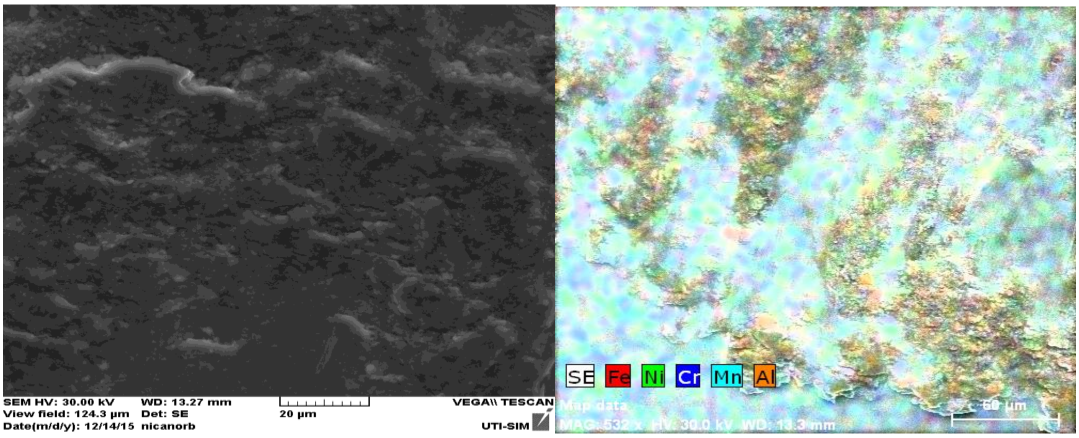

Fig 4. SEM micrograph after test wear rezistance and distribution of elements in high entropy alloy FeNiCrMnAl.

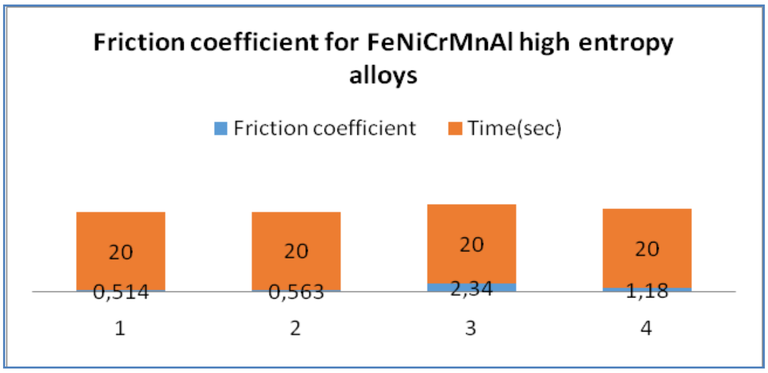

Fig 5. Friction coefficient for FeNiCrMnAl high entropy alloy in the first 20 s.

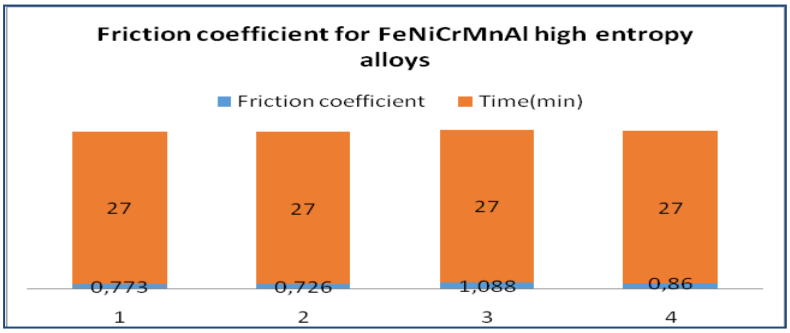

Fig 6. Friction coefficient for FeNiCrMnAl high entropy alloy for 1667 s.

The figure 5 and figure 6 represent friction coefficient for the high entropy alloy FeNiCrMnAl. The sample was performed by 3 attempts, represented in diagrams with 1, 2 and 3. No.4 represents the average of the 3 attempts. It has been observed that in the first 20 seconds friction coefficient was very high then up to the end of 1667 seconds and was observed constant movement.

Conclusions:

High entropy alloy proposed for mechanical properties analiyses and test wear resistance was successfully obtained and prepared.

Microstructural analysis show that the alloy investigated has a dendritic structure closer to solid solution structure.

Hardness value for FeNiCrMnAl high entropy alloy was 450 HV.

Medium value for friction coefficient FeNiCrMnAl was 0.87 for 1667 seconds and 1.18 in the first 20 seconds.

Acknowledgments

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