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Investigation of the mechanical properties of FeNiCrMnSi high entropy alloy wear resistant

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Abstract. In this paper we investigated microstructure, hardness and wear resistance for FeNiCrMnAl, high entropy alloy. The FeNiCrMnSi, high entropy alloy was elaborated in a medium induction furnace, by choosing the silicon, as an alliance element within the equi-atomic high entropy alloy, we managed to obtain a dendritic structure, the formation of intermetallic compounds or separated silicon. The medium hardness value of the investigated alloy was 948.33 HV and the medium value of the friction coefficient was 0.6655 in the first 20 seconds and 0.5425 for 1667 seconds. The volume loss of the high entropy alloy FeNiCrMnSi was 0.0557 mm³.

1. Introduction

High entropy alloys were discovered in 1995 by the researcher Yeh [1]. These sorts of alloys have appeared as a new type of material that has captivated almost instantly material science researchers. Unlike the traditional alloys, the high entropy alloys show a series of excellent physical and mechanical proprieties (elevated hardness, resistance to usage, resistance to corrosion) that recommends them for a wide range of functions [1-3]. The main principle that basses the existence of high entropy alloys (HEA) is that by increasing the number of principal elements of alliance, solid solutions are formed in a preferential way. This principle is derived from Boltzmann's hypothesis on the connection between the entropy and the complexity of a system. We can deduct from here that for an equi-molar alloy that contains at least 5 main alliance elements, the configurational entropy change during the forming of the solid solution is bigger than the entropy change necessary for the melting of the majority of metals [4]. Starting from this principle, in the last two decades, the researches for the evaluating method of the forming capacity of the HEA, for varied alloy systems, has intensified itself and also the investigation interest of a number of over 100 HEA compositions has grown. These alloys made themselves conspicuous by special functional proprieties, such as: elevated hardness, resistance to usage, resistance to high temperature, resistance to corrosion [5]. These properties are considered to be the result of 4 effects: a) the high entropy effect, b) the slow diffusion effect, c) the deformation of the crystalline network effect, d) the "cocktail" effect, which indicates the procurement of special properties by mixing a sufficiently big number of alliance elements [6].

Because of the great number of possible metal combinations that can be used to synthesize the HEA, a series of key selection criteria for the metals has been defined, they can be used for a HEA with certain properies [7-9]:



- The configurational entropy (ΔS_{mix}), that has to be higher than 1.61R
- The difference between the atomic radius, that has to be equal or less than 6.6% in order to form solid solutions
- The concentration of the valence electrons (VEC-Valence Electron Concentration), indicates the type of solid solution that can be formed: for $VEC < 6.87$ cubic solid solution with a centered volume, for $6.87 < VEC < 8$ mixed structure CVC and CFC and for $VEC > 8$ cubic solid solution with centered features
- The electronegativity difference, χ , that has to be between 3 and 6% in order to form solid solutions

2. Materials and methods

To obtain FeNiCrMnSi, high entropy alloy, we used a medium induction furnace 8000 Hz. We used metallic elements like: Fe, Ni, Cr, Mn and Si. The alloy obtained was poured into molds in the form of bars with a diameter of 12 mm and length of 100 mm. Grinding abrasives samples was executed with finesse abrasive grains increasingly smaller. Polishing was done by coating the disc with a cloth that has been moistened with continuous drip solution it Al₂O₃. To be analyzed sample was chemical attack with Nital. To investigate mechanical properties and wear resistance of FeNiCrMnAl, high entropy alloy, we used different 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), hardness (hardness tester Vickers Tukon 2100 B, hardness tester Rockwell (Roc 4JR, Instron B2000), and reciprocating sliding test machine Pin-on-disc contact. Friction coefficient was monitored continuously during testing and wear of the disk measured after the disk with 3D topography analysis (confocal microscope ALICONA FOCUS G4). Parameters for wear resistance have been: F_N (normal load) =30 N, p_H (contact pressure)=1 GPa, a (amplitude)=4 mm, f (frequency)=15 Hz, v_s (average sliding speed)= 0.12 m/s, t (time)=1667 s.

3. Results and discussions

Table 1. Characteristics of metal components of the FeNiCrMnAl high entropy alloy.

Metal	Atomic radius, [pm]	Electronegativity		Valence Electron Concentration
		Pauling	Allen	
Fe	127	1,83	1,800	8
Ni	125	1,91	1,880	10
Cr	128	1,66	1,650	6
Mn	126	1,55	1,750	7
Si	132	1,90	1,916	3

3.1. Chemical composition

The chemical composition of the FeNiCrMnSi high entropy alloy is shown in table 1.

Table 2. Chemical composition for FeNiCrMnSi high entropy alloy.

Element	(at %)	(m %)
Iron	20	22.4
Nickel	20	23.5
Chromium	20	20.8
Manganese	20	22.0
Silicon	20	11.3
Total	100%	100%

The chemical composition is determined using SEM-EDAX.

3.2. Optical microscopy for FeNiCrMnAl high entropy alloy

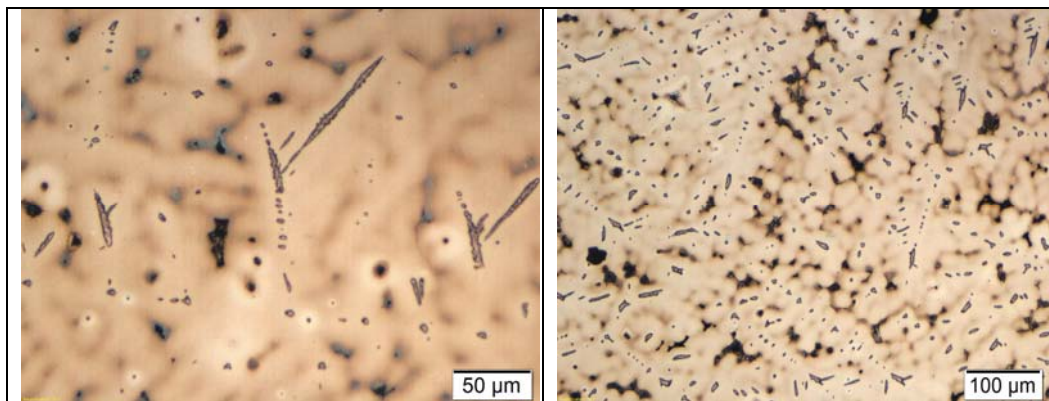


Figure 1. Optical microscopy FeNiCrMnSi high entropy alloy.

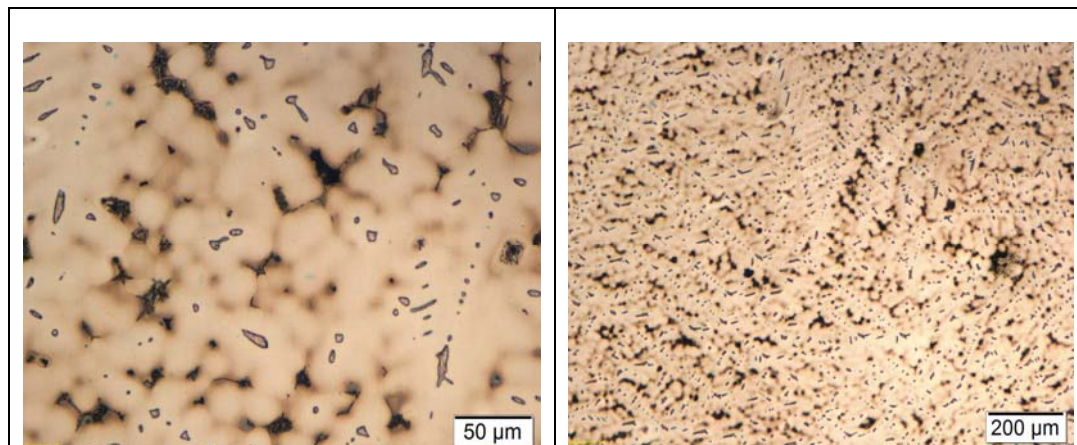


Figure 2. Optical microscopy FeNiCrMnSi high entropy alloy.

3.3. SEM analyse for FeNiCrMnSi high entropy alloy

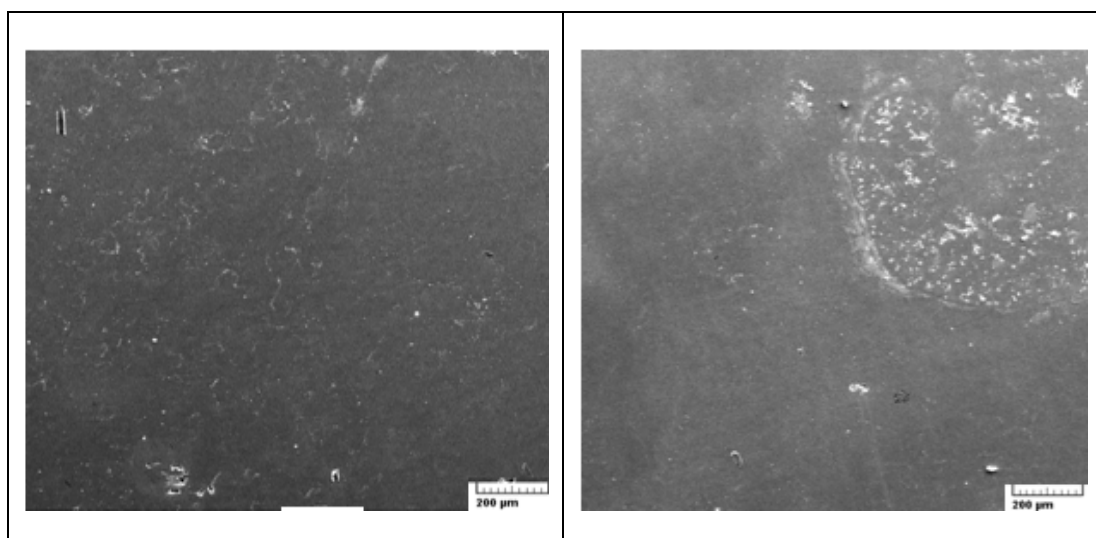


Figure 3. SEM microscopy for FeNiCrMnSi high entropy alloy.

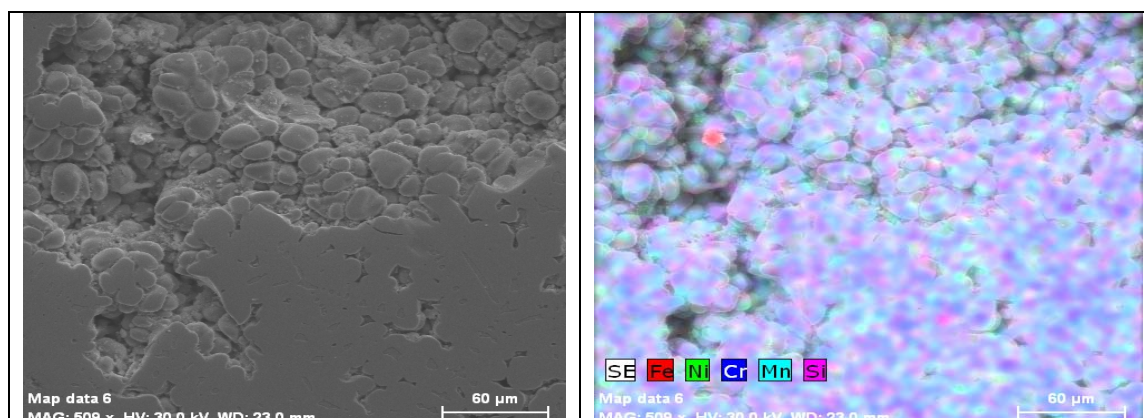


Figure 4. SEM microscopy FeNiCrMnSi high entropy alloy.

Figure 1 and figure 2 show the microstructural analysis which renders the fact that high entropy alloy FeNiCrMnSi has a dendritic structure. Inside the dendritic branches you can notice breaks on the secondary phase, possible silicon, due to the acicular shape or an intermetallic compound with silicon. The high entropy alloy, FeNiCrMnSi, gravitates towards a structure made out of a solid solution.

In figure 3 and figure 4, can see also notice the distribution of elements in the high entropy alloy FeNiCrMnSi that shows us that the investigated alloy has a homogeneous structure.

3.4 Hardness tests

Hardness is the ability an object to resist the tendency to destroy the superficial layers by another object, the pressure acting on its location on very small areas and do not get permanent deformations.

Table 3. Hardness value for high entropy FeNiCrMnSi.

High entropy alloy	Parameters		Vickers Hardness HV	Rockwell Hardness HRC
	F, [kgf]	t, [s]		
FeNiCrMnSi	1	15	948,33	68

The silicon influence as a principal alliance element in the high entropy alloy shows that it can elevate the hardness value to significant one.

The structure of the investigated alloy has led to a growth in hardness but to fragility in the alloy due to a pronounced deterioration of the mechanical proprieties.

3.5 Wear resistance for FeNiCrMnSi high entropy alloy

Wear resistance tests have been made with reciprocating sliding test machine Pin-on-disc contact, in mechanical testing laboratory Institute of Metals and Technology from Ljubljana, Slovenia.

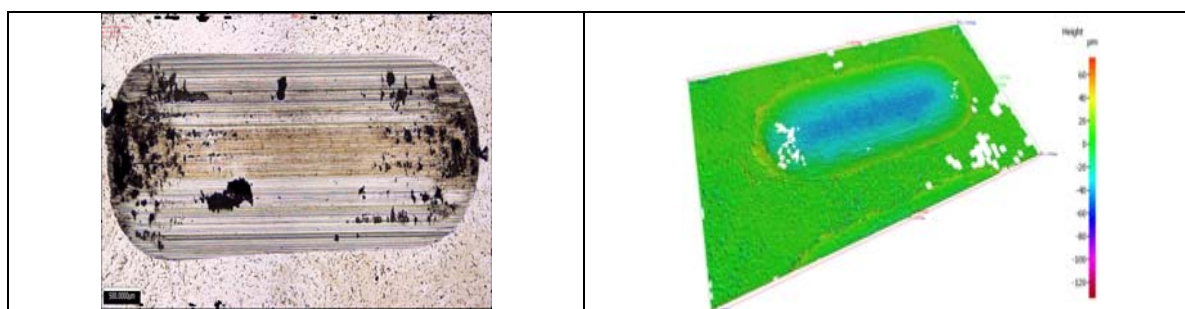


Figure 5. Trace on the surface test wear resistance of FeNiCrMnSi high entropy alloy.

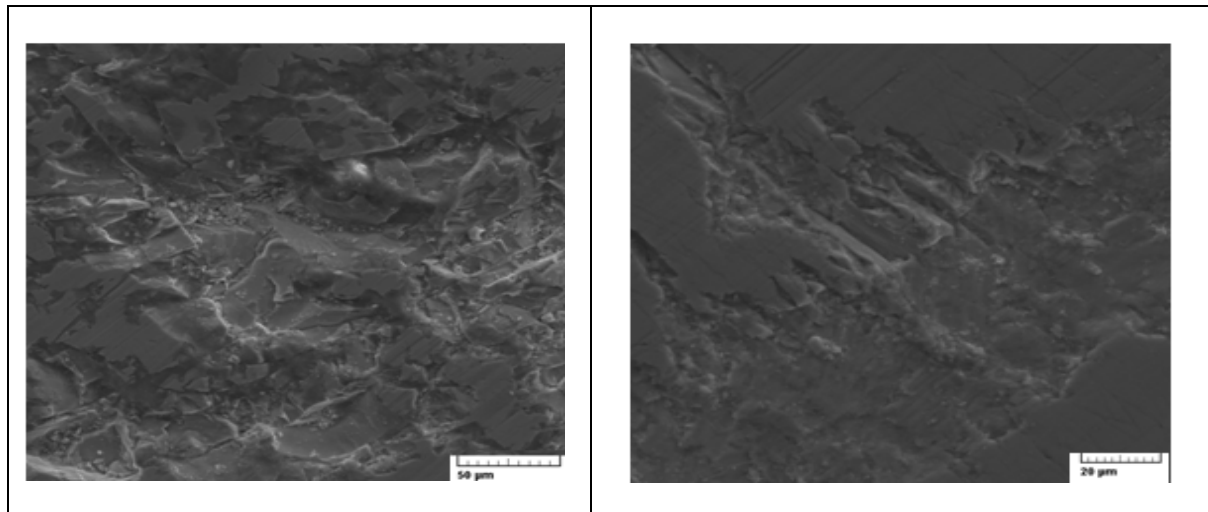


Figure 6. SEM microscopy after wear test for FeNiCrMnSi high entropy alloy.

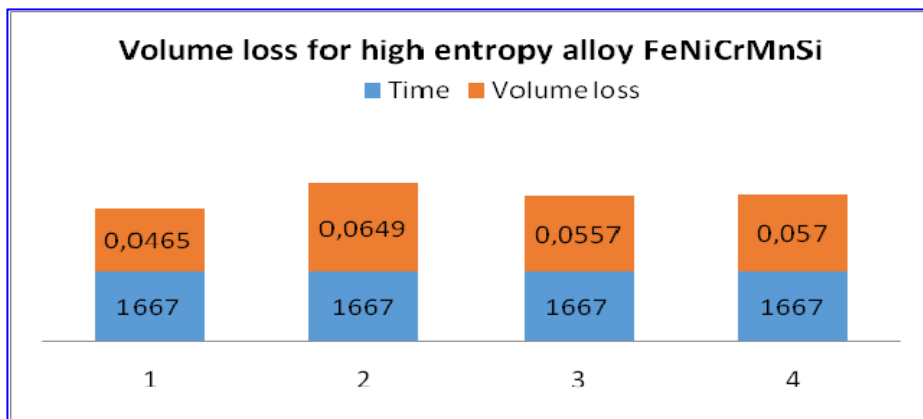


Figure 7. Volume loss for FeNiCrMnSi high entropy alloy for 1667 s.

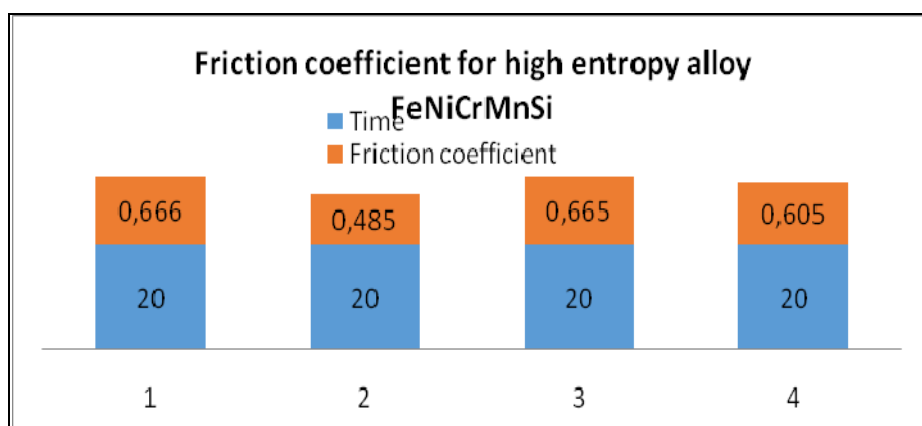


Figure 8. Friction coefficient for FeNiCrMnAl high entropy alloy in the first 20 s.

In figure 6 we can see that after a cycle of 1667 seconds we have a volume loss of 0.057 mm³ shown in figure 4. You can notice a volume loss of 0.0465 mm³ for the first time, represented in figure 1 and a 0.0649 loss for the second time, represented in figure 2 and a 0.0557 mm³ loss for the third time.

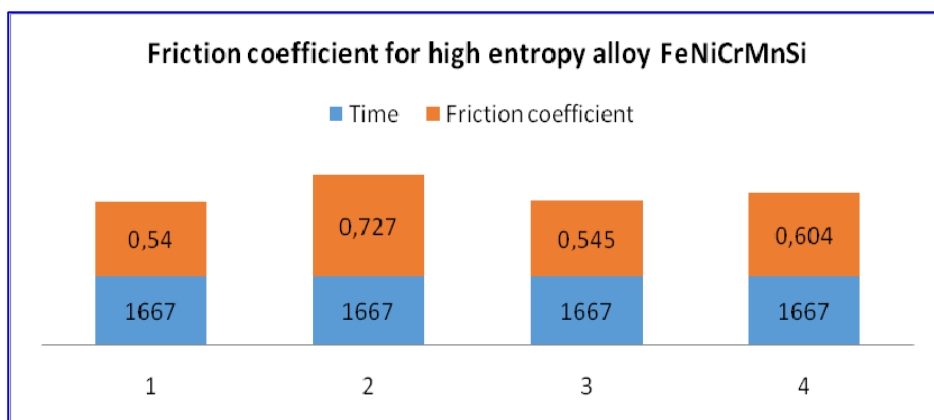


Figure 9. Friction coefficient for FeNiCrMnAl high entropy alloy for 1667 s.

Figure 7 and figure 8 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 was observed constant movement.

4. Conclusions

Microstructural analysis shows that the FeNiCrMnSi high entropy alloy has a dendritic structure closer to solid solution structure.

Hardness value for FeNiCrMnSi high entropy alloy was 948 HV.

Medium value for friction coefficient of FeNiCrMnSi high entropy alloy was 0,604 for 1667 seconds and 0,605 in the first 20 seconds.

After a cycle of 1667 seconds there is a volume loss of 0.0557 in the FeNiCrMnSi high entropy alloy.

Acknowledgments

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References

- [1] B.S Murty, J.W. Yeh, S. Ranganathan, 2014, *Elsevier*.
- [2] S. Dávid Molnár, 2015, *ELTE*.
- [3] B. Cantor, 2007, *Ann. Chim. Sci.Mat.*, 32, pp. 245-256.
- [4] J.W. Yeh, S. K.Chen, J. Y. Gan, S. J. Lin, T. S. Chin, T. T. Shun, et al., 2004 a. *Metall. Mater. Trans. A*, 35.
- [5] J. W. Yeh, 2006 *Chim. Sci. Mat.*, 31, pp. 633-648.
- [6] Y. Lu, et al., 2014 *Sci. Rep.*, 4, pp. 6200.
- [7] T. Ming-Hung and Y. Jien-Wei, 2014 *Materials Research Letters*, 2:3, pp. 107-123.
- [8] J.W. Yeh, 2006, *Ann. Chim. Sci. Mat.*, 31, pp. 633-648.