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Static Testing and Fatigue Behavior of Three High-Entropy Alloys

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Introduction The term "high entropy alloys" (HEA) was first introduced in 2004 to describe alloys with multiple major elements in equiatomic or near-equiatomic proportions [1,2]. A novel metallurgy was created that did not consider one or two major elements with the others as only minor additions, but rather all elements solidifying on equal conditions from the liquid state. High entropy alloys (HEA), that have been identified as multicomponent alloys which contain a at least five metallic elements with quantities in the range of 5 - 35 %, can easily lead to multicomponent solid solution phases and yield an interesting combination of high strength and toughness performance, superior ductility, excellent wear and corrosion resistance. One of the basic alloy from HEA category, AlCoCrFeNi, was discovered in 2014 by Zhang's group at University of Science and Technology from Beijing, China [3]. Many other groups have joined the research effort to understand this HEA characteristics as microstructure, hardness, strength, friction, thermal and corrosion resistance [4]. Although many interesting topics have been explored, only few studies deal with fatigue properties of this high-entropy system, in general depending of fabrication method. Experimental The high entropy alloys from the system AlCrFeCoNi were obtained in the ERAMET Laboratory of the Politehnica University of Bucharest, using the MRF ABJ 900 Vacuum Arc Remelting (VAR) installation [5]. The theoretical degree of assimilation of the chemical elements during melting and the possible losses by vaporization were taken into account for designing the metallic charge. Highly pure raw materials, including Al, Cr, Fe, Co and Ni (at least 99.99%) were used. In order to obtain the adequate homogeneity, the obtained alloys were flipped and re-melted in VAR equipment for 6 times (3 times on each part) under inert atmosphere of Argon. Tensile tests were performed at room temperature using a standard ASTM E8M specimen. The tensile test was performed at an initial strain rate of 10-3s-1 using a Bose Electro Force 3100 universal testing machine (Bose Corporation, Minnesota, USA) and the tensile test was carried out three times for every alloy. The high cycle fatigue test was conducted employing a standard ASTM E466 specimen. High-cycle fatigue terms were a frequency of 20 Hz and a stress ratio of R = 0.1 at room temperature. The fatigue resistance (fatigue limit) was fixed at the maximum stress level that does not produce fractures at 106 cycles. Prior to fatigue testing, the specimens were ground using 600 - 2500 grit emery paper and 0.3 μm alumina suspension to significantly minimize the influence of surface roughness as mentioned in the laboratory protocol [6,7]. Results and discussion Currently, many test procedures and models have been employed to estimate the fatigue behavior of materials. However, various test methods and types of materials have a substantial impact on the evaluation of fatigue performance. Therefore, to analyze the fatigue characteristics of different materials under various test procedures, the strength and fatigue properties of high entropy alloys were evaluated through tensile and compression tests at several different loading rates and stress ranges. In this work, three high entropy alloys of the AlCrFeCoNi system were tested (see Fig. 1). Based on this, the strength creep surface models associated with the loading cycles and the unified normalized fatigue model of the analyzed alloys under different stress conditions were determined. By comparing the differences between the fatigue performance of the three alloys, the results reveal that the fatigue performance of the analyzed materials were totally distinct under various test procedures. The standard fatigue equation cannot estimate the effect of sample size and stress level on the fatigue properties. Therefore, the fatigue model obtained in this paper can solve these difficulties. It is of course also clear that the fatigue behaviour of one sample is better than that of the other two alloys when the stress value is low. Therefore, the fatigue lifetime of this sample is considerably more sensible to the stress value than that of the other two alloys. On the basis of the settlement and the comparative examination of the standardized models of the fatigue properties of different high entropy alloys, the scientific transformation from alloy fatigue to structural fatigue is carried out, which offers perspectives on the anti-fatigue engineering of high entropy alloys. Conclusions The mechanical properties obtained from static testing and fatigue behavior of high-entropy alloys were correlated with other mechanical parameters (hardness and rugosity). From the comparison of the fatigue resistance grade of AlCrFeCoNi HEA with other metallic materials, it is clear that the fatigue resistance of the investigated materials is significantly higher than that of other tested materials.

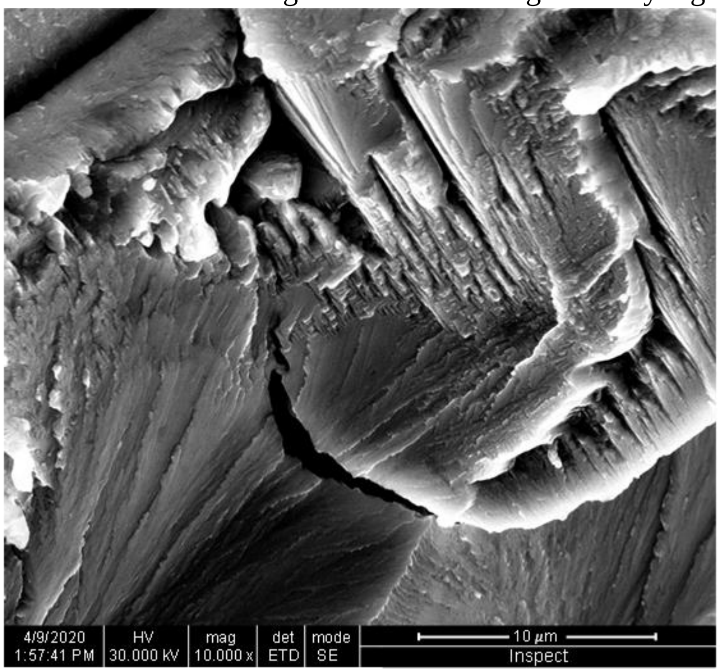

Figure 1. Fatigue fractography of the high-entropy alloy

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