Characterization of Sintered Fe-Cr-Mn Powder Mixtures Containing Intermetallics

A. Yönetken, A. Erol, M. Cakmakkaya

Abstract**—**Intermetallic materials are among advanced technology materials that have outstanding mechanical and physical properties for high temperature applications. Especially creep resistance, low density and high hardness properties stand out in such intermetallics. The microstructure, mechanical properties of %88Ni-%10Cr and %2Mn powders were investigated using specimens produced by tube furnace sintering at 900-1300°C temperature. A composite consisting of ternary additions, a metallic phase, Fe, Cr and Mn have been prepared under Ar shroud and then tube furnace sintered. XRD, SEM (Scanning Electron Microscope), were investigated to characterize the properties of the specimens. Experimental results carried out for composition %88Ni-%10Cr and %2Mn at 1300°C suggest that the best properties as 138,80HV and 6,269/cm3 density were obtained at 1300°C.

Keywords**—**Composite, Intermetallic, High temperature, Sintering.

I. Introduction

THE important tasks of modern materials science are the development of new materials capable working in extreme conditions, and the development of effective technologies for their preparation. Iron and Steel are the most versatile, least expensive, and most widely used materials for construction of many engineering systems Iron is a major alloying element in steels due to its strength and abundance. Bulk Fe is ferromagnetic with Curie temperature of 1043 K and crystallizes in the body-centered cubic (bcc) structure. Slightly above the Curie temperature (up to 1183 K), Fe maintains the bcc structure. With further increase of the temperature, it transforms from the bcc to the face centered cubic (fcc) phase. This transformation is believed to be martensitic [1]–[3]. Modern technology allows adjustment of elementary composition to obtain preset values of Curie temperature. Currently, in practice are used mainly Fe-Ni alloys and not so much Ni-Cu or Fe-Ni-Cr. There are also other alloying elements that adversely affect the value of Curie temperatures in this area, the alloying with Ni, as would be Si, Al, Mn. Fe (1043K) and Ni (627K) have higher Curie temperature than Fe-Ni alloy. Around 40wt% of Ni, the Fe-Ni alloy shows a minimum Curie temperature, approximately 573K. Also have been conventionally used Fe-Ni alloyed with Cr in England and other countries as a magnetic material with low Curie temperature [4]–[6]. Austenitic Fe-Cr-Mn stainless steels have received a lot of attention lately due to their important improvements over Fe-Cr-Ni alloys. The Mn-bearing alloys are not only less expensive compared to the Fe-Cr-Ni alloys, but have higher strength, creep, and wear resistance [7]–[9]. Several experimental as well as theoretical studies have been dedicated to the determination of the electronic structure, and the mechanical and magnetic properties of C- and N-containing Fe-Cr-Mn alloys. However, very few studies have been done on C and N-free Fe-Cr-Mn steel alloys so far. The aim of our study is to reduce this gap by studying the effect of Mn on the lattice stability of Fe-Cr-Mn solid solutions. Multi-component Fe–Cr–Mn–N alloys are a new class of engineering materials with superior mechanical properties and good corrosion resistance [10]–[14] which can be improved significantly by progression of an amorphous phase in these alloys. Powder metallurgy has given an enormous capacity to the processing of traditional metals and alloys as well as advanced materials known to researchers. This method can also be used to synthesize intermetallic phases such as FeCr, Fe_2Cr and etc., which are a few of the advanced technological materials that have outstanding mechanical and corrosion properties for high temperature applications [15]–[20]. The advantage of composite materials is the possibility to combine the beneficial properties of the reinforcement and the matrix and the use of the advantages resulting from their interaction and thus the formation of the desired resultant properties [21].

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II. Material-Method and Preparation of Sample

Starting powders employed in this study were as follows: the purity of 97% for Fe powders with a particle size-325 mesh, the purity of 99% for Cr powders a particle size -325 mesh and the purity of 99% for Mn powders with a particle size -325 mesh. The composition of %88Fe-%10Cr-%2Mn specimens was prepared in 5g circle compressed pre-form. They were mixed homogenously for 24 hours in a mixer following the weighing. The mixture was shaped by single axis cold hydraulic pressing using high strength steel die. A pressure of 300 Bar was used for the compacting all the powder mixtures. The cold pressed samples underwent for a sintering at 900, 1000, 1100, 1200 and 1300°C for 2 hours in a traditional tube furnace using Argon gas atmosphere. The specimens were cooled in the furnace after sintering and their micro hardness and shear strengths measurements were carried out using METTEST-HT (Vickers) micro hardness tester respectively.

Shimadzu XRD-6000 X-Ray Diffraction analyzer was operated with Cu K alpha radiation at the scanning rate of 2 degree per minute. LEO 1430 VP model Scanning Electron Microscope fitted with Oxford EDX analyzer was used for microstructural and EDX compositional analysis.

The volumetric changes of %88Fe-%10Cr-%2Mn composite material after sintering were calculated by using (d=m/V) formula (Fig. 1). The volume of post-sintered samples was measured with Archimedes principle. All the percentages and ratios are given in weight percent unless stated otherwise.

III. Experimental and Results

In the study, the samples prepared and shape were sintered at temperatures ranging from 900ºC to 1300ºC in conventional furnace and made ready for physical, mechanical and metallographic analyses. Density-temperature change curve is shown in Fig. 1. The highest sintered density was achieved at 1300°C as 6,26gr/cm3.

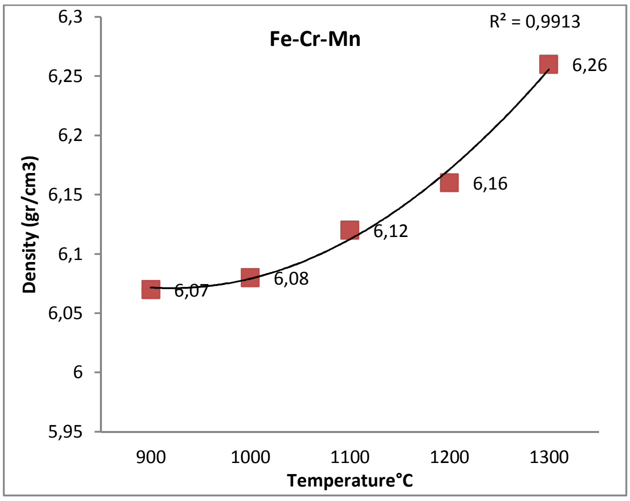


Fig. 1 The Density Change with Respect to Sintering Temperature

The micro hardness-temperature change diagram is shown in Fig. 2. The micro hardness values of the composite samples produced using conventional sintering technique within the temperature range 900-1300°C. According to this, the highest micro hardness value in the composite samples produced using powder metallurgy method was observed to be 138,8HV at 1300°C.

The shear strength and hardness of the metal-matrix composite specimens were also determined. The relation between the sintering temperatures and Shear strength values is shown in Fig. 3. The shear strength value in the composite samples was observed to be 125,28MPa at 1300°C.

A. Metallographic Analysis

The SEM analysis result of the metal matrix composite specimen obtained from Fe-Cr-Mn powders sintered at 900ºC is shown in Fig. 3 grain growth is observed and there isn't homogeneous structure. It can be seen that the more pores than from Fe-Cr-Mn powders sintered at 1300ºC. In Fig. 4, 1300ºC to become apparent degree of grain boundaries and grain boundaries can be seen that the pores very smaller and circular shapes. Sintering is better understood at 1300 ºC temperature. This density, hardness and shear strength values are confirmed.

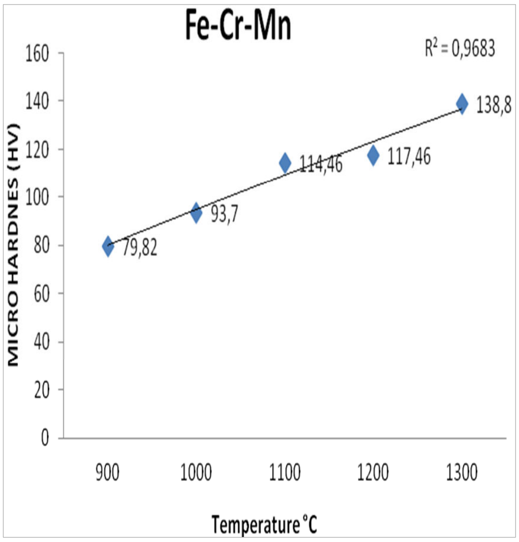


Fig. 2 The micro hardness tests results from sintered specimens treated at different temperatures

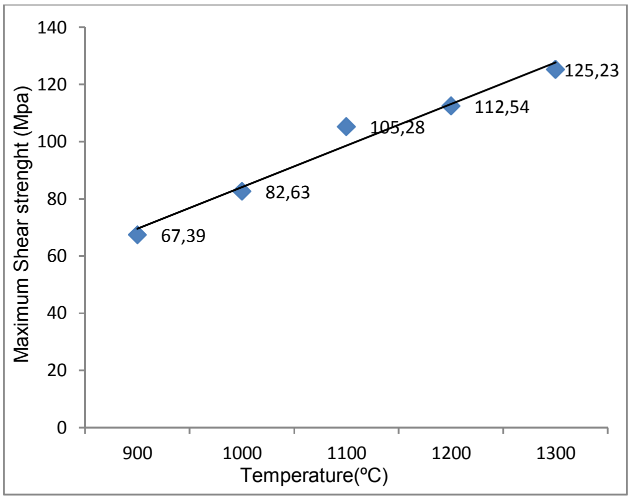


Fig. 3 Shear strength results from specimens sintered at different temperatures

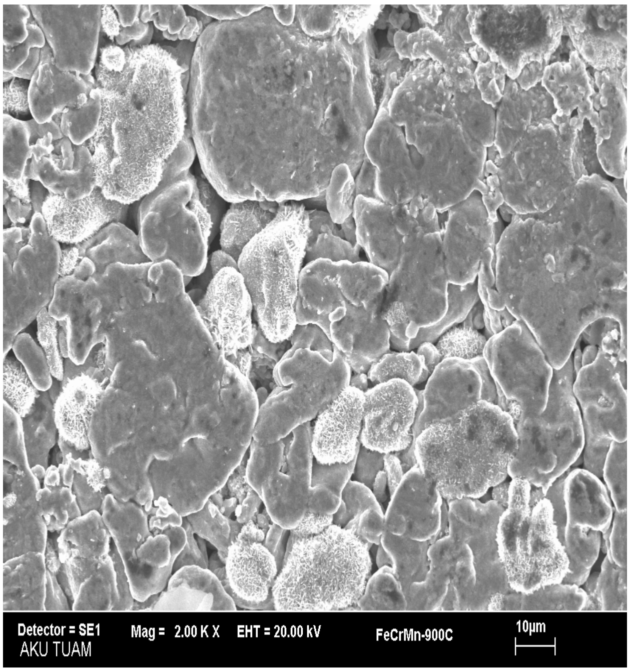


Fig. 3 SEM view of Fe-Cr-Mn composite 900°C

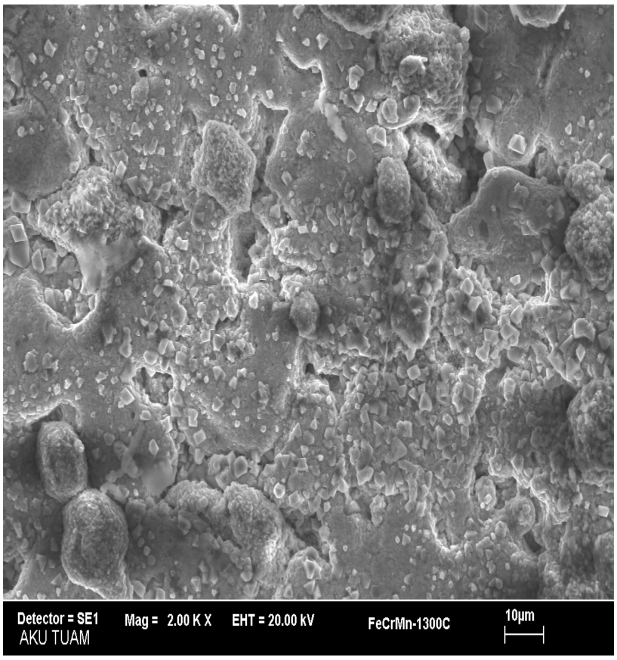
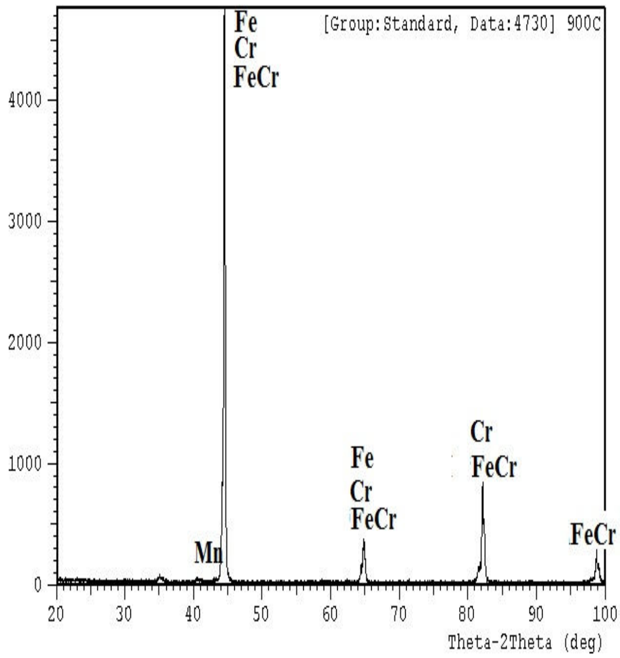


Fig. 4 SEM view of Fe-Cr-Mn composite 1300°C

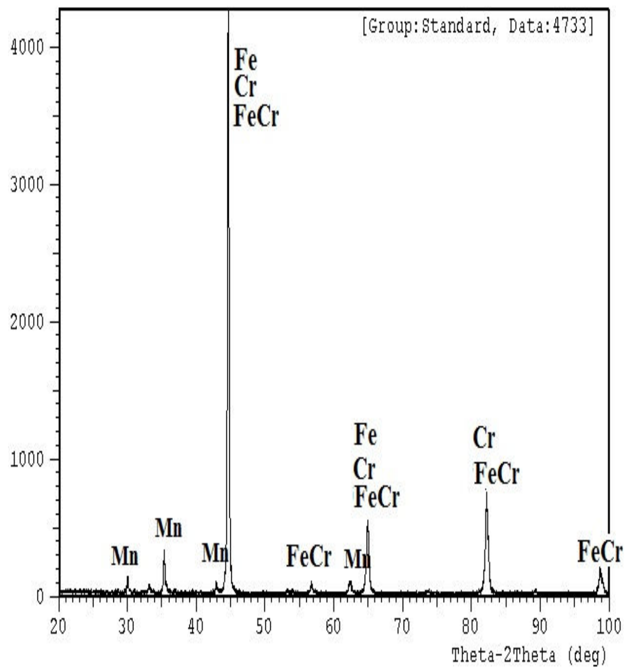
B. XRD Analysis

In Fig. 5, FeCr, Cr, Mn and Fe peaks can be seen in the XRD analysis from Fe-Cr-Mn composite sintered in tube furnace at 900°C and1300°C.

Fe-Cr-Mn powders were mixed and then sintered in a conventional furnace. After sintering, a considerable drop in the mechanical properties of specimens sintered at 900°C and 1300°C were observed. It was concluded that Fe-Cr-Mn particles were occured by FeCr intermetallic phase at 1300°C and Hardness test results suggest that Fe-Cr-Mn composite sintered at 1300°C shows Vickers micro hardness values respectively.



(a) 900°C



(b) 1300°C

Fig. 5 The XRD analysis Fe-Cr-Mn composites sintered at 900°C and 1300°C

IV. Conclusion

The following results were concluded from the experimental findings:

- The highest density in composite made from Fe-Cr-Mn powders sintered at different temperatures was obtained as 1300°C The highest density sample was found as 6,26gr/cm3 at 1300°C.
- The highest micro hardness in Fe-Cr-Mn composite samples fabricated using powder metallurgy method was found as 138,8HV at 1300°C.
- The maximum shear strength value in the composite samples was observed to be 125,28MPa at 1300°C.
- It was also found out for composition %88Fe-%10Cr-%2Mn at 1300°C suggest that the best properties.

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