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Fe-%40 Ni-%2X (X=Mn, Si) Süperalaşımlarında Yapısal ve Mekanik Özelliklerin İncelenmesi

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ÖZET

Bu çalışmada, Fe-Ni bazlı süperalaşımların alaşımlama elementlerinin yapısal ve mekanik özellikleri üzerine etkisini inceledik. Fe-%40Ni-%2X (X=Mn, Si) süperalaşımlarını ürettikten sonra sıra ile 1150 ℃ ve 1200 ℃'de 24 saat onları ısıl işleme maruz bıraktık. Yapısal ve mekanik özelliklerini mevcut şartlarda sırayla optik mikroskop (OM) ve taramalı elektron mikroskop (SEM) yöntemleriyle inceledik. Mekanik özellikler ise Vickers mikrosertlik (VS) ve zor-zorlanma yöntemleriyle belirlenmiştir. OM ve SEM görüntüleri bu iki numunenin oda sıcaklığında austenite yapıda olduğunu göstermiştir. VS ölçümleri Fe-%40Ni-%2Si numunesinin ortalama sertlik değerinin (147.2 VSD) Fe-%40Ni-%2Mn numunesinin ortalama sertlik değerinden (119.2 VSD) daha büyük olduğunu ortaya çıkarmıştır. Zor-zorlanma ölçümlerinde, austenite yapıdaki Fe-%40Ni-%2Mn numunesine plastik deformasyon için 6 kN'luk yük uygulanması gerektiği tespit edilmişken, Fe-%40Ni-%2Si numunesi 100 kN'luk yük uygulanmasına rağmen esnek bir davranış sergilemiştir.

Investigation of structural and mechanical properties of Fe-40%Ni-2%X (X=Mn, Si) Superalloys

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ABSTRACT

In this study, we investigated the effect of Fe-Ni-based superalloys on the structural and mechanical properties of alloying elements. After producing the Fe-40%Ni-2%X (X=Mn, Si) superalloys, we heat treated them for 24 hours at 1150°C and 1200°C, respectively. We examined their structural and mechanical properties by using optical microscope (OM) and scanning electron microscope (SEM) methods, respectively, under current conditions. Mechanical properties were determined by Vickers microhardness (VS) and stress-strain methods. OM and SEM images showed that these two samples were austenite at room temperature. VS measurements revealed that the mean hardness value (147.2 VSD) of the Fe-40%Ni-2%Si sample was greater than the mean hardness value (119.2 VSD) of the Fe-40%Ni-2%Mn sample. In the stress-strain measurements, while it was determined that 6 kN load should be applied to the Fe-40%Ni-2Mn sample in austenite structure for plastic deformation, Fe-40%Ni-2%Si sample in austenite structure showed a flexible behavior despite the application of 100 kN load.

1. INTRODUCTION

While exploring the earth, primitive man began an endless search for materials to improve the quality of life, explore the environment, and provide defense against both predators and forces of nature. He initially used naturally occurring ceramics, composites, and later metals. When these materials no longer meet their needs, he began to look for new materials [1].

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Steels are the alloys fabricated adding different elements into iron. It has been quite extensive researches on how alloying elements affect the properties of materials.

It is known that steel is Fe-C alloy and with or without having one or more of alloying elements such as Si, Mo, Cr, Ni and Mn. Approximately 90% of the metals used by humans for various purposes are ferrous alloys composed of steel and cast iron. There are very common fields of application of iron since it is cheap, plentiful in nature, the ability to be alloyed with most metals and to have a range of features by controlling the microstructure during the thermal treatment [2]. An important group of industrial alloys with a wide range of features is consisted of austenitic steels. These steels contain austenite stabilizing elements as Mn or Ni. In particular concentrations, these elements are retain the fcc austenite phase at room temperature and below. Microstructures resulting deformation of austenitic steels are quite complicated [3]. The effect of cooling rate on the microstructure of the alloy is an area open to research for the rapid solidification process to alter the microstructure of the alloy in a remarkable way. It has been seen equally important in the microstructural change of chemical composition and solidification conditions of the alloy [4].

Nickel-, iron-nickel- and cobalt-based alloys that are generally used at temperatures above about 1000 F (540 C) are called superalloys. When iron, nickel and cobalt form the basis of super alloys, it is generally known that the crystal structure is face-centered cubic (fcc-austenitic). However, it has been experimentally observed that the structures of iron and cobalt element metals at normal room temperature are not fcc. Both iron and cobalt undergo transformations and become fcc at elevated temperatures or in the presence of other elements that alloy with iron and cobalt. On the other hand, it is known that nickel has fcc structure at all temperatures. Therefore, in iron and cobalt-based superalloys, the fcc forms of these elements are often stabilized by the addition of the alloying element nickel specifically to provide the best properties.

Superalloys contain various elements in many combinations to obtain materials with desired properties. In iron-nickel-based and nickel-based superalloys, the improvement of microstructure was much more pronounced than in cobalt-based alloys.
[5].

Many scientists trying to define superalloys often prefer to use specialized and limiting technical terminology in the definition. Simply, Superalloys are alloys with the following properties:

a) are rich in at least one of the elements nickel, cobalt, titanium, niobium, and/or iron.
b) Maintain theirs structural, surface and stability properties at high temperatures, high stress and harsh environments

Although superalloys have a wide range of applications and extraordinary potential, it is known that most of today's superalloys are widely used in the aircraft gas turbine industry. Some superalloys have a wide range of uses in the form of coating materials and inserts. These applications are very diverse and include components for reciprocating gasoline and diesel engines as well as rapid firearm barrel inserts [6].

Generally, the additive elements added to the alloy affects the mechanical properties of the alloy depending on composition ratio [7]. It is known that microhardness is very significant measurement to define mechanical properties of a material. In microhardness measurement, a diamond pyramid indentor is penetrated on surface of materials at a certain load for a certain period. Hardness is an indicator of resistance of a material to be penetrated [8]. In some special scientific studies, it is very sufficient to know the elastic and plastic properties of materials [9].

If a load is applied uniformly static or changes relatively slowly for a time on a cross section or surface of a material, the mechanical behavior of materials can be detected by a simple stress–strain test; these are most commonly carried out at room temperature for metals [10].

2. EXPERIMENTAL

2.1. Heat Treatment

The superalloys in this study were prepared by vacuum induction melting method under an argon atmosphere of the alloying elements with 99.9% purity. It is given heat treatment time, temperature and chemical composition of the alloys in Table 1. The samples were homogenized by applying heat treatment, mechanical and microstructural investigations were carried out.

Table 1. Heat treatment and chemical compositions

Alloy	Heat Treatment	Chemical Composition
1	1150 °C→24h→water quench	Fe- 40%Ni- 2%Mn
2	1200 °C→24h→water quench	Fe- 40%Ni- 2%Si

2.2. SEM and Optical Microscope Observation

For the SEM observations, samples were mechanically polished. Prepared samples are etched with a suitable solvent then in order to make a good observation by Scanning electron microscope (SEM) and optical microscope (OM).

2.3. Vickers Microhardness

In this study, the Vickers microhardness method was used to obtain the hardness values of materials. Vickers hardness test of the implementation on the surface of the material of the pyramid-shaped indenter, suppressing a certain period of time under load selected according to the type of material consisting permissions result is shaped to measure the diagonal lengths.

2.4.Stress-Strain Method

It takes usually a stress-strain test a few minutes to perform and would be devastating; i.e., the test sample is permanently deformed and often fractured. The degree to which a structure deforms or strains depends on the magnitude of an imposed stress. For most metals that are stressed in tension and at relatively low levels, stress and strain are proportional to each other through the relationship

$$E = \frac{\sigma}{\varepsilon} \tag{1}$$

This is known as Hooke's law and the constant of proportionality E (GPa or psi). σ is tensile stress and ε strain. Deformation in which stress and strain are proportional is called elastic deformation; a plot of stress (ordinate) versus strain (abscissa) results in a linear relationship The slope of this linear segment corresponds to the modulus of elasticity E. This modulus may be thought of as stiffness, or a material's resistance to elastic deformation. The greater the modulus, the stiffer the material, or the smaller the elastic strain that results from the application of a given stress. The modulus is an important design parameter used for computing elastic deflections. Elastic deformation is nonpermanent, which means that when the applied load is released, the piece returns to its original shape. For most metallic materials, elastic deformation persists only to strains of about 0.005. As the material is deformed beyond this point, the stress is no longer proportional to strain (Hooke's law, ceases to be valid), and permanent, nonrecoverable, or plastic deformation occurs [8].

3. RESULT AND DISCUSSION

In SEM images, it is observed that the Fe-40%Ni-2%X superalloys are the austenite structure at room temperature. Figure 1. (a) and (b) show morphologies of Fe40%Ni-2%Mn superalloy heat treated at 1150 °C for 24 h and Fe40%Ni-2%Si alloy at 1200°C for 24 h.

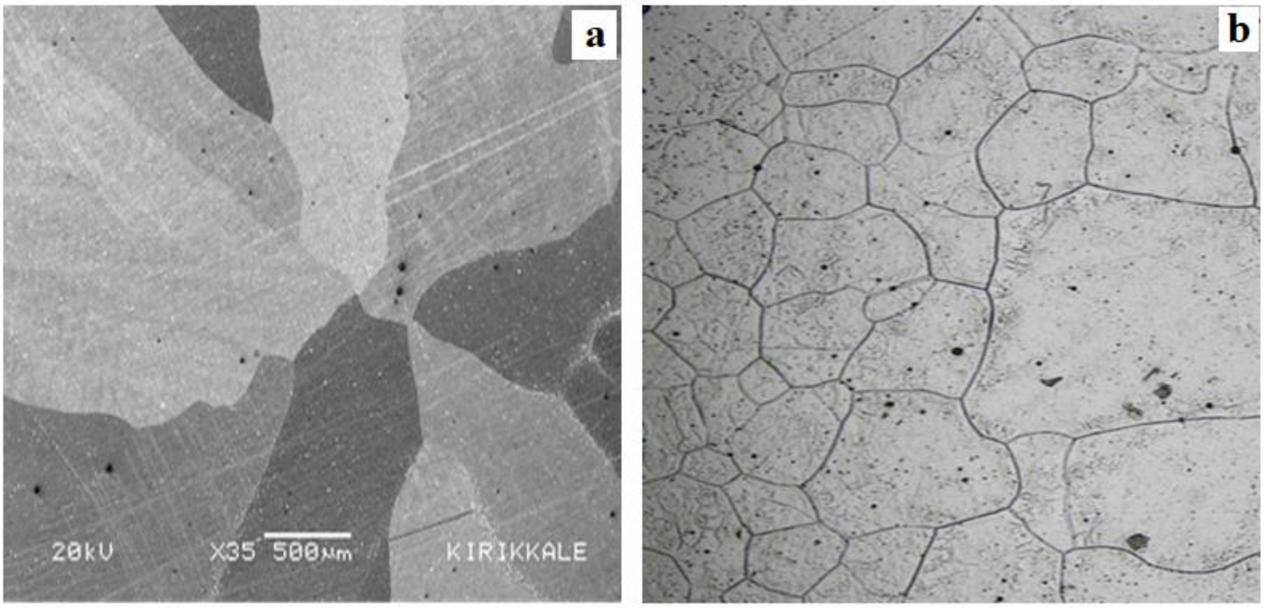

Figure 1. (a) SEM micrograps of austenite structure of Fe40%Ni-2%Mn superalloy heat treated at 1150 °C 24 h, (b) OM micrograps of austenite structure of Fe40%Ni-2%Si superalloy heat treated at 1200 °C 24 h

It is observed that austenite grain boundaries extend cylindrical towards the edges starting from the middle point of the Fe-40%Ni-2%Mn superalloy. In this image, it is understood to move towards the edge, starting from the middle of the sample to solidify during the preparation of the alloy. For SEM images of Fe-40% Ni-2% Si superalloy cannot be obtained for good, OM image is provided.

After the heat treatment time and temperature are revealed significant effects for homogenizing the material, it is also investigated whether if another phase occurs or not in these alloys. In both superalloys, it is determined that martensite structure which may be caused by temperature effects in the austenite structure was not occur. The elements forming the alloy and their ratios significantly affect the phase transformations and properties of the material.

VS measurements have revealed that the average value of hardness of the Fe40%Ni-2%Si sample (147,2 VSD) is greater than the Fe-40%Ni-2%Mn sample (119,2 VSD). It has been shown that the silicon in alloy has provided greater hardness than manganese. In addition, in moh-s hardness measurement (mineral hardness measurement system), while the value of the hardness of silicon is 7moh-s, the value of the hardness of manganese is 6moh-s. Therefore, hardening of the alloy of silicon is greater than the hardening of the alloy of manganese.

The stress-strain curves formed by applying plastic deformation in Fe-40% Ni-2% Mn and Fe-40%Ni-%2Si superalloys are taken up in Figure 2 and Figure 4, respectively. Figure 3. and Figure 5. show the variation graphs of the compression amount of the sample against the force applied to the sample in Fe-40%Ni-%2Mn and Fe-40%Ni-2%Si super alloys, respectively. In stress-strain measurements, it has been found that Fe-40%Ni-2%Mn sample in austenite structure should be applied to a load of 6 kN for plastic deformation. Besides, Fe-40%Ni-2%Si sample has exhibited elastic behavior despite applying a load of 100 kN.

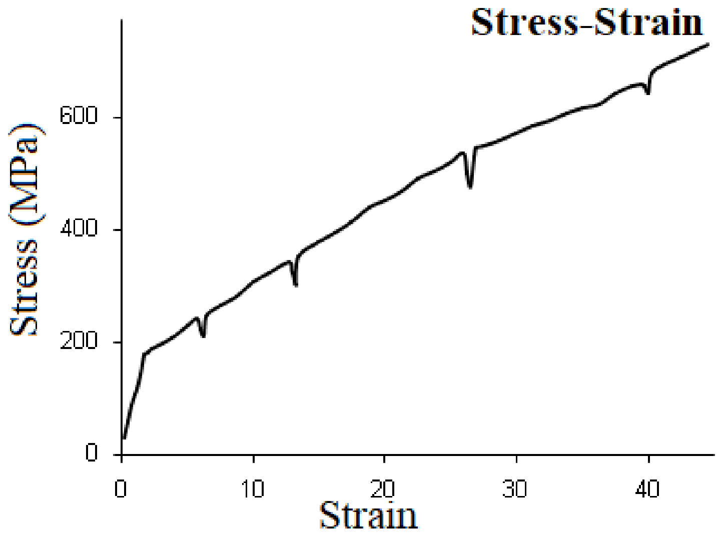

Figure 2.Stress-strain curve formed by applying plastic deformation in Fe-40% Ni-2% Mn superalloy

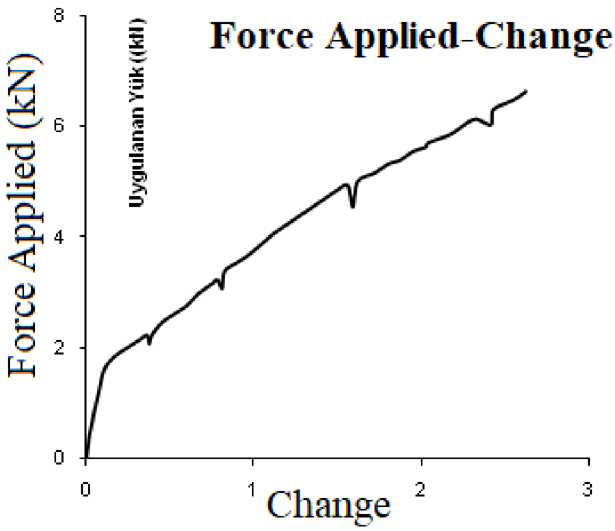

Figure 3. The change in the amount of compression of sample against force applied on the sample in Fe-40%Ni-2%Mn superalloy

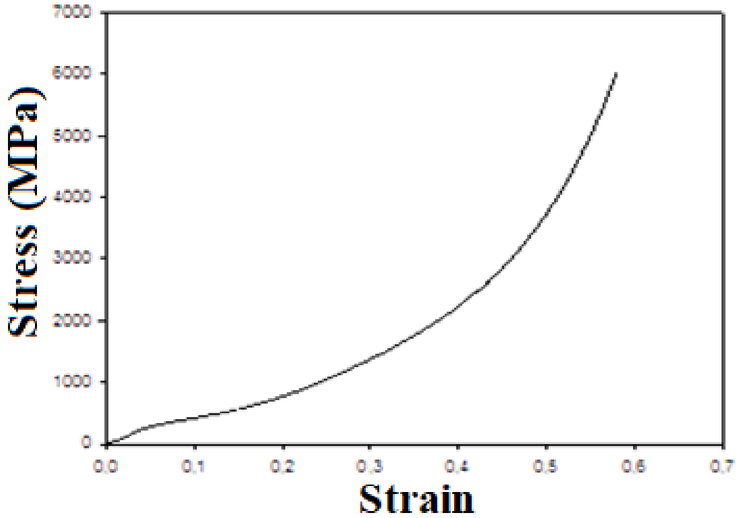

Figure 4. Stress-strain curve formed by applying deformation in Fe-40% Ni-2% Si superalloy

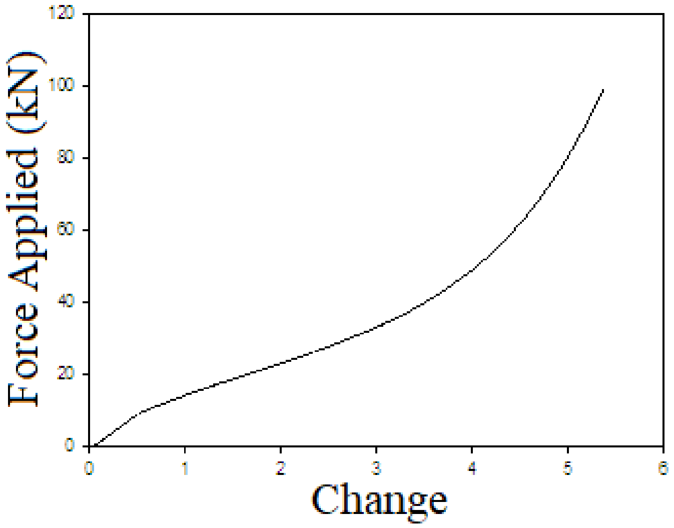

Figure 5. The change in the amount of compression of sample against force applied on the sample in Fe-40%Ni-2%Si superalloy

4. CONCLUSIONS

The structural and mechanical properties of Fe-40%Ni-2%X (X=Mn, Si) superalloys have been investigated by means of SEM, OM, Vickers microhardness and Stress-strain methods. The experimental results can be summarized as follows:

(1) Fe-40%Ni-2%Mn and Fe-40%Ni-2%Si superalloys are in austenite structure at room temperature.
(2) VS measurements have revealed that the average value of hardness of the Fe40%Ni-2%Si sample (147,2 VSD) is greater than the Fe-40%Ni-2%Mn sample (119,2 VSD).
(3) In stress-strain measurements, it has been found that Fe-40%Ni-2%Mn sample in austenite structure should be applied to a load of 6 kN for plastic deformation. Besides, Fe-40%Ni-2%Si sample has exhibited elastic behavior despite applying a load of 100 kN.

Because iron and iron-based alloys are low-cost and abundant in nature, they have wide application areas in the technology. It has been made intensive academic studies on these superalloys for centuries. And we will also continue to do so. Superalloys are widely used in industrial fields such as aircraft, nuclear, space industry, due to their metallurgical properties and high structural strength at high temperature. Although much early, I hope that we make a scientific contribution to this work.

ETHIC

There are no ethical problems in publishing this article.

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