SJST
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Surman Journal for Science and Technology
ISSN: Online (2790-5721) - Print (2790-5713)
مجلة صرمان للعلوم والتقنية
Vol 7, No.1.Jan – Jun. 2025
Pages: 232 ~ 239

Study of The Impact of Adding AIC on the Wear Properties of Unalloyed Steel Produced by Metallurgy Powder

Salem Khalifa Rhoma[1], Fathi Etaher Elbakoush[2], Salhain M. Salhein [3]
[1.2.3]Surman Collage of science and technology, Surman, Libya
basheremd@gmail.com[1], Fathi808@scst.edu.ly[2], slancora2@gmail.com[3]

ABSTRACT

In the powder metallurgy method, the desired properties are produced in a more comprehensive and controlled manner compared to the casting method. Based on this reason, our study is planned to be realized by powder metallurgy method. In our study, Graphite and Aluminum Carbide (AlC) were added to the Fe matrix. AlC was added at different determined proportions. The mixtures were mixed for one and a half hours using the Turbulo device. In order to bring these mixed powders into block form, 700 MPa was applied with one-way pressing. Block samples were sintered in an argon atmosphere at 1350°C. SEM and optical microscope device were used for microstructural properties and post-abrasion examinations. (SEM microstructure, SEM EDS). Hardness and wear tests were carried out to determine the mechanical properties.

Keywords: *Metallurgy, Aluminum, Hardness, SEM, Mechanical properties*

INTRODUCTION

Powder metallurgy method is the process of mixing fine-grained metal powders, pressing them in the desired geometric form and sintering them at a temperature below the melting point. The pressing process is also called compacting. In the sintering performed after this process, strong bonds are formed as a result of partial melting between the metal powders with the effect of temperature and high pressure. The strength of the produced part is provided in this way.

Steels produced by powder metallurgical method have excellent surface quality. In addition, they are materials that are resistant to wear and can maintain their hardness at high temperatures, thanks to the alloying elements that form high hardness carbides such as W, Mo, V, Cr. Compared to the cold work tool steels and high-speed steels produced by the conventional method, the properties such as hardness, abrasion resistance, high temperature resistance, surface quality of powder metal materials are higher even though they have similar chemical compositions.

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STEEL DEFINITION AND CLASSIFICATION

Iron-carbon alloys according to the carbon ratio they contain; It is examined in two main groups as “Steels” and “Cast Irons”. According to this category; Steel to alloys containing less than 2% carbon and alloys containing more than 2% carbon; It's called cast iron. There are different distinctions in the classification of steels. These; usage areas, chemical composition, applied heat treatment, forming method, microstructure and production method. It is of great value to take samples of the alloying elements they contain in the classification process of steels, since they can acquire various microstructures and properties depending on the thermal and mechanical processes they undergo until they reach the final product form. When we classify the steels according to their chemical composition, they are divided into two as “Non-Alloy Steels” and “Alloy Steels”.

DEVELOPMENT OF STEELS

Steel is an alloy that has been used in the oldest periods of human history and continues today. Although it was known in ancient times, the use of steel was limited to weapons and similar war materials, since a comprehensive production and production level was not applied. In the following years, with the development of technology, when the exact time was determined, raw iron production and production started in England in the 18th century. After this stage and history, steel and iron structures have started tobe made in the world, albeit a little. We can say that the first steel structures were bridges. One of the most important structures built using steel and iron is the Eiffel Tower. The tower, which was finalized in 1889, is sufficient to present the use of iron and steel as an example over the years.

STRENGTH INCREASING MECHANISMS OF STEEL

The mechanical properties of materials are highly dependent on the behavior of their metallurgical structures. Since the metallurgical structure changes with the thermal and mechanical processes applied to the material together with the chemical composition, it can be said that the mechanical properties of the material also depend on these conditions. One of the most important material properties is strength. Other properties vary depending on strength. resistance in materials science; can be explained by the resistance of the material to plastic deformation. Plastic deformation of metals is formed by the progression of linear defects, which we call dislocation as the essence of the narrative, in the crystal.

ADVANTAGES AND DISADVANTAGES OF ALLOY STEELS

Compared to plain carbon steels, alloy steels have superior hardness, strength, wear resistance, toughness, hardenability, hot hardness. In order to gain these advantages, heat treatment may be required. It has high strength. The ratio of its own weight to the load it carries is very small; therefore, the overall weight of the structures decreases. Strong carbide-forming elements such as V, Ti and Nb make carbide. Alloying elements also affect the eutectoid temperature. Mn and Ni reduce the eutectoid temperature. That's why they are known as austenite builders. Carbide-forming elements raise the eutectoid temperature and are known as ferrite-formers. It is more costly than unalloyed steels.

USAGE AREAS OF ALLOY STEELS

It is a valuable alloy that contributes to a large part of our lives, from the construction sector to the healthcare field, from the materials used to the technological materials. Stainless steel, which does not cause chemical changes in the human body and the foods it uses; It also includes materials used in the health sector such as hips and knee caps, screws, prostheses, needles and scalpels. Stainless steel, which does not spoil thecolor and smell of the food; Plates, oven molds, coated pots are safely preferred in storage containers produced for food and beverages.

ALLOYING ELEMENTS AND SOME ADDITIVES

Alloying elements play an important role in performing thermomechanical processes. While Mo, Cr and Mn elements act especially thanks to their hardening, there are different mechanisms in Nb, V and Ti microalloying elements. The toughness and strength increase here is extended by hardening and grain refinement methods. But grain refinement; It contributes to the increase of toughness and strength at the same time (Taş, 2012). The alloy that contains 0.2%-2.1% carbon (C) in its composition and is formed by the effect of the carbon-iron (Fe) mixture is called steel. Some of the other elements that make up this alloy are; vanadium (V), tungsten (W), magnesium (Mg), chromium (Cr), cobalt (Co), molybdenum (Mo), manganese (Mn), nickel (Ni). When these elements are included in the material, the steel turns into stainless form or becomes harder.

POWDER METALLURGY

DEFINITION OF POWDER METALLURGY

Powder metallurgy is the science of production that aims and ensures the production of products with the expected quality using specially manufactured powders. It extends to the action of mixing unalloyed or alloyed powders using determined proportions, compressing the homogeneously mixed powders with the help of a suitable mold, and then sintering the powders in a controlled atmosphere in order to gain their metallurgical properties. The production of homogeneous parts ensures that their chemical, physical and mechanical properties can be controlled (Panda and Dobransky, 2018).

8000 alloys have emerged from 86 elements in the periodic table, which are considered metals. Essentially, it is possible to produce around 1025 alloys from the 86 elements mentioned, with different mixtures such as binary, triple and quaternary. The only method that will make this possible is the powder metallurgy method. When analyzed considering today's time, the preference for part production with the powder metallurgy method will become one of the most valuable and productive features with the technological advantages that develop and renew itself increasingly on the basis of the cost part. The parts planned to be produced by powder metallurgy method will have the feature of being used immediately after they are produced, or they can be left for secondary processes upon request. The production of materials that cannot be produced with the classical production and casting method can be realized with the powder metallurgy method (Siyonr, 2007).

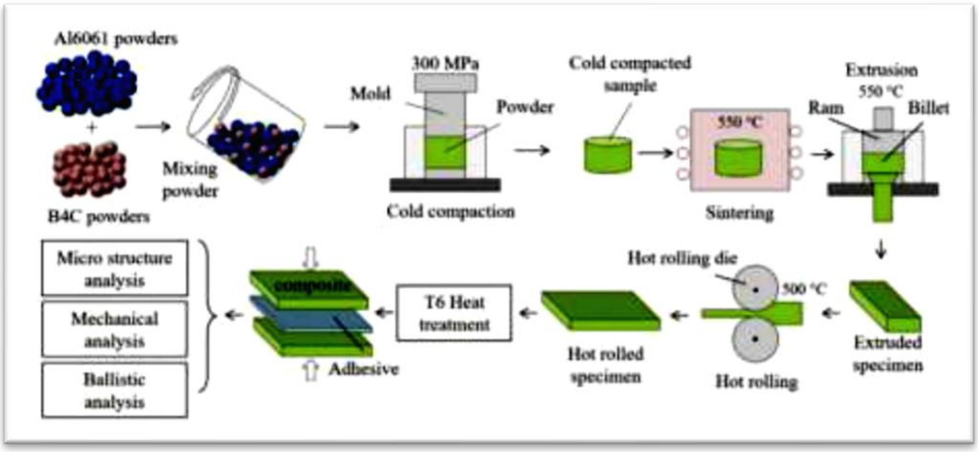

Figure 1. Powder metallurgy production scheme of a material (Karakoç et all 2018).

POWDER PRODUCTION PROCESSES

The methods used in the production of metal powders determine many properties of powders. The geometric form of the powder can be very different, from complex shape to spherical shape, depending on the production method. The surface condition of the dust particle also varies according to the production method. Many of the materials can be pulverized by a technique suited to their properties. Among the powder production techniques, there are those that are used commercially. These;

- Mechanical (Grinding)
- Chemical
- Electrolysis
- Atomization
- Other Production Techniques (Sarıtaş, 1994).

POWDER METALLURGY USAGE AREAS

Powder metallurgy is used in various fields. These; Manufacture of wear-resistant parts produced using super alloys, refractory materials such as tungsten and molybdenum, tool steels, stainless steels, copper alloys, magnetic alloys, aluminum and titanium alloys, cermets and nuclear materials. In particular, the automotive industry is at the forefront. In addition, jet engine parts, tungsten lamp filaments, orthopedic equipment, gear wheels, non-lubricated bearings, high temperature filters, electrical contacts, aircraft brake pads, welding electrodes, catalysts, soldering tools, high temperature filters, nuclear power fuel elements, circuit boards There are application areas such as dentistry, paints, explosives, welding electrodes (Akoral, 2003).

ANALYSIS OF MATERIALS PRODUCED BY THE METHOD OF POWDER METALLURGY

Mechanical Properties

The choice of material depends on the mechanical properties of that material for a particular application. It is important to familiarize yourself with the standard techniques used to calculate these properties and to evaluate the results from these experiments depending on different parameters. The potential of a material to withstand static loads is determined by the compression and tensile technique. Information about the resistance to plastic deformations can be obtained by means of static tests. The impact process technique is used to determine the resistance of the material against the stresses under the impact. By performing these experiments at different temperatures, the brittle-ductile transition temperatures of the material are calculated. With the fatigue process technique, the behavior of the material under repeated stresses and variability and its useful life under these influences can be calculated. Creep tests are applied to see the manifestation of the behavior of the material under long-term loads at high temperatures (Odabaşı, 2017).

Microstructural Features

The microstructure of a material, the structural and chemical nature of its geometric formation, is expressed by the arrangement of the components that make up the material, and to this extent includes the imperfections it contains and the component phases of the material. The microstructure is sufficient to significantly determine the properties of a material. In addition, in order to use the ore, it is necessary not only to learn the factors that contribute to the determination of the microstructure of the material, but also to understand the relationships between the microstructure and properties. It is necessary to determine the relations in materials science from one part and the microstructure of the material from another aspect (Odabaşı, 2017).

Surface Related Properties

Events such as oxidation and corrosion are among the surface properties of the material. If the porosity rate in the structure of the materials produced by the powder metallurgy method is high, corrosion occurs faster due to the fluid formed in the pores and subsequently accumulated. It has been observed that the materials produced under suitable sintering conditions have a high degree of environmental resistance.

EXPERIMENTAL METHOD

MIXING, PRESSING AND SINTERING OF THE SUPPLIED STEEL SAMPLE POWDERS

Before the mixing process, the powder particles were weighed with a precision of 0.0001 with a precision balance at the rates given in Table below. The powder mixtures obtained as a result of weighing were mixed with a triaxial mixer for 1 hour without
a ball in order to form a homogeneous structure.

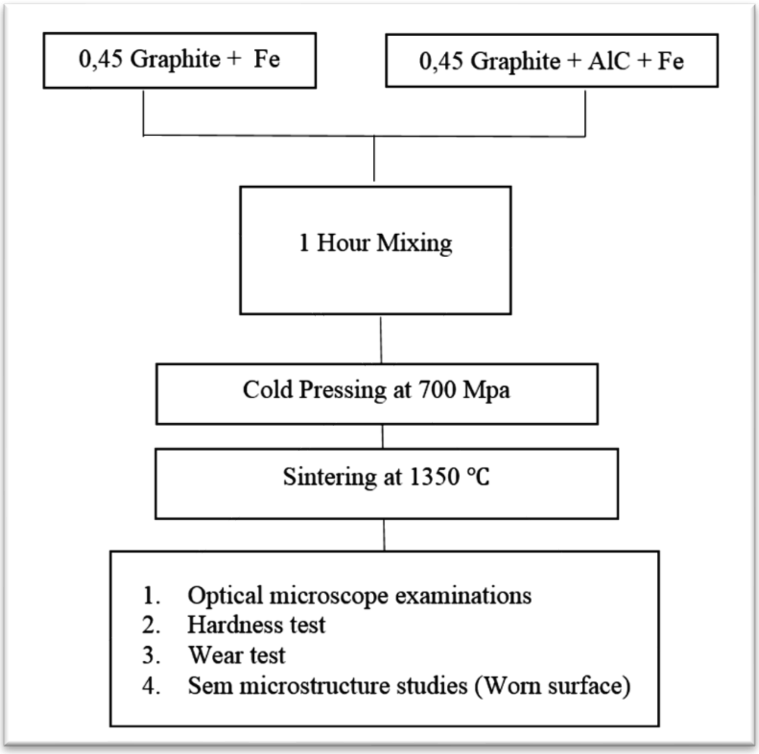

Figure 2. Process steps followed in the experimental study.

Table 1. Powders and Properties

No.	Elemental Powders	Powder Size (µm)	% Purity Value	Supply Company
1	Iron (Fe)	<150 µm	99.9	Höganäs
2	Carbon (C)	10-20 µm	96.5	Höganäs
3	Aluminum Carbide (AlC)	~325 mesh	95	Aldrich

Table 2. Chemical Compositions of Alloyed PM Steels

Compositions	Carbon (%wt.)	AlC (%wt.)	Iron (%wt.)
Fe+0.45 Carbon (Composition 1)	0.45	-	The rest
Fe+0.45 Carbon + 0.2 AlC (Composition 2)	0.45	0.2	The rest
Fe+0.45 Carbon + 0.5 AlC (Composition 3)	0.45	0.5	The rest
Fe+0.45 Carbon + 1 AlC (Composition 4)	0.45	1	The rest
Fe+0.45 Carbon + 2 AlC (Composition 5)	0.45	2	The rest

The pressing process of the prepared powders was carried out by subjecting them to the cold process. The samples, which were subjected to cold pressing process, were made in the form of wear samples in a one-way, 700 MPa pressing pressure, with a mold manufactured according to ASTM (E8M) powder metal material standards, in a 96-ton capacity Hydraulic press.

HARDNESS TEST

Hardness measurements were made for all samples. Hardness measurements were measured on samples prepared for microstructure examination. Microhardness measurements of the samples were made in SHİMADZU brand hardness measuring device. Hardness measurements were carried out by applying a load of HV0.5 (500gr). 5 hardness measurements were taken from each sample and the average of these
measurements was the sample hardness value.

WEAR TEST

The analyzes of the wear test were carried out at the MARGEM Laboratories at the Iron and Steel Institute of Karabuk University. The samples sintered at 1350°C were sanded up to 1000 mesh sanding number and the Reciprocating Wear Test was applied on the UTS-10 Tribometer test device, which performs back-and-forth type wear test. AISI 52100 material steel ball was used for this application. The stroke distance was determined as 3 mm. The applied load is 30 and 60 N, and the sliding distance is 25
meters. After the wear test, the wear volumes were measured from the worn surfaces with a surface profilometer device. Then, the wear surfaces of the powder metallurgy steel samples were investigated by SEM.

EXPERIMENTAL RESULTS AND DISCUSSION

OPTICAL MICROSTRUCTURE RESULTS AND EVALUATION

Microstructure examinations were carried out with a Nikon Epiphot 200 optical microscope with a magnification of X200-X500. Images of different sizes were taken from different parts of each sample and care was taken to ensure that these images were representative of the whole microstructure. Alloyed steel with the desired composition was produced by adding AlC at different rates into the Fe matrix by powder metallurgy method. The microstructure and mechanical properties of the alloy steels produced with the addition of AlC from 0.2% to 2% were compared

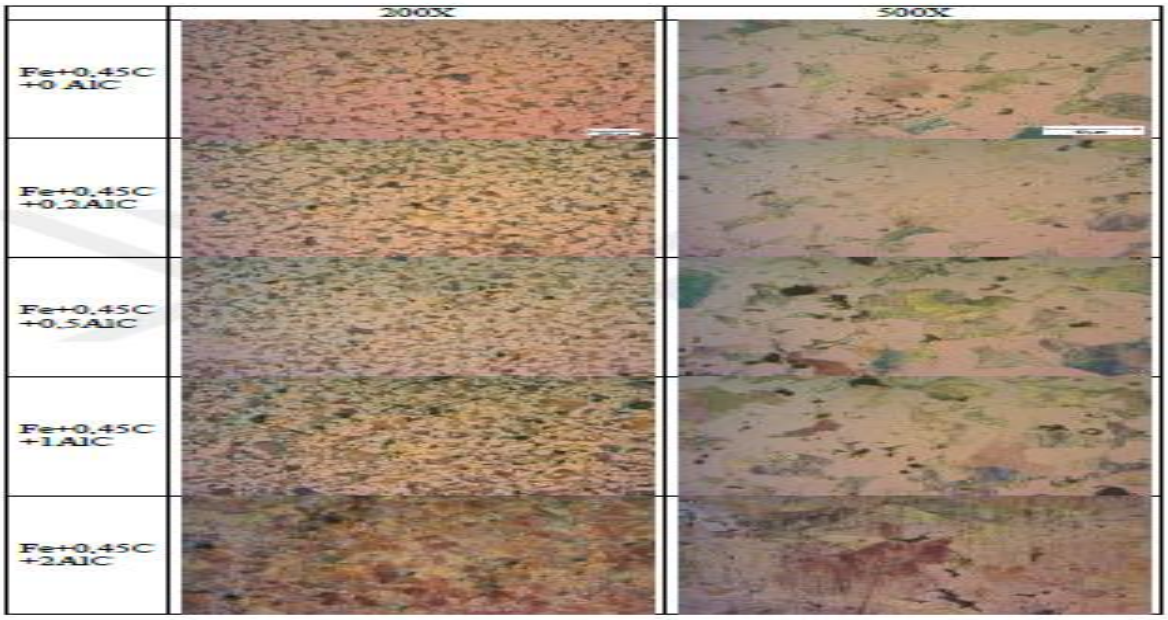

Figure 3. Microstructure pictures of steels containing different ratios of AlC

As seen in Figure above all structures consist of ferrite and pearlite phases. When the microstructure pictures were examined, it was determined that there were partially unclosed pores at the grain boundaries. Although it is stated in the literature that porosity affects the strength negatively, it has been stated that the pores are very small and spherical in shape, but do not reduce the strength (Sarıtaş et al., 2007).

It is seen in Figure that the average grain size decreases with the addition of AlC. This situation arises when AlC precipitates formed during sintering prevent the growth of austenite grains (Ollilainen et al., 2003). One of the properties of microalloying elements is that they prevent grain growth during austenitization or sintering with the carbides and nitrides they form. The formation of small precipitates during austenitization inhibits the growth of austenite grains and causes the formation of small ferrite grains during cooling (Xiang-done et al., 2013; Bakkali et al., 2008; Gladman, 1997).

CONCLUSIONS AND RECOMMENDATIONS

• Steel produced from Fe+0,45C+X AlC steel to which AlC was added by powder metallurgy method was supplied.

• In general, ferrite and pearlite were observed in the microstructure. An increase in the amount of perlite was observed with increasing AlC amount.

• In general, since the amount of AlC inhibited grain growth, finer grains were obtained with increasing AlC content, and this was reflected in the mechanical properties.

• The wear test values were directly proportional to the hardness results. The lowest wear volume and the lowest wear depth were obtained in the sample with the highest hardness.

• If large samples are produced, mechanical properties can be characterized in detail by performing tests such as tensile test and fatigue test.

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