Research Article

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Investigation of coatability of powder metal iron parts by galvanising technique

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Abstract

Nowadays technological developments are seen in the material field as well as in every field. In fact, technological developments depend on the developments in material technologies. Because each new material has different physical and chemical properties. In this study, it is aimed to investigate the galvanization of powder metal sinter materials used in many fields of industry. For this purpose, 384-512MPa powder metal iron parts were pressed at five different pressures and sintered by conventional sintering method. After the determination sintered densities of the sintered samples, they were coated with hot dipping technique in the galvanized pool at a temperature of 525°C. Optical and SEM images of galvanized coated samples were taken and microstructures were evaluated. The effect of porosity on coatingability was determined.

Keywords: galvanization, powdered metals, sintering, microwave sintering, hot deep galvasing

Introduction

Ranging from thick-sectioned to micron and nano-size section use very wide range metallic materials are using of industrial areas from electronic technologies to biomedical area and machine manufacturing sector. The materials used in each of these areas have different functional properties. Some of them are used in heavy-duty work areas some of them in metallic materials where corrosion resistance is required or in porous structures such as metallic filters and as self-lubricating friction element for bearing material. However, material production technologies are also very different. Production methods have been developed to provide different properties in different areas of use, such as rolled steel, cast iron produced by casting, and powder metal materials produced by powder metallurgy. The choice of material is very important because of the reasons such as economics, production rate, or some of the features of a production method. There are many important factors in choosing powder metal parts;

I. Economic production of complex geometry parts.

II. High precision and cost for high quantities of parts.

III. Microstructural suitability.

IV. Possibility of alloying in desired proportions.

V. Production of porous parts, In the manufacture of non-production parts (tungsten filaments)

VI. Proper shaping.

VII. High quality.

VIII. Full density can be achieved.

IX. Production of homogeneous microstructures.

X. Amorphous, microcrystalline, nano-sized materials can be synthesized.

For this reason and many other reason powder metallurgy is one of the most popular production methods of the present and it will continue to be at future.[1] The materials that are not resistant to corrosion in atmospheric or acidic environments are made resistant to corrosive environments by passing through some surface treatments. These processes are painting, Cr or Ni coating or galvanizing techniques. Galvanized coating is an easy, inexpensive and fast coating technique therefore; it is a coating technique which is used frequently in the coating of non-corrosive materials. In powder metallurgy, the process starts with the production of metal powders and the characterization of the powders consists of pressing the appropriate powders in the form of dimensions and shape in the mold, strengthening the pressed materials by sintering heat treatment. Powder metallurgy is generally based on the pressing of metals, ceramics or mixture of this kind of powders in a rigid mold. It is based on the principle of producing parts which are close to the theoretical density and having a certain amount of pore by applying heat treatments to the raw compacts having low density and strength.[2] Although the history of the Powder Metallurgy is old, it can be considered as a new industrial use. The work done with platinum in the 18th and 19th centuries in Europe is considered to be one of the most important stages for modern Powder Metallurgy. Platinum coins, introduced in 1826, were the first industrial application of Powder Metallurgy.[3] Powder metallurgy allows the production of materials (small, complex shaped, functional, composite) that are difficult to produce by conventional methods, with economical, high strength, minimum tolerance (low waste). Powder metal parts, which have been used in many sectors in recent years, are mostly used in the automotive industry. Gears, self-lubricating bushings, electrical contacts, rigid cutting tool bits, etc. many parts are produced by the TM method.

In recent years, the amount of powder metal parts production is increasing both in terms of quantity/tonne and size. However, it is used in many different areas. For this purpose, surface treatment of powder metal materials is very important. Because it has a porous structure, the pores have the disadvantage of reducing the mechanical properties as well as being used as a selflubricating bearing by acting as an oil reservoir when used as bearing material. For surface treatments such as painting and galvanizing, open pores increase the bonding strength of the coating layer to the surface. Galvanized coating is a surface coating process that was invented and developed in England and

France in 1837. Galvanizing can be defined as the process of cutting the contact of the surface with oxygen by covering the surfaces of non-corrosive materials such as iron and steel with zinc. The galvanizing material is immersed in the hot zinc pool in a liquid state and after cooling the zinc layer is applied to the surface of the substrate. Preparations prior to galvanizing are important for successful coating. These are; pre-coating surface preparation, galvanizing and control steps. The most important step in any coating application is surface preparation. The main reason of the deterioration before the expected service life is the inaccurate and inadequate surface preparation.[4] The cleaning steps using to remove impurities and pollutants are varied and their effectiveness depends on the requirements of the particular application. The design of the materials to be coated must allow for surface preparation. The accuracy of the surfaces of the materials to be coated is very important for the appearance of high quality coating.[5]

On uncleaned surfaces, the reaction between the zinc and the coating surface will not occur at the desired level, so zinc-free zones are formed. The cleaning cycle usually consists of three stages. The first one is oil degreasing. Then acid immersion to romove lime and rust. Lastly the fluxing steps to prevent oxidation before dipping molten zinc.[6] Today, two types of chemicals are used to remove oil and solid residues: 1- Hot alkaline degreasing 2- Acidic degreasing. Hot alkaline solution is used to clean organic structures, paint marks and grease from the metal surface. Welding slag, asphalt and vinyl remains should be cleaned by sand blasting or other means before galvanization.[4] The acid immersion method is a chemical cleaning of rust and impurities on the metal surface by immersing the material in acid solutions in appropriate concentrations. It is the most commonly used sulfuric acid bath for cleaning steel and its alloys. 5% or 10% H_2SO_4 used in these processes. Depending on the pollution, the particles are kept in acid for 5-15 minutes. Diluted nitric acid baths are also used for cleaning parts made of steel and its alloys. Cleaned steel and alloys in nitric acid have a brighter appearance.[7] Fluxing is a process to remove both the remaining oxide layers on the surface as well as to form a protective layer prior to immersion in the zinc bath and fundamentally improve the zinc-iron reaction. Fluxing process is selected according to wet or wet galvanizing method. In dry galvanizing process; steel products are first immersed in a flux bath containing zinc ammonium chloride and then dried to the zinc bath. In the wet galvanizing method, a cover layer containing zinc ammonium chloride is formed on the zinc bath and the steel products to be galvanized are passed through the flux and dipped into the zinc. When the materials are taken out of zinc, this flux cover is pulled aside to avoid contact with the surface.[4] Hot-dip zinc plating is usually used for corrosion protection.[8] Because the coating materials are predominantly metal and the melting point of the coating materials used does not generally exceed 1000°C the coatings made from them are traditionally called hot-dip.[9] The materials to be galvanized are dipped in a liquid solution of commercially pure zinc containing a minimum of 98% zinc. In order to prevent the formation of a thick, continuous zinc-iron intermetallic layer which may cause poor coating adhesion, 0.1 to 0.2% aluminum is added to the zinc bath.[10] During galvanizing, zinc is bonded to the metal by forming corrosion resistant alloys with the help of metallurgical bonds.[11]

During the hot-dip galvanizing process, chemical reactions between steel and liquid zinc lead to the formation of different intermetallics. Thus, four phases grows over substrate. These consist of gamma (Fe_3Zn_{10}), delta ($FeZn_{10}$), zeta ($FeZn_{13}$) and finally a solid iron solution in zinc, eta.[12] The thickness of the coating depends on both the surface properties of the steel material to be coated and the composition of the steel. The roughness of the steel surface increases the reactivity to zinc and thus the zinciron alloy is formed during the galvanizing process in the rough areas and the coating thickness increases.[13] The molten zinc bath is usually operated at temperatures between 445-465°C (830-870°F). At 480°C (900°F) and above, the dissolution rate of iron and steel in the zinc is greatly increased and these temperatures often have a detrimental effect on the workpiece and galvanizing tank. When working in the normal temperature range, the effect of the increase in temperature will be as follows: a) The fluidity of molten zinc increases, b) Oxide formation accelerates on the bath surface, c) The temperature of the treated part increases, so the time required for the zinc to solidify when the part is removed from the bath, d) The dipping time is shortened, so that the benefit factor increases. Each of them has different effects and can be used to control the galvanization process. The increase in the fluidity of the bath provides better drainage and it is preferred to ensure that the normal operating temperature of the bath temperature is not exceeded. The increase in the bath temperature results in a sharp increase in temperature as it travels to the middle of the surface, depending on the surface shape of the part. The coating thickness is controlled by dipping time while hot dip galvanizing is applied to the finished parts. However, the timing depends on the ease of transport of the part, and the plunging time must be determined by making experiments for the plated parts. Usually it is between 1-5 minutes. The immersion speed affects whether the coating is uniform or not. Particularly for long parts, the difference between the immersion time of the first and last entering parts of the bath should be taken into consideration.[14]

Experımental methods

In this study, galvanized coating properties of powder metal iron materials were investigated. The study was carried out at different pressing pressures at 384,416,512MPa pressures and samples were produced at different porosity rates. The densities of pre-sintered and sintered parts measured by Archimedes' principle. Surface treatment of sintered and densified parts was performed before galvanizing. Then they were immersed in 525° C degree liquid zinc pool for five minutes and then left for cooling. The plated cross-sectional surfaces of the coated samples were examined and analyzed by optical and scanning electron microscopy. In addition, the bonding strength of the coating layer was determined by applying bending test to the samples.[15]

Results and discussions

The raw and sintered densities of the pressed powder metal parts are as follows in Figure 1. As seen in Figure 1 the pressing pressure in the powder metal materials increases both the raw density and the sintered density. Condensation formed by contact of dust particles during pressing; Condensation occurs as a result of contact of the powder particles during the pressing process. By increasing the applied pressure, filling of the cavities by small size particles and increasing the particle contact areas are the result of plastic deformation. During sintering, the formation of the neck between the particles in mechanical contact and the growth of the formed neck region is caused by the shrinkage of the pore and closure of the opened pores. In addition, sintering temperature, sintering time and sintering atmosphere are also effective in increasing the sintered density. In this study with the lowest pressing pressure 384Mpa, the raw density increased from 6,16g/cm^3 to 6,25g/cm^3 after sintering, at 416Mpa the raw density increased from 6,27g/cm^3 to 6,32g/cm^3, at 512Mpa the raw density increased from 6,54g/cm^3 to 6,65g/cm^3. At the lowest pressing pressure 384 Mpa, 79.8% of the theoretical density is reached while the highest pressing pressure at 512 MPa,

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84.9% of the theoretical density is reached. Figure 2 shows the optical microscopy of the microstructures of the sintered samples.

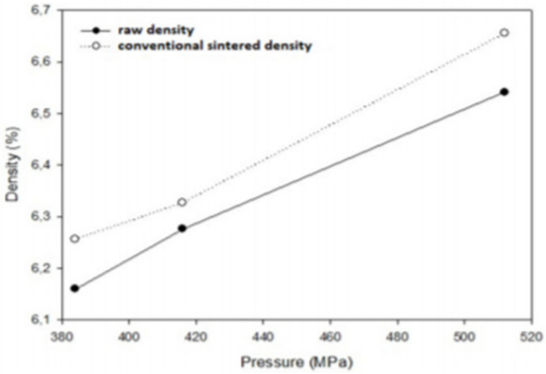

Figure 1 Change of densities green and sintering.

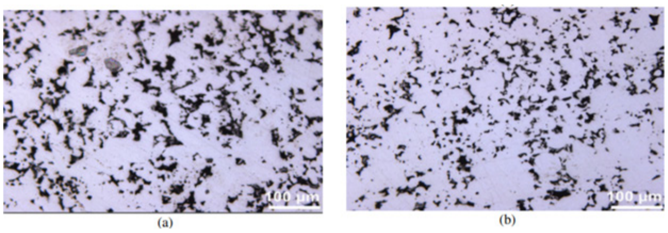

Figure 2 Shows the optical microscopy of the microstructures of the sintered samples A) Pressed at 384 MPa, B) Pressed at 512Mpa.

Sintered powder metal samples were immersed in 525°C, 99% Zn 1% Al liquid galvanization pool. The galvanized coating layer obtained on the surface after immersion is given in Figure 3. As can be seen from the figure, the powder metal material has a porous microstructure. The pores are both closed in the whole section and open to the surface. The open pores to the surface play an effective role in the bonding of the coating layer to the surface. As a result of filling the open pores with liquid galvanization, it causes both mechanical bonding and increases the coating surface area and increases chemical bonding. The size of the open pores is effective in galvanizing. In small and non-spherical pores, when the liquid and galvanized pores are filled with pores, mechanical and chemical bonding occurs, while the gases in the coarse pores expand during the coating and want to rise to the atmosphere. When the gas pressure value is high, it causes cracking in the undyed galvanized layer before it cools and causes cracks in the coating. This is shown in the Figure 4. The microstructure of galvanized coated powdered metal iron materials by electron microscopy is shown in Figure 5. As can be seen from the figure, a complete integrity is obtained between the galvanized and the backing material on the surface outside the pore area. The open pores of the surface are filled with galvanized liquid and partial weak bond areas are observed around the pore. The coating thickness is approximately 50 micrometers.

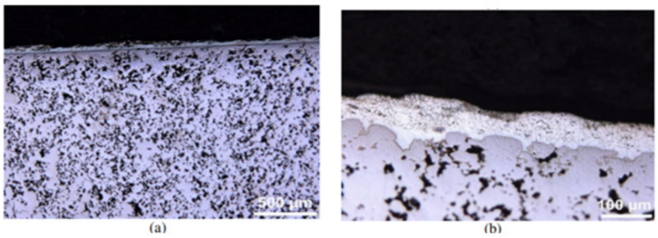

Figure 3 Optical microscope image of galvanized coated surface of powder metal iron material.

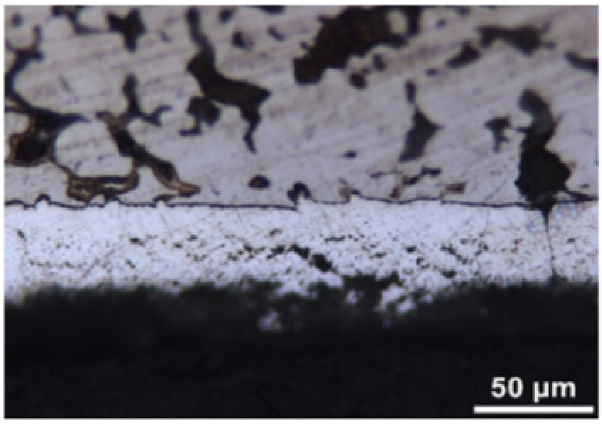

Figure 4 Effect of pore size and shape on coating layer.

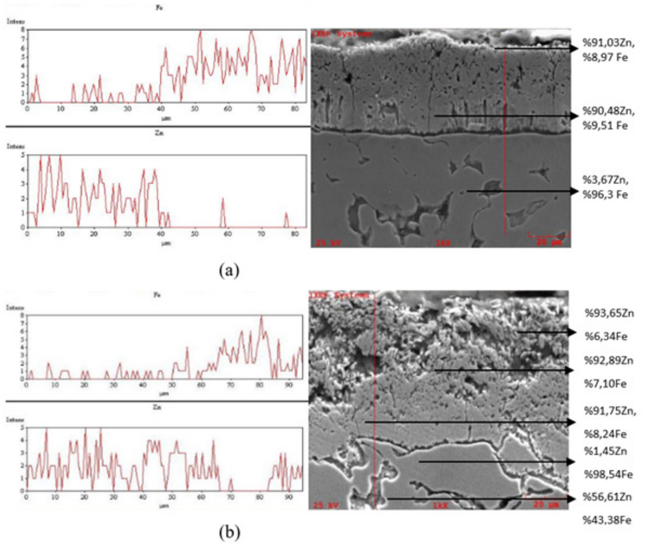

Figure 5 SEM image of the galvanized layer of powder metal Fe material, (A) classic sintered-galvanised, (B) microwave sinteredgalvanised.

As can be seen from the SEM (Figure 5) images at the end of galvanizing of the parts pressed under 384MPa pressure, mechanical and chemical joints are seen when the pores open to the surface are filled with coating liquid. Galvanized liquid seep through the pores open to the surface, causing zinc-rich areas to form in the base metal. In areas where the pore quantity is low, the galvanized layer appears distinctly from the base metal. As a result of chemical reactions, different phases were observed. As can be seen in Figure 6 there was an increase in hardness values along with the increase in press pressures applied. Sintering time and method is the main reason for changes in hardness. In classical sintering, it is possible to reach the desired temperature in a short time due to the slower rising of the temperature to be sintered and due to the volumetric heating in the microwave sintering, this caused the hardness to be lower than the microwave sintering and this change is also shown in the graphic in Figure 6.

Conclusions

The following results were obtained in this study to investigate the galvanisability of powder metal iron materials with porous structure;

a) Powder metal iron materials have different porosity depending on the pressing pressure and sintering conditions.

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b) It has been observed that a successful coating has been achieved with the galvanization technique in powder metal materials.

c) Pore shape and size were found to be effective on the quality of the coating. It has been observed that the capillary or angular pores open to the surface, increase the bond strength as a result of increasing the mechanical and chemical bond surface area.

d) It has been observed that the gases that are trapped in the large pores open to the surface form cracks in the coating layer as a result of the effect of surfacing during hot dipping.

e) With the galvanized layer, a very good bond was formed in the dense areas of the powder metal material, while the partial bound areas around the pore were observed.

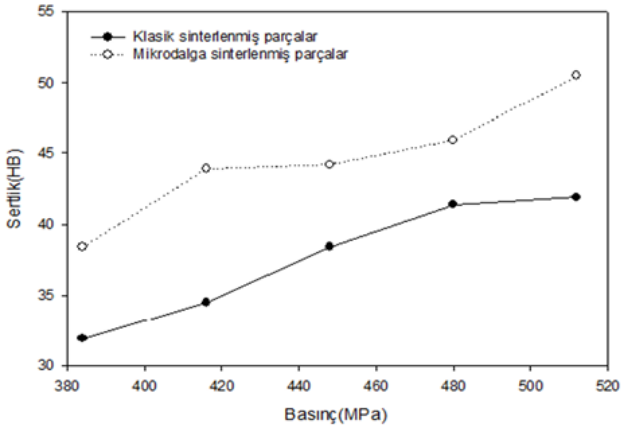

Figure 6 Hardnes value of sintering method.

Acknowledgments

None.

Conflicts of interest

The authors declare that there is no conflict of interest.

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