Investigation of Microstructure and Mechanical Properties of Spray Atomized Al-5wt. % of Zn Alloy

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Abstract

This paper describes the processing of an Al-5 wt.% Zn alloy using the spray atomization technique and investigates the resulting microstructural and mechanical properties of the alloy. The average grain size value is 163 m, hardness of the alloy is 27 MPa and the density was 2.13±0.0145 g/cc. This paper gives the information about the arrangement of grains in the alloy of spray deposits. Optical Microscope revealed the peripheral region of the alloy is having coarse, elongated and equiaxed grains are observed. The ultimate tensile strength of the spray formed material was 426 MPa.

Keywords: Hardness, Spray forming, density, porosity, Al alloys.

Introduction

The Al-5 wt.% Zn alloy is commonly used in applications requiring high strength and light weight, such as aircraft and vehicles. However, the traditional casting process used to produce this alloy results in a coarse dendritic microstructure [1, 2]. This microstructure is not suitable for applications that require specific mechanical properties [3, 4]. Powder metallurgy (P/M) is an alternative method for producing alloys, but it involves several processing steps, including powder generation, compaction, and sintering, which can be time-consuming and costly [5, 6]. Spray atomization, on the other hand, offers a more efficient processing technique for producing near-net-shape components through rapid solidification [7, 8]. In the spray forming process, the molten metal is atomized by a fast-moving inert gas and then deposited onto a copper substrate. The resulting microstructure of the deposit is influenced by various factors, including the spray height, gas-to-melt ratio, melt superheat, and diameter of the flow tube [9, 10, 11].

By utilizing spray atomization, the alloy can achieve a fine-grained microstructure, which is desirable for improved mechanical properties [12, 13]. The rapid solidification during spray forming prevents the formation of coarse dendritic structures seen in conventional casting processes. The resulting fine grain size enhances the strength and other mechanical characteristics of the alloy, making it more suitable for high-performance applications [14-15].

Experimental Procedure:

Material Processing:

To meet the requirement of the work, a direct as cast and spray formed alloy of Al-5 wt% of Zn. The cast of Al-5wt % of zn alloy prepared by melting aluminum and zn in a crucible and maintained electric resistance furnace temperature 8000 C for one hour and poured in to a mold. The spray deposition method integrates the atomization and consolidation in to one operation which results in a rapid solidification process. Billet of Al-5wt% of zn were produced by spray deposition method with the help of arrangements as shown in the fig.1.

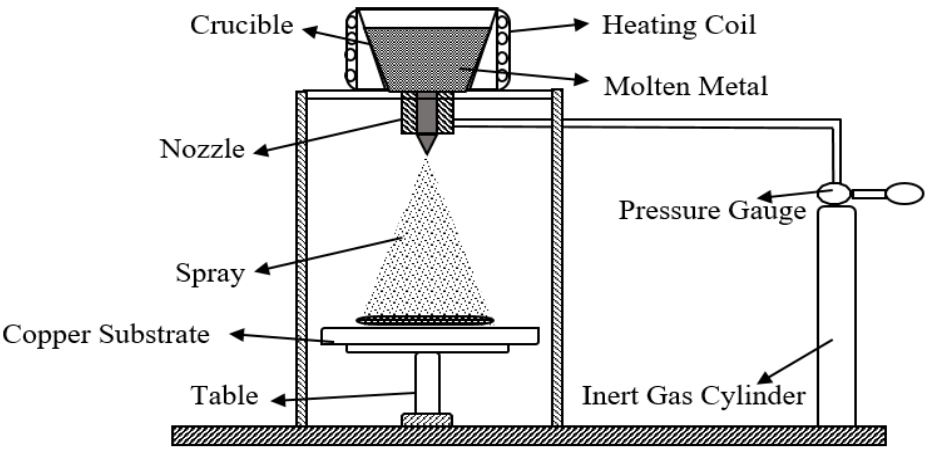

Fig.1 Spray Atomization Setup

Alloy melted in a graphite crucible using electric furnace and kept at the top of the arrangement which consists heating coil to maintain the alloy in the molten state. Crucible has one exit hole at the base which is kept exactly concentric with the axis of ceramic flow tube. Copper substrate is placed below the flow tube by maintaining different spray heights of 300 mm 325 mm and 350 mm for each process of spray forming substrate. Inert gas cylinder is connected to the nozzle to maintain the melt flow with proper pressure. The chemical composition and process parameters are shown in the table 1 and 2 respectively.

Table 1. Chemical Composition of Al-5wt% of Zn

Elements	**Zn**	**Al**
Spray Form	4.5 -5 wt%	Bal.

Table 2. Process Parameters for Spray forming of Al-5wt% of Zn

Process Parameters	**Spray Height (mm)**	**Gas Pressure (Bar)**	**Diameter of the Flow Tube (mm)**	**Mass Flow Rate of the melt (Kg/min)**	**Melt Super Heat (deg. C)**
Value	300	100	02	1.5	100

Material Characterization

The polished samples of spray formed alloys were etched Keller's reagent to reveal the microstructures and the specimens were examined by optical microscopy (OM). The make and model of optical metallurgical microscope is Olympus BX53M. The grain size of the spray deposits was measured by line intercept method (ASTM E-112).

2.3. Physical and Mechanical Characterization: The density of the spray deposits samples were measured by displacement method (Archimedes principle) using CAH-1003 Contech electronic digital-weighing balance. The hardness of the samples was measured using Vicker's hardness tester using a load of 9.81 N for the dwell time of 10 seconds. The hardness was measured in different locations at outer most region of the 300 mm spray height deposit. For compression testing, L/D ratio maintained less than 2 as per ASTM E9 standard.

Results and discussions:

Physical Properties and Microstructural Characterization:

The average density of peripheral region of spray atomized deposit was 2.13±0.0145 g/cc. The average grain size was 163 μm measured by line intercept method of the optical microscope as shown in the figure 2 a, b) explain the more percentage of the porosity due to a liquid is atomized into small droplets, it exposes a large surface area to the surrounding environment. This rapid cooling leads to the formation of pores or voids as the material solidifies quickly. And figure 2 c) gives the information about the coarse, elongated and equiaxed grains present in different regions in the alloy for the spray height 300 mm.

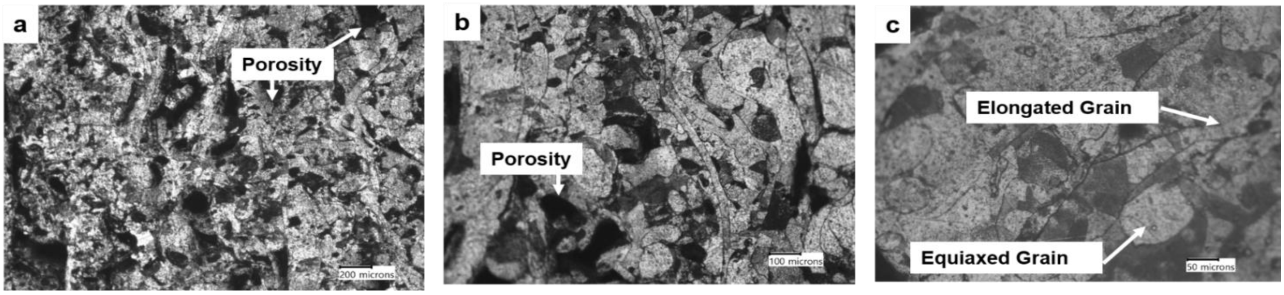

Fig.2 Optical Micrographs of Peripheral Region Spray Deposit a, b) porosity c) Elongated & Equiaxed grains

Mechanical Characterization:

The hardness was measured at different locations in the outer most region of spray deposit and it was found that results were uniform. The Vicker's hardness value for the spray deposit was 27 MPa. Figure 3 shows the stress-strain curves of 300 mm spray height deposit for three samples, the average ultimate strength was 426 MPa. Three specimens were prepared from the different locations of the peripheral region and results of varying the value of ultimate strength is observed in the sample 2 due to higher the value of the porosity.

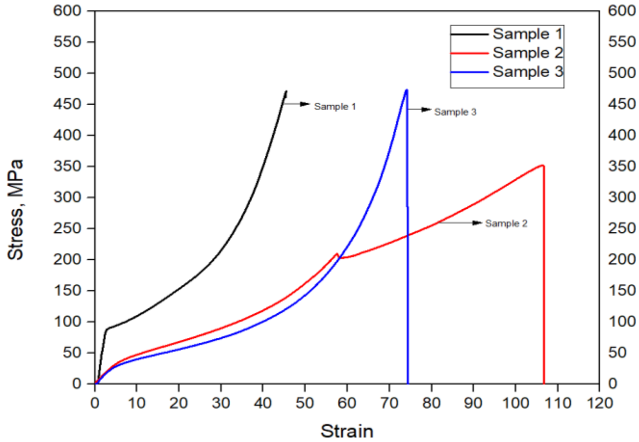

Fig.3 Stress-strain diagram of Spray Atomized Alloy (300 mm Spray Height out most layer)

Tribological Properties

Wear test was conducted on the specimen using pin on disk machine using following parameters, for first trial of the experiment 20 N load was applied on the specimen and speed was 200 rpm, 400 rpm and 600 rpm the graph was constructed wear rate & frictional force vs time as shown in the figure 4. The frictional force is almost constant at 200 and 400 RPM and wear rate increased as increase in the load and the speed with respect to time as shown in the figure 4 a) 20N load and 200 RPM b) 20 N load and 400 RPM of Spray Atomized Alloy.

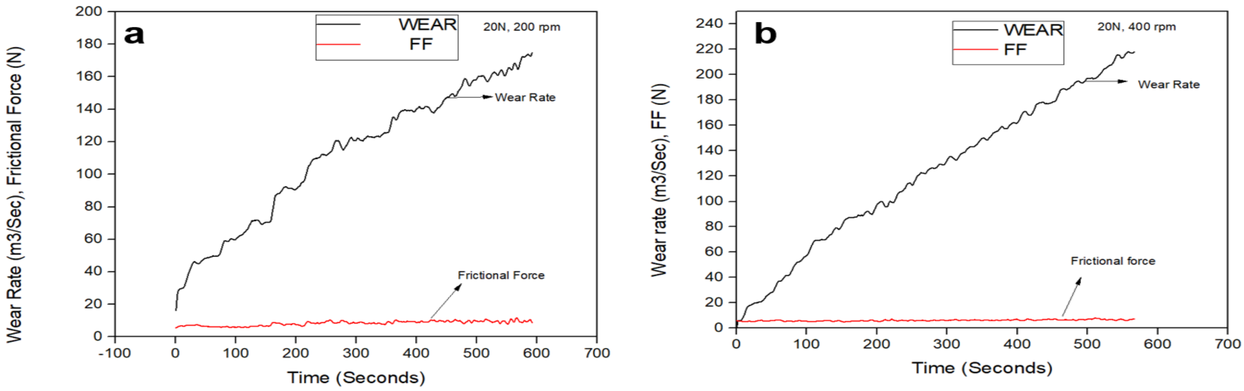

Fig.4 wear rate & frictional force diagram for constant load (a) 20N load and 200 RPM (b) 20 N load and 400 RPM of Spray Atomized Alloy for the Spray Height of 300 mm

In figure 5. It showed that wear rate & frictional force diagram for constant speed a) 20N load and 300 RPM b) 30 N load and 300 RPM of Spray Atomized Alloy in this alloys shows the wear rate increased with increase in the application of the load its due to lower the hardness of the alloy at

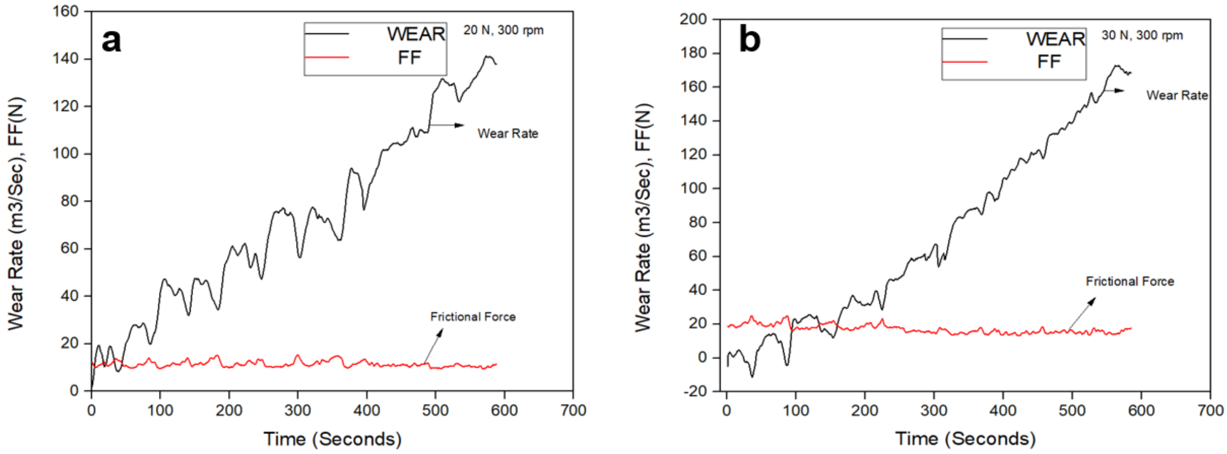

Fig.5 wear rate & frictional force diagram for constant speed (a) 20N load and 300 RPM (b) 30 N load and 300 RPM of Spray Atomized Alloy for the Spray Height of 300 mm

Conclusion:

The alloy is composed of aluminum (Al) with 5% zinc (Zn) by weight (wt.%). This alloy composition suggests that it is primarily an aluminum-based alloy with a moderate amount of zinc as an alloying element. The average grain size of the alloy is 163 µm. Optical microscopy analysis revealed that the peripheral region of the alloy has a microstructure consisting of coarse, elongated, and equiaxed grains. This suggests that the alloy's microstructure is not uniform throughout and varies in different regions. The hardness of the alloy is 27 MPa. Hardness measures a material's resistance to deformation or penetration, and this value indicates the material's relative hardness, the density of the alloy is 2.13±0.0145 g/cc. The alloy has a specific grain structure, hardness, and density, and it exhibits a significant ultimate tensile strength, indicating its mechanical strength under tensile loading. The varying grain structure in the peripheral region suggests potential differences in properties across the material**.**

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