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# EFFECT OF SECONDARY PROCESSING ON THE MICROSTRUCTURE AND POROSITY OF SPRAY CAST Al-Si-Pb ALLOY

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**Abstract-** In the present work, effect of secondary processing on the microstructural and porosity of spray cast Al-Si-Pb alloy was studied. Al-6Si-10Pb alloy were prepared by spray deposition technique and then cold rolled to various thickness reductions. The length of aluminum grains and the distance between these grains was observed to increase with the increase in percentage of thickness reduction. Porosity was observed to decrease with the increase in percentage of thickness reduction. Aluminum grains were observed to be elongated in the rolling direction after 80 % thickness reduction.

**Keywords:** Al-Si alloy, porosity, spray casting, rolling.

## I. INTRODUCTION

The spray deposited preform generally results in exclusive microstructure exhibited spheroidal or equiaxed grains [1,2]. In fact, spray forming technique exhibits the beneficial characteristics of powder metallurgy processing without the numerous processing concerns, that is, powder production, storage and handling, sintering and hot consolidation. The use of Al-Si alloys has been well known. Spray forming technology has been widely used to produce preforms with homogenous microstructure. However some porosity is always there in the spray deposited perform which detroit the mechanical properties [3]. The spray deposited preform must further be densified in order to eliminate porosity. Forging, extrusion, rolling, etc are effective methods used to produce fully dense metal sheet as well as to achieve the high mechanical properties [4]. Out of these rolling is most effective method because of having both hydrostatic and deviatoric components. The application of these components on porous materials causes flattening of pores and brings about rapid densification by collapsing the pores at a faster rate [5].

Deshmukh et. al [6] have studied the analysis of cold densification rolling of a sintered porous metal strip. For 25 % thickness reduction the density was observed to decrease. Longitudinal cracks developed in the strip for a thickness reduction of 30 % or greater in a single pass. The rolling behaviour of steel backed spray deposited Al-Sn strip has been studied by Tripathi et. al [7]. They found that during rolling densification in the Al-Sn deposit take place.

In the present work Al-6Si-10Pb alloys were spray formed in the form of a disc and then cold rolled. The changes in microstructural and porosity are reported for different percentage reduction in thickness.

## II. EXPERIMENTAL

A spray forming set-up is given elsewhere [8]. The base alloy composition used in the present work consisted of Al-6Si. The alloy was superheated to 200 $^0$C in the graphite crucible using an induction furnace. A 10 wt. % of lead was added in the Al-6Si alloy before atomization of melt. Nitrogen gas at a pressure of 10 bar was supplied for atomization prior to melt flow. The spray droplets were deposited over a copper substrate which was kept at a distance of 400 mm from the nozzle. The preform was taken out of the substrate after deposition and then samples were cut from the preform. After that these samples were cold rolled in a two-high mill. The speed of the rolls was 8 rpm and the diameter of the rolls was 110 mm.

Above samples were cut down for its microstructural study. These samples were polished using standard metallographic technique of polishing with an emery paper of 1/0, 2/0, 3/0 and 4/0 specification and then followed by wheel cloth polishing using an emulsion of alumina powder particles suspended in water. Afterwards, these samples were etched with keller's reagent and examined with Letiz optical microscope.

To measure total porosity at different locations of the deposit, the measured density was determined by Archimedes principle and followed by the ASTM B 328-96 practice. Mean value of three measurements was taken and reported in the present work.

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## III. RESULTS AND DISCUSSION

### A. Microstructure

Fig. 1 shows the optical micrographs for (a) 0, (b) 40 and (c) 80 % thickness reduction of spray deposited Al-6Si-10Pb alloy.

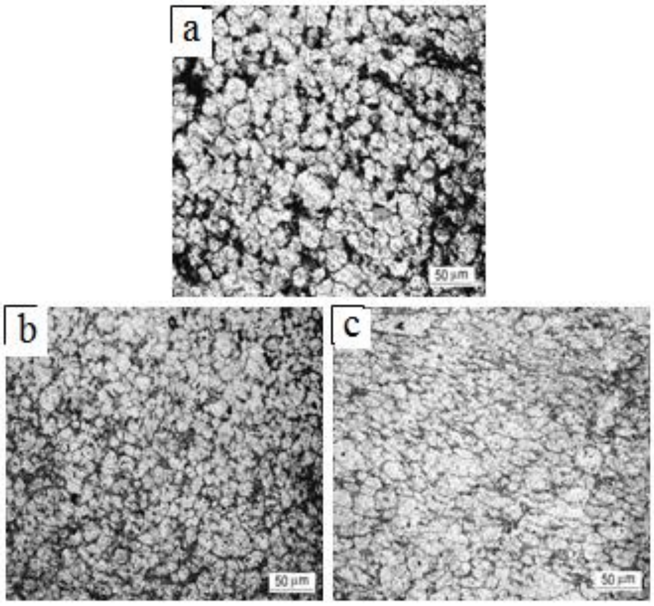


Figure 1*:* Microstructure of spray deposited Al-6Si-10Pb alloy for (a) 0, (b) 40 and (c) 80 % thickness reduction.

The microstructure exhibits fine equiaxed grain morphology of the Al phase as shown in fig 1(a). The identification of phases in spray deposited alloy was carried out by EDS analysis. The results indicate that the dark region corresponded to lead phase and the gray contrast region predominantly contained the Si phase whereas the bright region was of Al phase. A uniform distribution with a particulate morphology of primary Si phase has been shown in spray deposit Al-6Si-10Pb alloy. The shape of the Pb phase is irregular in feature and it is located mainly at the grain boundaries. It can be seen that Pb distribution is almost uniform throughout the aluminum phase. The average Al grain size is 20-30 µm and the size of Si particles is sub-micron to 5 µm. Some irregular pores of 10-15 µm size can also be seen in the matrix.

Grains are elongated in the rolling direction as shown in fig. 1(b) and (c). Wherever there is lead phase along the grain boundary, the distance between the Al-grains increases due to the spread of lead on rolling. The average length of Al-grains is also increases with the thickness reduction. In fig. 1 (b), the average length of Al-grains is 25-35 µm. The average length of Al-grains is 35-45 µm in fig. 1(c).

The microstructural features of spray deposited preform are due to rapid solidification achieved during atomization of melt in to fine droplets. The turbulent fluid flow condition and the high velocity gas jets give rise to the fragmentation of dendritic arms and thus homogeneity in the microstructure [9]. It is well known that there exists a certain amount of porosity in the spray deposited preform. The reduction in thickness is accompanied by an elongation of the grains in the rolling direction [10] as shown in Fig. 1(b) and (c)).

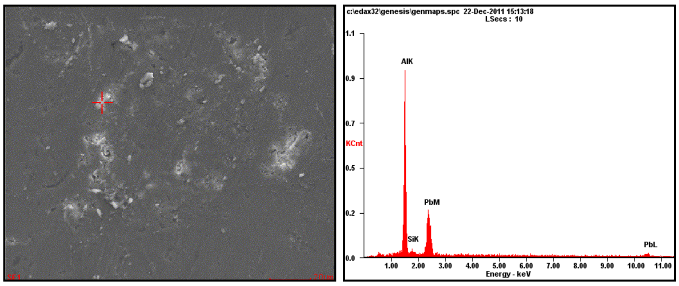


Figure 2:. EDS spectrum with analyzed region, indicating Pb and Si phases in spray deposited Al-6Si-10Pb alloy

Fig.2 shows the EDS spectrums with micrographs of the analyzed region for Al-6Si-10Pb spray formed alloy. EDS analysis of the micrograph gives Al, Si and Pb peaks and are shown in micrographs in the same figure.

### B. Porosity

Fig. 3 shows the Variation in the porosity of spray deposited Al-6Si-10Pb alloy as a function of thickness reduction at different locations of the preform viz. centre, middle 1, middle 2 & periphery.

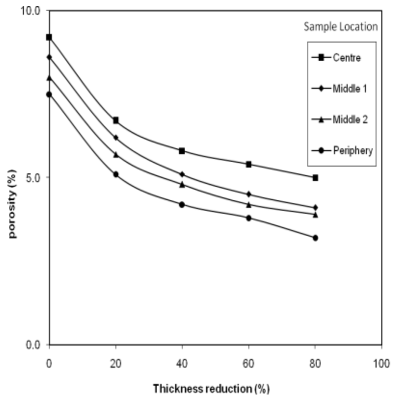


Figure 3: Variation in the porosity of spray deposited Al-6Si-10Pb alloy as a function of thickness reduction at different locations of the preform viz. centre, middle 1, middle 2 & periphery.

It can be seen that the porosity decreases up to a thickness reduction of 80 %. It is well known that there exists a certain amount of porosity in the spray deposit preform. In the initial stage of rolling, the metal flow is mainly in the thickness direction in the Al-Si-Pb deposit. Porosity is removed by restacking and rearrangement of spray deposited particles. Afterwards, plastic deformation becomes the predominant mechanism of densification during rolling [11,12]. As a result the porosity is eliminated by a process involving pore elongation followed by fragmentation into several smaller size pores in the direction of rolling.

## IV. CONCLUSIONS

1. The grains are elongated and length of the Al grains increases with the thickness reduction as well as the width of the grain boundary increases due to the spread of lead on rolling.
2. Porosity decreases with the increase in thickness reduction and it is minimum for 80 % thickness reduction.

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