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Modification of Al-11.1Si Alloy with Antimony through Casting Route

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1.Abstract

Aluminium silicon alloys is used in auto mobile (pistons, cylinder heads, brake disks etc) components because it shows high specific strength, low thermal expansion, high strength at elevated temperature, excellent castability, high corrosion resistance and wear resistance. The aim of the present work is to enhance the mechanical property of Al-Si alloy by changing the needle structure by chemical modification through casting process. These have been done by using pure antimony (Sb) as modifier with different composition 0.2, 0.3 and 0.4 wt% respectively and holding time 10, 15 and 20 minutes on Al-11.1 Si alloy. Modification has occurred in most cases but in some case it is not up to the mark because in all cases the microstructure has shown the fine fibrous eutectic particle which is uniformly distributed throughout the sample and the size of α-Al grains are also reduced. Modified alloy is showing increase in density, hardness, elongation and ultimate tensile strength.

Key words: Al-Si alloy, modification, modifiers, mechanical properties.

2. INTRODUCTION:

Aluminium silicon alloys is used in automobile (pistons, cylinder heads, brake disks etc) components because it shows high specific strength, low thermal expansion, high strength at elevated temperature, excellent castability, high corrosion resistance and wear resistance. It is also used in structural application, marine application, military applications etc.[1-2] Instead of their widespread applications, their use in industry

have been limited due lack of ductility. Microstructure of this alloy contains plate or needle like eutectic particles.[3-6] This plates provides abundant stress riser which limits maximum strength an ductility.[7] Modification is one of the most common ways to change the morphology of eutectic silicon from a plate to fine fibrous form. As a result the mechanical properties, corrosion and wear resistance are increased. It was first done by Pacz in 1921 using Na and it is widely used in commercial application. Modification by modifiers is the most effective and economic one.[8] Modification is done by two different ways: (a) Chemical modification (by adding certain elements) and (b) The quench modification (by changing the process parameter The investigation was carried out by chemical modification, where L-11.1%Si alloy was used as reference material and pure antimony (Sb) is used as modifier. The aim of the present work is retaining the good properties of this alloy (i.e, low density, relatively high strength and good wear resistance etc.) besides improving ductility, hardness. This paper reports the effect of antimony addition at different holding time on eutectic particle by optical image analysis. Also study on density, hardness and tensile property has been carried out.

3. EXPERIMENTAL PROCEDURE:

Firstly, the pure Ai-11.1Si alloy of 750gm charged in 1kg graphite crucible in electrical resistance furnace. Then, it was kept it in crucible until furnace temperature reached to 7000C. After melting at 7000C, the melt degassed for 10 minutes by hexachloroethane degassing agent using a 0.1% addition of the melt by weight and mean time the melt was stirred for two minutes. Then the modification was carried out by adding 0.2, 0.3 and 0.4wt% pure antimony to the melt. After that it was stirred for 2 minutes and held it for 10 minutes and melt was removed from furnace and slag was removed. After that approximately 250gm melt was poured into a 26mm diameter and 175mm length mild steel die and remaining molten metal was kept in furnace and consecutive 5 minutes it was poured. In die the metal was kept for 3 minutes for solidification and it was removed from die. After removing from die the sample was kept in sand for cooling. Metallographic study was carried out by using the optical microscope. The standard technique was followed for preparing metallographic study and sample etched by kellar's reagent. Vicker's Microhardness test was carried out for microhardness. A square based pyramid indenter with an angle 1360 was used and a load of 0.3kg was applied for a dwell time of 30 seconds. Tensile tests were carried out on a tensometer and the specimen were gauge dimensions of 9mm gauge diameter and 36mm gauge length. The sizes of the eutectic particle are bigger. Also primary silicon coarse particle are present in the sample.

4. RESULTS AND DISCUSSION:

4.1 MICROSTRUCTURE

4.2 RESULTS AND DISCUSSION:

4.3 MICROSTRUCTURE

Figure 1 shows the microstructure of hypoeutectic composition of Al-Si alloy without

any modifying element. The eutectic particles are as a needle form which is uniformly distributed over the entire sample holding time. (d-f) 0.2, 0.3 and 0.4 wt% Sb at 15 minutes ; (g-h) 0.2, 0.3, and 0.4 wt% Sb at 20 minutes holding Time.

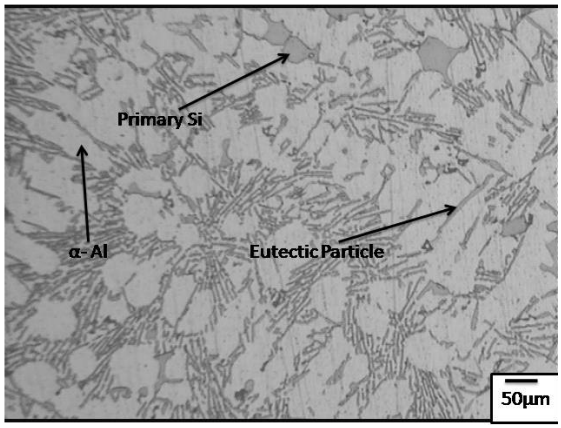
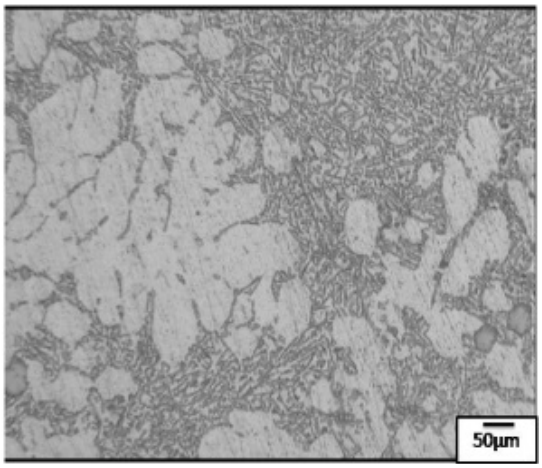
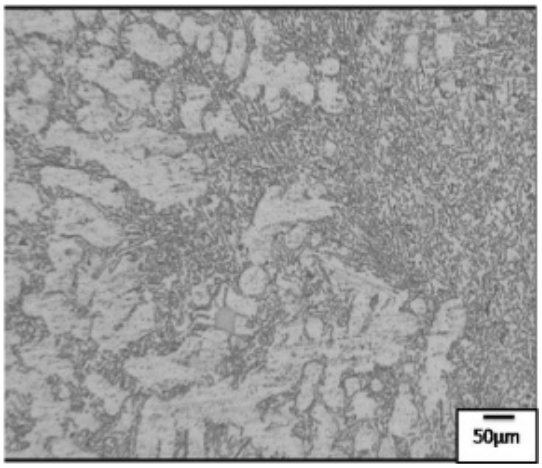


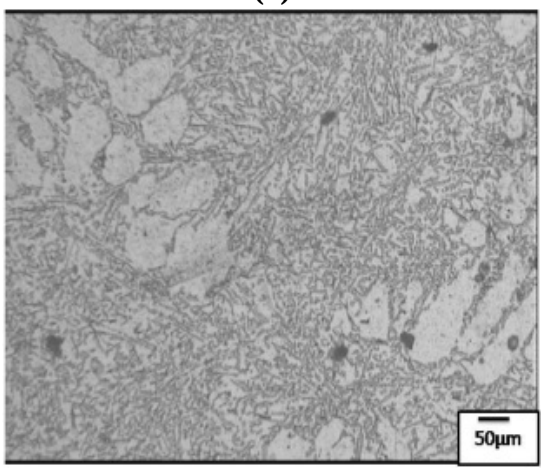
Figure 1: Microstructure of Base metal



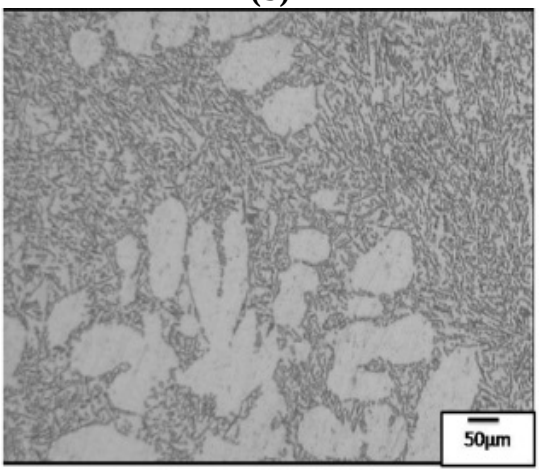
(a)



(b)



(c)



(d)

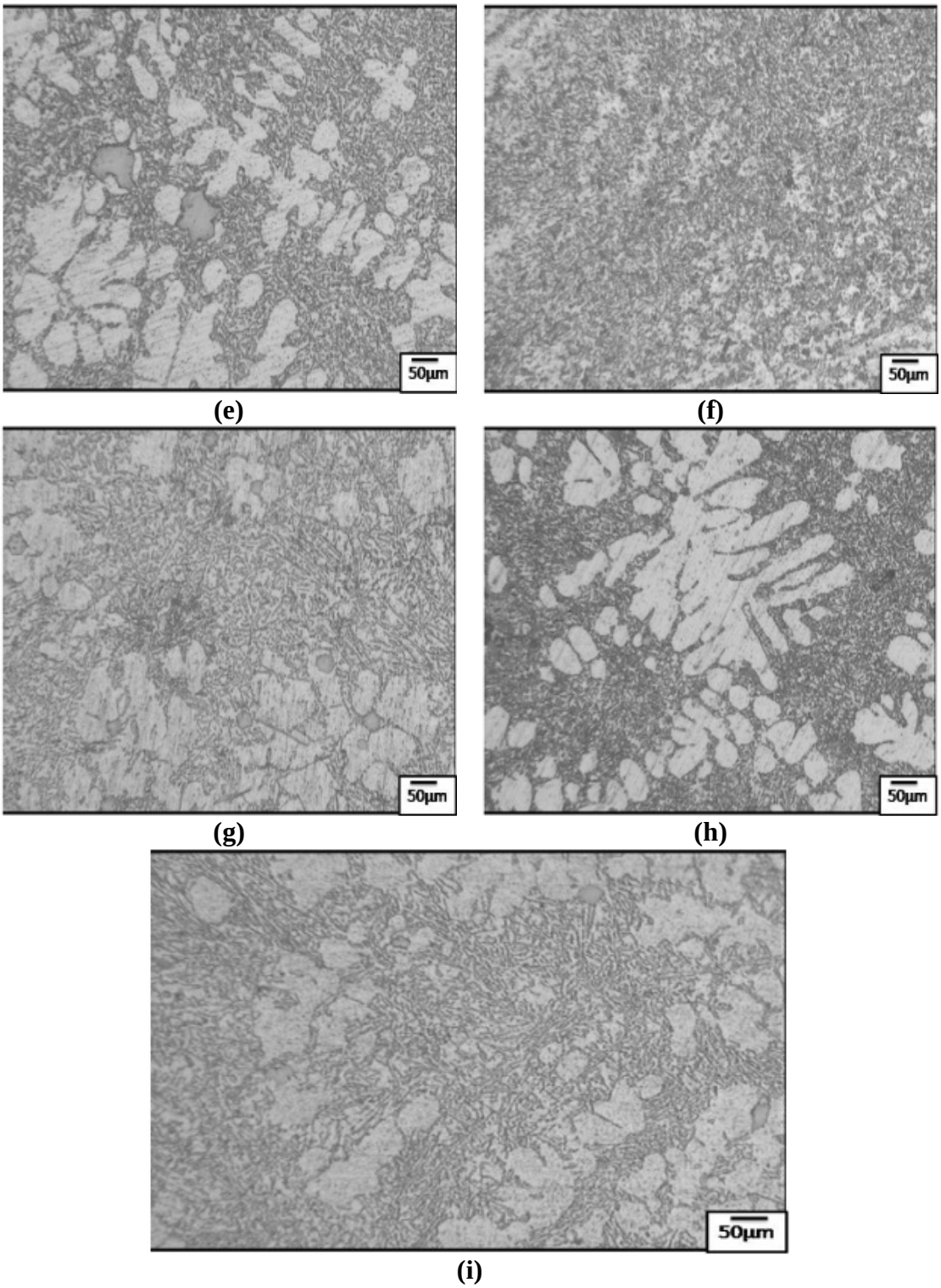


Figure 2 (a-c) shows the microstructure of modified sample with 0.2, 0.3 and 0.4 wt% antimony at 10 minutes.

In the figure (a-c) all the eutectic silicon particles are modified and in fig 2 (a) and (b) shows the localized modification and some primary silicon are present but fig. (c) shows the uniform modification . In figure (b) eutectic particle size is smaller than the other one. In fig (c) the eutectic particles are more amount than the α-Al grains.

Similarly figure2 (d-f) is showing the microstructure of modified Al-Si alloy with 0.2, 0.3 and 0.4 wt% at 15 minutes holding time. Figure (a) shows that the modified eutectic particles are larger in size then the other two and the α-Al grains are also larger than the other. Figure 4 (b) shows that the eutectic particle size as well as α-Al grains are smaller than Fig. (a) but primary silicon present. Figure (c) is showing the best modification with maximum eutectic particle and also size of those are smaller than other.

Figure2 (g-i) is showing the microstructure of modified Al-Si alloy with 0.2, 0.3 and 0.4 wt% at 20 minutes holding time. Figure (g) shows the larger eutectic particle size and modification ratio is not good and primary silicon is also present. Figure (h) is showing smaller eutectic particle size but larger α-Al grain which is in the center of sample. Figure 2 (i) shows the good modification and eutectic particle and α-Al grains are distributed uniformly.

5.DENSITY MEASUREMENT*:*

Table II list the results of the density values for non- modified and modified alloy.

Table II: Density of modified and non-modified Al-11.1Si alloy

Sample Name	% of Modifiers	Holding Time (min.)	Density (gm/cm^3)
Sample 1	00	15	2.6600
Sample 2	0.20	10	2.7247
Sample 3	0.30	10	2.7245
Sample 4	0.40	10	2.7243
Sample 5	0.20	15	2.7309
Sample 6	0.30	15	2.7296
Sample 7	0.40	15	2.7315
Sample 8	0.20	20	2.7277
Sample 9	0.30	20	2.7307
Sample 10	0.40	20	2.7253

6. DISCUSSION:

From the above results it is visible that the density of sample-5, 7 and 9 are comparable due to fine structure of grains. Sample-7 is sowing the maximum density among the all. Sample 3 is showing the minimum density among the others because of less modification ratio and localized modification.

7. MICROHARDNESS:

The Vickers microhardness values are given in table III for non-modified and modified alloy.

Table III: Vickers microhardness of non-modified and modified alloy.

Sample Name	% of Modifiers	Holding time (minutes)	Avg. hardness (VHN)
Sample 1	0.00	……	69.6±2
Sample 2	0.20	10	104±6
Sample 3	0.30	10	98.9±0
Sample 4	0.40	10	114±2
Sample 5	0.20	15	100±5
Sample 6	0.30	15	92±7
Sample 7	0.40	15	108±8
Sample 8	0.20	20	106±4
Sample 9	0.30	20	98±5
Sample 10	0.40	20	118±3

8. DISCUSSION:

If we compare the hardness value of antimony added sample then it is easily find out that sample-9 is showing the minimum value i.e, 98 VHN because the large and more amount of α-Al grains are present in microstructure. Similarly the hardness of sample-3 and 5 are comparable. Sample-2, 8 and 10 are comparable which gives the medium hardness among the other because of fine structure of eutectic particle. In this set sample-10 is showing the maximum hardness value followed by sample-4 and the values are 118 and 114 respectively, because the eutectic particle size is smaller and uniformly distributed in the microstructure. Maximum and minimum increase in hardness value is 69.8% and 41.16% than the unmodified alloy (sample-1). Hence, sample-10 i.e, modified 0.4 wt% antimony at 20 holding time is showing the maximum hardness and sample-6 i.e, modified with 0.3 wt% antimony at 15 holding time is showing least hardness.

9. TENSILE TEST:

Table IV: Tensile properties of non-modified and modified Al-11.1Si alloy

Sample Name	% Elongation	UTS (MPa)
Sample 1	9.72	168
Sample 2	10.23	174
Sample 3	12.20	178
Sample 4	10.83	223
Sample 5	11.11	237

Sample 6	12.6	237
Sample 7	10.60	201
Sample 8	9.92	189
Sample 9	11.38	177
Sample 10	10.11	229

10. DISCUSSION:

From the above we can easily find out that sample-6 is showing the maximum elongation 12.6% and ultimate tensile strength 237 MPa followed by sample-4 which gives the values 12.2% and 223MPa respectively, because of the fine fibrous structure of eutectic particle and it is uniformly distributed throughout the sample, also the α-Al grains are smaller in size. Sample-9 is showing the least elongation 8.61 and it is less than the unmodified sample because of slag inclusion was present in the sample but modification was good. According the results the sample-5 and 10 are comparable due to fine structure of eutectic particles. Hence sample-6 i.e, modified with 0.3wt% antimony at 15 holding time is showing the maximum increase in elongation and ultimate tensile and those are 29.6% and 41.1% respectively.

11.CONCLUSION:

After analyzing the result following conclusions can be done.

1. Modified Al-Si alloy shows the fibrous structure and primary silicon sizes also reduced and maximum case it has dissolved.
2. Mechanical properties are increased in all cases.
3. On antimony addition of 0.4 wt% at 20 minutes holding time gives the highest microhardness and at 15 minutes holding time gives the maximum density. But 0.3 wt% antimony at 15 minutes holding time gives the highest elongation as well as ultimate tensile test.

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