Effect of cryogenic treatment on corrosion resistance of hybrid Aluminium-7075 metal matrix composites

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Abstract— Metal matrix composites are important class of materials, which contain metal or alloy as matrix and a ceramic particulate or fiber or whiskers as reinforcements. Aluminium based Metal Matrix Composites exhibit enhanced corrosion resistance, wear and mechanical properties. Corrosion can affect the metal matrix composite in a variety of ways which depend on its nature and the environmental conditions prevailing. Studying corrosion resistance of Al-based materials is important especially for automotive and aircraft applications. The main aim of the work is to study the corrosion resistance(with and without cryogenic condition) of Al-sic-Gr hybrid metal matrix composites of aluminium grade 7075 with addition of various percentage compositions of silicon carbide particles and graphite made by stir casting technique. The specimens were prepared according to ASTM standards. Tensile and hardness tests were performed and the properties were investigated. Result showed that as percentage of reinforcement increases corrosion resistance has improved for cryogenic condition.

Keywords — Corrosion Resistance, silicon carbide, graphite, Al 7075, cryogenic condition, stir Casting, Metal matrix composites, Scanning Electron Microscopy

1. INTRODUCTION

Aluminum alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density. These properties have made particle-reinforced metal matrix composites (MMCs) an attractive candidate for the use in weight-sensitive and stiffness-critical components in aerospace, Transportation and industrial sectors. Corrosion behavior is very important parameter for assessing the application potential of composites as structural materials. Aluminum alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density. These properties have made particle-reinforced metal matrix composites (MMCs) an attractive candidate for the use in weight-sensitive and stiffness-critical components in aerospace, Transportation and industrial sectors. Corrosion behavior is very important parameter for assessing the application potential of composites as structural materials. Table 1 shows the composition of aluminium 7075.

Aluminium	87.4-91.4%
Silicon	0.40%
Iron	0.50%
Manganese	0.30%
Magnesium	2.1-2.9%
Zinc	5.1-6.1%
Chromium	0.18-2.8%
Titanium	0.20 %
Others, each	0.05%
Others ,Total	0.15

Table.1 Composition of Al-7075 alloy

2. OBJECTIVE

The main objective of this work is to fabricate Al7075-Sic-Gr metal matrix composite by stir casting process, to prepare specimens according to ASTM standards. To investigate tensile and hardness properties and to evaluate corrosion resistance (with and without cryogenic condition) by suitable magnification using SEM.

3. MATERIAL AND METHODS

From literature survey it was cleared that, there is wide scope to studies on corrosion behavior of Al-Si-Gr hybrid metal matrix composites, so aluminium-7075 is chosen as matrix material, silicon carbide and graphite as reinforcement materials.

Table.2 shows Composition of Al 7075, Sic and Gr for specimen preparation. The quantities of silicon carbide and graphite were taken in a crucible and were heated to a temperature of 400^{o} C for 15 mins. Al 7075 was heated in the furnace at a temperature of 900^{o}C.The molten material was stirred with a stirrer speed of 220 rpm to create vortex, then the heated reinforcements were added and stirred. The composites were cast using conventional methods. The specimens are casted in 5 different combinations and it is shown below in table 2. Fig 1 shows the stir casting apparatus required to fabricate specimens.

Sl.No	Reinforcement %
Specimen 1	As Cast Al 7075
Specimen 2	1.25%
Specimen 3	2.5%
Specimen 4	3.75%
Specimen 5	5%

Table.2 Composition of Al 7075 & Sic and Gr for specimen preparation

Fig.1 Stir Casting Apparatus

4. TESTING

1. TENSILE TEST

Tensile Test was carried out on a computerized UTM according to ASTM E8. Fig 2 shows the tensile test specimens.

Fig.2Tensile Test Specimens

2. HARDNESS TEST

Hardness test was done with standard Brinell Hardness Testing Machine. Test was performed according to ASTM E10. Fig 3 shows the specimens prepared for hardness test.

Fig.3 Hardness Test Specimens

3. CORROSION TEST

Corrosion test is carried out according to ASTM standard G110.Solutions are prepared in the ratio of 1:4. Fig 4 shows the specimens required for corrosion test.

Fig.4 Corrosion Test Specimens

4. MICROSTRUCTURE STUDY AND ANALYSIS

The corrosion and fracture analysis of composites were established by scan electron microscopic (SEM) analysis of the surface morphology of the test samples.

TESTING PROCEDURE:

1. Preparation of solutions to conduct corrosion test:
2. **Etching cleaner** shall be prepared as follows: To 945 mL of reagent water add 50 mL of nitric acid (70 %) + 5 mL of hydrofluoric acid
3. **Test solution** shall be prepared as follows: 57 grams of sodium chloride +10 mL of hydrogen peroxide (30 %—add just prior to initiation of exposure) diluted to 1.0 L with reagent water.
4. The etched specimens in the test solution are immersed for a period of at least 6 h.
5. After exposure, rinse each specimen with reagent water and allowed to dry.
6. Examine each exposed specimen at various magnifications to locate areas of corrosion attack.

5. RESULTS AND DISCUSSION

1. TENSILE TEST RESULTS

Specimen	Tensile Strength in N/mm^2	Yield Strength N/mm^2
As cast Al 7075	113.119	105.617
1.25%	137.250	115.364
2.5%	113.379	106.772
3.75%	135.159	114.102
5%	99.569	81.28

Table.3 output data after tensile test

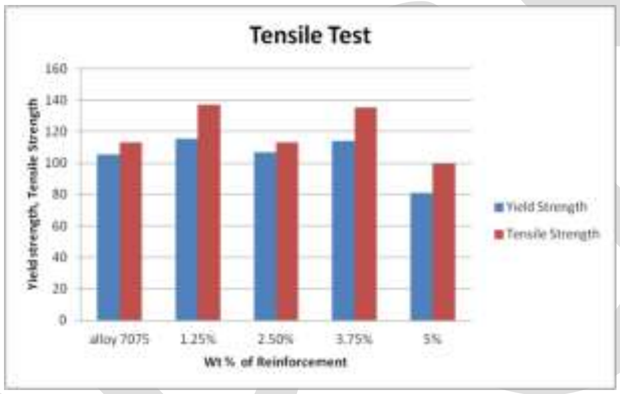

Fig.5 Variation of Tensile and Yield Strength for different composition of Sic and Gr

Table .3 shows the output data obtained after tensile test. From fig.5 it can be seen that as the percentage of silicon carbide increases the tensile strength and yield strength increases this is due to the good bonding between matrix phase and reinforcement phase, as silicon carbide dispersed with matrix phase the specimen will become harder and stronger and hence strength increases. But in the case of Al7075+ 2.5% (Sic + Gr) both tensile and yield strength decreases this is due to poor wettability. In the case of Al7075+ 5% (Sic + Gr) both tensile and yield strength decreases, as the percentage of graphite increases the specimen will become more brittle this because graphite has added in free State , In free state the carbon content in the graphite will not make good bonding with matrix phase hence the strength decreases.

2. HARDNESS TEST RESULTS

Specimen	Brinell Hardness Number
As Cast	86.8
1.25%	104
2.5%	112
3.75%	86.8
5%	95

Table.4 output data after hardness test

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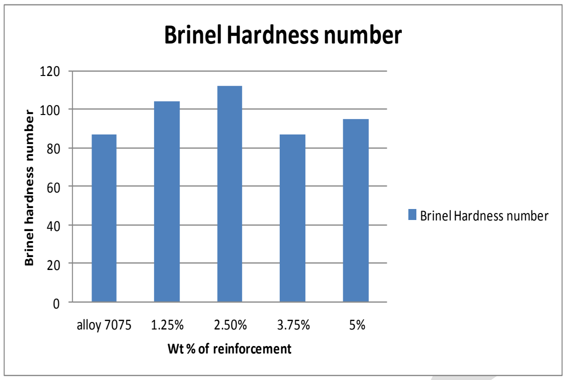


Fig.6 Variation of Brinell Hardness Number for different composition of Sic and Gr

Table.4 shows the output data obtained after hardness test. From fig.6, it can be seen that as the percentage of reinforcement increases Brinell hardness number also increases and reaches its maximum at 2.5% of reinforcement. As the percentage of graphite increases, it nullifies the property of silicon carbide and hence the specimen will become less hard.

3. CORROSION TEST RESULT

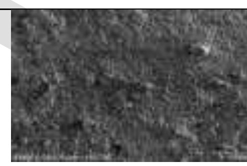
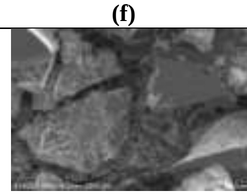
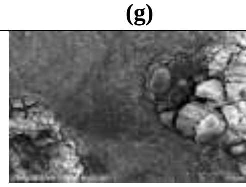
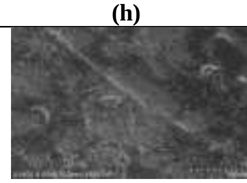
Wt.% of reinforce- -ment	Without cryogenic condition	With cryogenic condition
As cast Al-7075	 **(a)**	 **(b)**
1.25% (Sic + Gr)	 **(c)**	 **(d)**
2.5% (Sic + Gr)	 **(e)**	 **(f)**
3.75% (Sic + Gr)	 **(g)**	 **(h)**
5% (Sic + Gr)	 **(i)**	 **(j)**

Table .5 comparisons between surface of specimens after corrosion test (with and without cryogenic condition)

Table .5 shows comparison between surface of specimens after corrosion test (with and without cryogenic condition). Comparing images (a) & (b). In image (a) small pits are more on the surface of the specimen and corrosion resistance has reduced. In image (b) pits are reduced and corrosion resistance has been improved.

Comparing images (c) & (d). In image (c) pits and cracks are observed more on the surface of the specimen. But in image (d) it can be observed that cracks are not found and less porosity when compared to image (c).

Comparing images (e) & (f).both small and larger pits are observed in image (e). No larger pits are observed in image (f). Therefore corrosion resistance has been improved in cryogenic condition when it is compared with non cryogenic condition.

Comparing both the images (g) & (f).in image (g) pits are observed and uneven surface is shown by arrow this is due to casting defect. Due to this defect the surface has been damaged in image (h) that is the presence of cryogenic condition.

Comparing both the images (i) & (j).in image (i) more pits and corrosion initiation near grain boundaries are observed. But in image (j) no pits are observed and rough surface can be seen.

4. MICROSTRUCTURE ANALYSIS

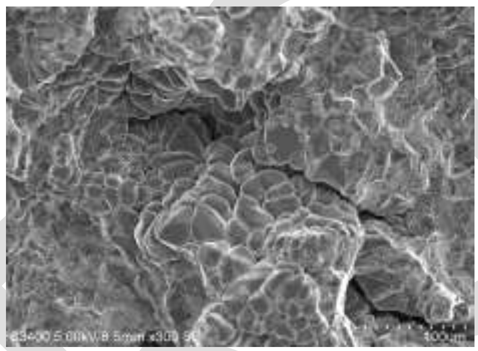


Fig.7 Microstructure of Al 7075 as cast

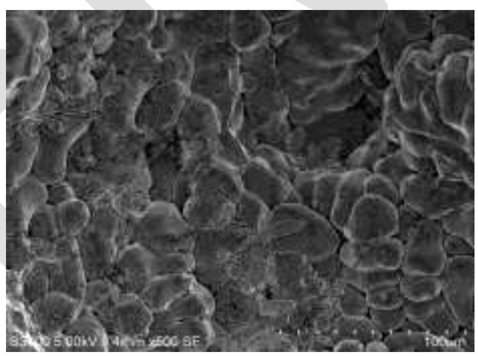


Fig.8 Microstructure of 3.75% Sic and Gr

Fig 7 shows the microstructure of as cast aluminium 7075 specimen. Fig.8 manifests the homogenity of the composites. The homogenous distribution is achieved by the shearing force caused by stirring which leads to better wear and mechanical properties. Additionally, tiny pores can be witnessed along the grain boundaries this is due to air entrapment during casting process.

6. CONCLUSION

Aluminum alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density. Studying corrosion resistance of Al-based materials is important especially for automotive aircraft and marine applications. Al 7075 matrix composites reinforced with silicon carbide and graphite has been successfully produced by the stir casting method.

1. The result from tensile test shows, increase in tensile strength and yield strength from Wt.% 1.25 to 3.75 of reinforcement over as cast Al-7075. After 3.75% both tensile strength and yield strength Has decreased. This is because as Gr has been added in free state it will not be having good bonding with matrix phase. Hence strength decreases.

2. The result of hardness test shows increase in hardness of specimen till Wt. 2.5% of reinforcement. After Wt.2.5% of reinforcement hardness decreases.

3. Without cryogenic condition, as the Wt.% of Sic and Gr increases number of pits and cracks has increased.hence corrosion resistance has decreased.

4. With cryogenic condition, as the Wt% of Sic and Gr increases, corrosion resistance has increased this is due to precipitating microfine eta carbides on the surface of the specimen.

5. Comparing with and without cryogenic condition, it can be concluded that corrosion resistance has improved for all Wt% of reinforcement for cryogenic condition except 3.75% of reinforcement because of casting defect.

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