

Study of Mechanical Properties of Grain Refined and Modified Al-Si-Mg Alloy (A357) Gravity Die Cast Reinforced with Graphite and Dual Size Alumina

Pramod S N¹

Assistant Professor, Department of Mechanical Engineering, S.K.I.T Bangalore, Karnataka, India¹

ABSTRACT: This research is designed to investigate the results on reinforcement effects on the hybrid composite material that could enhance the mechanical properties, which is the need of the hour. The proposal describes a framework for using two reinforcement materials one of them in two sizes. In terms of methodology it is proposed to cast A357 alloy as a hybrid composite with reinforcements of alumina and graphite powders in the form of cylindrical bars. The composite will be grain refined using Al-10Sr and modified using Al-5Ti-1B. Further the specimens will be precipitation hardened as per standards applicable for the base alloy A357. The specimens will be subjected to hardness, tension, and wear tests and also microstructure

I. INTRODUCTION TO COMPOSITE MATERIALS

A Composite material is defined as a combination of two or more individual materials with different physical or chemical properties, and which remain separate and distinct on a microscopic or macroscopic level within the finished structure. The main advantage of composite material is their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for weight reduction in the finished part.

Composites are made up of two materials, they are matrix and reinforcement. The matrix surrounds and binds together a cluster of fibers, particles, or fragments of a much stronger material called reinforcement. The reinforcing phase provides the strength and stiffness. In most cases the reinforcement is harder, stronger and stiffer than the matrix. The reinforcement is usually a fiber or a particulate. Particulate composite have dimensions that are approximately equal in all directions. They may be spherical, platelets or any other regular or irregular geometry. Particulate composite tend to be much weaker and less stiff than fiber composites, but they are usually less expensive. Particulate reinforced composites usually contain less reinforcement due to processing difficulties and brittleness.

Aluminium-Silicon alloys are known for their excellent combination of characteristics namely, low density, excellent castability, formability, good mechanical properties, cryogenic properties and good machinability. Aluminium and its alloys have a wide range of applications particularly in automobile, aerospace and marine sectors on account of their light weight, good surface finish, resistance to wear and corrosion, high strength to weight ratio. Since components with complex geometries can be produced cost effectively, they find enhanced utility particularly in aerospace sectors. Large aluminium extrusion components can be produced with fewer joints, resulting in less welding. Reduction in weight due to low density leads to increased load capacity, increased mileage, reduced pollution of environment and higher profits to the manufacturers. The low melting temperature, ease of handling, easy formability, easy recycling has led to increased demand for aluminium alloy components.

Different systems of identification are for wrought and cast aluminium alloys. A 3- digit and 1-decimal place system is used for cast alloys whereas, the wrought alloys have a 4 digit system

A four digit numerical system developed by the Aluminium Association is used to designate wrought aluminium alloys.

From the four digits, the first digit (Xxxx) indicates the principal alloying element and many a time used to describe the aluminium alloy series, i.e., 1000 series, 2000 series, up to 8000 series. The second single digit (xXxx) if different from 0, indicates a modification of the specific alloy and the third and fourth digits (xxXX) are arbitrary numbers used to identify a specific alloy in the series.

The designation system followed for cast aluminium alloys is based on a 3- digit-plus decimal designation system xxx.x (i.e., 356.0) the first digit (Xxx.x) indicates the principal alloying element. The second and the third digits identify the specific alloy. The zero after a period identifies the alloy as a cast product, number 1 after a period, indicates an ingot composition.

The presence of either a secondary alloying element or its purity level is indicated by a letter prefix. The designation Axxx.0 would indicate a higher purity level than the alloy xxx.0.

In alloy A357.0, the capital A (Axxx.x) indicates a modification of alloy 357.0. The number 3 (A3xx.x) indicates that it is of the silicon plus copper or magnesium series. 57 in A357.0 (Ax57.0) identifies the alloy within the 3xx.x series and .0 (Axxx.0) indicates that it is a casting.

Series	Principal Alloying Element
1xx.0	99% Minimum
2xx.0	Copper
3xx.0	Silicon with Copper or Magnesium
4xx.0	Silicon
5xx.0	Magnesium
6xx.0	Unused
7xx.0	Zinc
8xx.0	Tin
9xx.0	Other

A357.0 Alloy and its Equivalent in LM (Light Metal) and Wrought Series

The cast A357.0 alloys find applications in automotive, aerospace industries, and general engineering, on account of its superior combination of properties like good fluidity, high strength-to-weight ratio, good wear resistance and corrosion resistance.

Chemical composition, impurities, melts treatments and solidification rate strongly influence the mechanical properties attainable in this alloy. These alloys are categorized as premium quality castings which assure higher quality and reliability than conventional cast products. These alloys possess high mechanical properties, low porosity levels, good dimensional accuracy and good surface finish. They guarantee minimum property levels in any part of the component. The alloy group can be arranged as 3xx, 4xx, 5xx, 2xx and 7xx in the order of decreasing castability.

II. LITERATURE SURVEY

Aluminium alloys have been used since 1940 when cast Al-Tin bearings were used for heavy machinery. The development of light weight Al-Si alloys led to the usage of wear resistant components. The property of light weight and good thermal conductivity of hypoeutectic, hypereutectic alloys such as A357 enabled automobile industries to manufacture Al-Si cylinder blocks by die casting during late 1950's. However, since these alloys exhibited only modest wear resistance, the early engine blocks were provided with cast-in steel cylinder liners. A major boost was given to the use of light weight Al-Si alloys in automobiles when the energy crisis in early 1970's resulting in the government mandating improved fuel consumption in automobiles. Since fuel consumption is directly related to weight of the vehicle, the use of Al in place of C.I in engine components became highly desirable. But the production of Die-cast Al engine blocks with C.I liners proved to be too costly and resulted in the development of hypoeutectic Al-Si such as A357 which had greater wear resistance and could be used without liners.

L. Lasa and J.M Rodriguez-Ibabe [2] tested wear behavior of eutectic and hyper-eutectic AL-Si-Mg alloys with various compositions and processing routes against a composite brake pad using Pin-on-Disc configuration. They observed that at lower disc speed, the influence of the composition and alloy processing was very strong and a severe wear transition was observed for alloys with low Si content. At higher speeds, the alloys offered higher resistance to wear.

M. Chen and A.T. Alpas [3] and **M. Chen et.al** [4] have studied the effect of silicon particle morphology in maintaining the UMW regime for eutectic Al-11% Si, Al-12 Si alloys and Al-18. 5% Si alloy. The characteristics of UMW were similar for eutectic alloys. The matrix hardness played a major role in controlling the wear mechanisms for a given aspect ratio and size of Si particles.

S.A. Kori and T.M. Chandrashekharaiah [5] studied the effect of grain refiners on the dry sliding wear tests on hypo-eutectic and eutectic Al-Si-Mg alloys for varied parameters such as composition, loads, sliding speeds and sliding distances. They observed increase in mechanical and Tribological properties with the addition of Al-Ti-B grain refiner and modifier, Strontium due to change in microstructure and formation of fine particles.

A.T. Alpas and J. Zhang [6] investigated the dry sliding wear behavior of cast Aluminum 7% Si alloys (A357) reinforced with SiC particles with 10-20% (vol) SiC over load range 1-150 N and sliding velocities ranging from 0.16-0.8 m/s. They observed that Si particles acted as load bearing elements and their abrasive action on the steel counter face caused transfer of Iron rich layers on to the contact surfaces leading to better wear resistance of reinforced composites compared to as-cast alloys in which wear occurred by surface crack nucleation around Si particles and their growth.

A.D. Sarkar and J. Clarke [7] investigated the wear characteristics, friction and surface topography in dry sliding of binary as cast and age hardened hypo-eutectic and hyper-eutectic Al-Si-Mg alloys using a pin-bush machine. The SEM study of the worn surfaces and sub surfaces showed the presence of Aluminum deposits on the bush and the subsequent back transfer of some of this deposit to the bush material.

Dheerendra Kumar Dwivedi [8] studied the influence of alloying elements on the wear behavior of binary (Al-17% Si) and multi component (Al-17Si-0.8Ni-0.6Mg-1.2Cu -0.6Fe) cast hyper-eutectic aluminum alloys which were cast via foundry route. Dry sliding wear tests were performed at sliding speeds of 0.2-0.4m/s and contact loads of 10-30N. SEM studies were made on wear surfaces and wear debris. The results indicated increase in hardness and wear resistance due to alloying and multi component hyper-eutectic alloys offered better wear resistance compared to binary alloys.

P.R. Gibson et.al [9] studied wear of cast aluminum-silicon alloys containing graphite produced by compo casting followed by gravity die casting using pin-on-disc wear test rig and observed the reduction in coefficient of friction and temperature rise with increase in graphite content. At low

III. METHODOLOGY

A357 and its composites are casted in the form of cylindrical bars. The chemical composition of the alloy is obtained using Optical Emission Spectrometer. Reinforcing of alloy with varied percentage of dual size Alumina particulates, graphite with Strontium as grain refiner and Titanium and Boron as modifier. The specimens for microstructure analysis, hardness, tensile, compression, wear and impact are prepared and tested as per ASMT standards.

- Samples for microstructure examination are prepared and analyzed using ASTM E407-07 standard metallurgical procedures.
- Tensile test is conducted as per ASMT E8 Standards. The properties such as UTS, YS are evaluated.
- Compression test is conducted as per ASTM E9 Standards. The properties such as Peak load and Compression Strength are evaluated.
- Wear test is conducted as per ASTM G99 Standards, using Pin on Disc apparatus, % weight loss is calculated.
- Hardness test is conducted as per ASMT E10 standards, using Brinell hardness Tester.
- Impact test is conducted as per ASTM E23 standards using Charpy test. Impact Energy is evaluated.

IV. RESULTS

Tensile Test Results

Tensile specimen was prepared and the test was conducted as per ASTM E8 Standards. The test was conducted on Universal testing machine. Following results are tabulated and compared.

Parameters	Load at Yield (KN)	Elongation at Yield (mm)	Tensile Strength (N/mm ²)	% Elongation
As cast	19.57	7.440	196.777	3.78
60 Mesh 1%	16.63	7.910	165.044	2.12
60 Mesh 3%	20.68	8.440	199.177	3.86
60 Mesh 5%	22.49	8.620	222.528	6
80 Mesh 1%	17.12	7.760	174.588	1.24
80 Mesh 3%	18.25	8.603	178.539	1.82
80 Mesh 5%	19.81	8.760	198.498	3.32

Table 5.1: Tensile Test Results

Microstructure Results

Microstructure specimen was prepared and the test was conducted as per ASTM E407-07 Standards. The specimen was etched and polished to obtain mirror finish. The test was conducted on Optical metallurgical microscope (NIKON Epiphot 200) using Keller's reagent.

Result

Microstructure consists of inter dendritic eutectic Silicon in a matrix of aluminium solid solution. No segregation or porosity was seen in the section.

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Hardness Test Results

Hardness specimen was prepared and the test was conducted as per ASTM E10 Standards. The test was conducted on Brinell hardness testing machine and on Brinell microscope. Following results are tabulated and compared.

V. CONCLUSION

From the studies conducted on A37 alloy based, Al-Sr grain refined and Al-Ti-B modified reinforced composite, the following conclusion have been drawn.

- Gravity die casting method is used to obtain homogeneous microstructure of A357 alloy with Al-Sr as grain refiner And Al-Ti-B as modifier.
- Microstructure reveals the uniform distribution of grain refiners in the aluminium solid structure.
- Microstructure consists of inter dendritic network of eutectic silicon matrix of aluminium solid solution. No segregation or porosity was seen in the section.
- Extrapolation of experimental data shows that UTS of more than 220Mpa can be obtained for A357 when reinforced with Strontium as grain refiner and Titanium Boron as grain refiner, such high strength composites would be of immense advantages for automotive and aerospace industries.
- Metal matrix composite of A357 reinforced with Alumina and Graphite were found to be having improved tensile strength when compared to A357 alloy alone.
- Test conducted to determine the compressive strength revealed very encouraging results as the reinforced composite was able to take more compressive load due to presence of alumina and graphite.
- Test conducted to determine wear indicated no exact trend. However the composites shown a lower rate of wear for certain compositions.
- There is increase in the hardness of composite as the % of reinforcement increased. But the values were less than the as cast values.
- There is increase in the impact energy of composite as the % of reinforcement increased.

A357 composite reinforced with 60 mesh 5% exhibits superior mechanical properties compared to as cast.

VI. SCOPE FOR FUTURE WORK

- The experiments can be carried out on varying content of Alumina and Graphite addition and properties can be analyzed.
- Since our project is confined to tensile, compression, hardness and wear tests other tests like SEM, XRD, corrosion, and torsion tests can be carried out.
- Tests can be conducted on different alloys of aluminum like A358, A359 etc. With varied composition.

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