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A Review on Composition & Mechanical Strength of Wrought Aluminum Alloy Series

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Abstract*— Aluminum is one of the majorly used construction & engineering material now a days because of its relatively lower specific weight and corrosion resistance compared to steels or other materials. Besides the weight & corrosion resistance, they are also comparatively easier to machine, form & fabricate. The increased concerns for saving energy and environment has further increased the demand for light weight structure or frames in day to day life applications such as automobile, aerospace and marine industries[1]. Aluminum is an economical (lower in price) and easily produced metal which can be used for equipments & frames bearing high level of stresses & versatile environmental conditions. Aluminum and its alloys have been one of the primary choice for materials used in structural parts of marine, aerospace, military, construction sectors for more than hundred of years. Further advancement in its properties are made to enhance their properties further as per specific engineering requirement.

Index Terms*— Aluminum Alloy, Corrosion Resistance, Automobile, Aerospace, and Marine.

I. INTRODUCTION

An alloy is a mixture of two or more metals together .Similarly Aluminum alloys are those alloy those having Aluminum as a predominant (majority) metal. The most commonly used alloy-ing element is zinc, silicon, magnesium, iron, manganese, copper, and tin. The additional alloying elements to Aluminum enhance various properties of Aluminum such as the workability, electrical conductivity, protection from corrosion and the strength.[1] Aluminum alloy has already been extensively used in manufacturing of engineering parts and components those required resistance to corrosion with light weight is of major consideration. It has already been majorly used in the manufacturing of marine, military, and construction & aircraft components.[2]

II. CLASSIFICATION OF ALUMINUM ALLOY

Aluminum alloys is mainly categorized as:

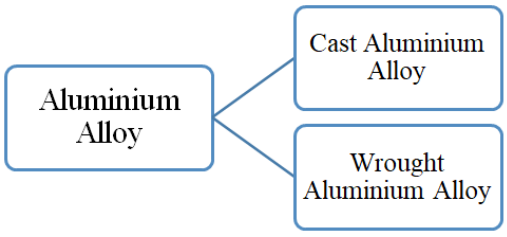

Fig.1 Classification of Aluminum Alloy

Cast aluminum alloys:

These alloys are made by melting metal within the furnace & poured down into different desired shapes of moulds. In comparison to the wrought aluminum alloy the cast alloys have more percentage of alloying elements. Because of the traditional approach in formation it has lower tensile strength in comparison to the wrought alloys[2]. Having majority of application in cast wheels, farms equipments etc, they uses a 4 digit number system and a decimal point is putted after third digit. The reviewed tensile & yield strength is referred below

Grade	Composition (wt %)	Mechanical Strength-Tensile* (MPa)	Mechanical Strength- Yeild* (MPa) 0.2%
1xx.x	99.00% to 99.99% Al	131 – 448	28 – 152
2xx.x	4% to 4.6% Cu	131 – 276	90 – 345
3xx.x	5% to 17% Si	117 – 172	66 – 172
4xx.x	5% to 12% Si	117 – 172	41 – 48
5xx.x	5% to 12% Mg	131 – 448	62 – 152
6xx.x	Not Used	207 – 379	117 – 310
7xx.x	6.2% to 7.5% Zn		

*Average values for comparison of alloy only [2]

Wrought aluminum alloys:

When aluminum alloy is fabricated & worked in the solid form with some specific tools they are called wrought aluminum alloys. They have exceptional mechanical & chemical properties with good process ability in comparison to the cast aluminum alloys because of the absence of casting defects as were there in casted aluminum alloys. Majority of wrought aluminum alloy is used in electrical, aircraft and automobile industries[2]. They are also represented by 4 digit number in which first one shows the main alloying element, the second digit represents modification in alloy. The third & fourth digit represents for the specific alloys. The tensile & yield strength of different grades of wrought aluminum alloys are as given below:

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Grade	Composition	Mechanical Strength- Tensile* (MPa)	Mechanical Strength- Yeild* (MPa) 0.2%
1xxx Series	99.00% to 99.99% Al	82 – 166	28 – 152
2xxx Series	2.2% to 6.8% Cu	186 – 467	76 – 345
3xxx Series	0.3% to 1.5% Mg	110 – 283	41 – 248
4xxx Series	3.6% to 13.5% Si 0.1% to 4.7% Cu 0.05% to 1.3% Mg	172 – 414	45 - 180
5xxx Series	0.5% to 5.5% Mg	124 – 352	41 - 345
6xxx Series	0.2% to 1.8% Si 0.35% to 1.5% Mg	124 – 310.3	55.2 – 276
7xxx Series	0.8% to 8.2% Zn 0.1% to 3.4% Mg 0.05% to 2.6% Cu	228 – 572	103 - 503

*Average values for alloy comparison only [2]

III. ADVANTAGES OF WROUGHT AL-ALLOY OVER CAST ALUMINUM ALLOYS

The potential benefits of Wrought Aluminum Alloys over casted Aluminum alloys are given below:

- Excellent mechanical properties
- Structural integrity
- Effective surface finish
- Ease of fabrication & manufacturing
- Ease of its forming, i.e., it can be formed or extruded within different vast range of designed sections that can be customized as per application.

IV. CATEGORIZATION OF WROUGHT ALUMINUM ALLOYS

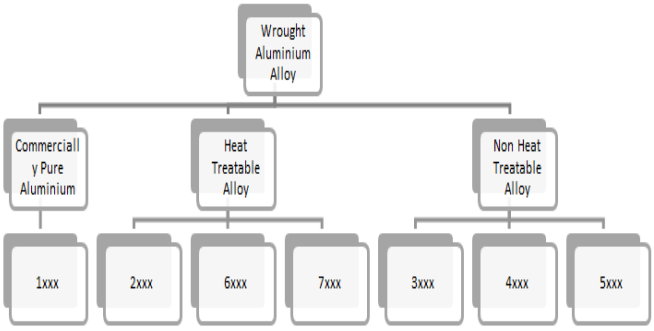

Fig. 2 Categorization of Wrought Aluminum Alloy

Pure aluminum

Commercially pure aluminum

- **1000 Series**

The 1000 Al- alloy series comprises of ninety-nine or more percentage of aluminum within its forming (composition). This 1000series has exclamatory work-ability, excellent corrosion resistance and extreme thermal conductivity properties and electrical properties. [3]

Heat-treatable alloys

The operation of heating & cooling of metal under specified conditions to achieve desired properties is known as heat treatment process. Some Aluminum alloys are also strengthened and enhanced their performance by solution heat-treating process. [4]

- **2000 Series**

The series of Aluminum alloys in which copper is the main alloying element comes in 2xxx series. 2000 series Al-alloy are majorly used in aero-industry where the higher mechanical property of strength is in focus. By applying heat treatment in this series their mechanical properties can be improved further [4]. Alloy 2024, is majorly known as aero-industry alloy, because of its wonderful property combination of resistance towards fatigue and enhanced mechanical strength.

- **6xxx Series**

The 6xxx series is also heat treatable type of Aluminum alloy. They have magnesium & silicon as the principal alloying element, majorly used in architectural extrusion & automotive components.. They are versatile, weld able, highly formable, highly corrosion resistance and have moderately high strength[4]. Aluminum alloy series (AA6061) is the majorly used alloy for frames of truck and marine ship. The Apple's iPhone product uses 6xxx series alloy as their frame due to its mechanical peroperties, resistance in rusting and light weight because of addition of copper in it.

- **7xxx Series**

Zinc is used as the majority alloying element in 7000 series of Al-alloys with addition to magnesium which makes it treatable under temperature conditions for a extremely high mechanical strength. The most commonly used alloys in 7xxx series are 7075&7050, they are mainly used in the aircraft industry. The 7000series Aluminum alloy are the stiffest series, having strengths (yield) of ≥500 MPa (≥73 ksi) possible.[4]

Non heat-treatable alloys

When alloys are heated upto a desired temperature and then cooled down under certain conditions to achieve desired properties in the sample is known as heat treatable alloys. They are strengthened through cold and hot working process. Rolling and forging are good examples of heat working which strengthen the metals/alloys[6].

- **3000 Series**

The major or main alloy-ing element in this series is mainly (Mn)manganese, which is added with minute amount of (Mg)magnesium in it. But the % addition of Mn to Aluminum is very constrained in comparison to other alloying elements. [7] Al-alloy3004 and the further modified

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versions are many times used in the fabrication of aluminum drink cans.

- **4000 Series**

The main or principal element as alloy in 4xxx Al-alloy series is silicon, which is put in appropriate quantities mainly to reduce the Aluminum's melting point without generation of any structural brittleness in it. [10]

- **5xxx Series**

Main alloying element in 5xxx series is (Mg) Magnesium it the majorly used Al-alloy throughout. Al-alloy in this alloy series consisting of good properties of welding ability, rusting-resistance and medium to increased mechanical strength properties. The application of 5xxx (Aluminum-magnesium alloys) are mainly in construction industry, marine applications, storage tanks and pressure vessels[11].

V. CONCLUSION

In this paper, the different categories of aluminum alloys are reviewed and described as their composition and mechanical properties. Each series of aluminum alloy is divided on the basis of the alloying element. There were 3 main classes of aluminum alloy consisting of pure aluminum, heat-treated aluminum alloy and non-combustible aluminum alloy, divided mainly according to their ability to withstand the heat treatment process to improve their properties. Due to the efficient and flexible use of aluminum alloys, their demand for use has increased significantly in various sectors be it automotive, aviation, shipping, construction, etc. The two main industries that benefit most from aluminum alloys are the automotive industry and aerospace. due to the light weight and good mechanical strength. The continuous use and advanced research on aluminum alloys guarantees thousands of future opportunities as the use of aluminum alloy is virtually unlimited and ensures a sustainable and green environment which is a requirement of an hour of sustainable vision.

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