American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-3, pp-146-150
www.ajer.org

Research Paper Open Access

5083 type Al-Mg and 6082 type Al-Mg-Si alloys for ship building

Burcu Ertuğ[1*], Levent Cenk Kumruoğlu[2]
[1](*Metallurgical and Materials Eng., Istanbul Technical University, Istanbul, Turkey.*)
[2](*Metallurgical and Materials Eng., Cumhuriyet University, Sivas, Turkey.*)

ABSTRACT: *Marine transport is increasing its use of aluminium by capitalizing on its two leading qualities: lightness and corrosion resistance. The most popular aluminium alloys for use in corrosive environmentssuch as seawater are the 5xxx and 6xxx series alloys, which demonstrate adequate strength and excellent corrosion resistance. The traditional and the most often used Al-alloys in shipbuilding are 5083 type Al-Mg alloy for plates, and 6082 type Al-Mg-Si alloy for extrusions. These alloys were found to be reliable in marine service as well as during manufacturing.*

Keywords - *Aluminium alloy, corrosion, ship hull, strength.*

I. INTRODUCTION

Aluminum alloys suitable for use in a marine environment have been available for approximately 30 years, offering significant advantages inreducing structural weight and hull maintenance[1]. Marine transport is increasing its use of aluminium by capitalizing on its two leading qualities: lightness and corrosion resistance. Advanced alloys have enabled the design of high-speed ships, by lightening hulls by 40% to 50% over steel[2]. A lighter hull offers better performance, a shallow draught, lower fuel consumption, less capital outlay for engine and propulsion systems[3].Corrosion resistance, even on the water, makes for more durable hulls, masts and superstructures on pleasure boats and the bridges and superstructures of passenger ships and merchant ships[2].When correct attention has been paid to design, especially as regards use with other materials (and the risk of galvanic corrosion), aluminium is an excellent material in a marine context. One example of this is the extensive use of aluminium in many types of ships and boats. Cathodic protection against corrosion is widely used here[4].

b.

Property	Aluminium	Steel
Specific weight, g/cm^3	2.66	7.85
Melting point (liquidus), °C	640	1450
Coef. of linear exp., 10^{-6} °C^{-1}	23.8	11.7
Specific heat, J kg^{-1} °C^{-1}	960	460
Thermal conductivity, W m^{-1} °C^{-1}	120	50
Proof stress, 0.2 PS, MPa	215	235
Tensile stress, UTS, MPa	305	400
Elongation, %	10	40
Elastic modulus, GPa	70	210

Figure 1 a. The bearing welded into a tube in an aluminium hull, [5]and b. the properties of aluminium versus steel[6].

Figure 1 compares the properties of minimum values for 5083 H116 aluminium alloy and for ordinary strength hull structural steel[6].The most popular aluminium alloys for use in corrosive environmentssuch as seawater are the 5xxx and 6xxx series alloys, which demonstrate adequate strength and excellent corrosion resistance. These series are highly suitable in various marine structures, machinery and portbuildings. To prevent aqueous corrosion when in contactwithsea water, several techniques and methods were developed and annual corrosion were reduced[7-9].

II. THE UNIQUE PROPERTIES OF ALUMINUM

Aluminium is the most widely used non-ferrous metal. It is used excessively in the modern world, and the uses of the metal are extremely diverse due to its many unusual combinations of properties.Topaluminium markets for the industry are transportation, beverage cans and other packaging, and building/construction.Although aluminum is sometimes used as is, many applications involve the addition of small quantities of other metals to create alloys with special properties. Certain alloying elements increase strength, corrosion resistance, machinability, ductility, weldability and strength at high temperatures.

II.I LIGHTNESS-SPECIFIC STRENGTH

With a specific mass of 2700 kg/m^3,on a volume basis, aluminium is only about one-third the weight of steel. Significant weight savings can be made in almost every type of mechanical application.Aluminum's unbeatable strength to weight ratio gives it many uses in the transport industry. As aluminum is lightweight, less energy needs to be used to move a vehicle made with aluminum than one made from a heavier metal, such as steel[2,10,11].

II.II Durability-Corrosion Resistance

Because aluminium quickly forms an impervious oxide skin on exposed surfaces, it is highly resistant to atmospheric corrosion, even in marine conditions. So it does not require painting for protection.Due to its resistance to corrosion, even in a marine environment, aluminum is the primary material of choice in the shipbuilding sector - hulls, masts, pleasure boat superstructures as well as bridges and superstructures on liners and merchant ships. Rigid aluminum packaging is mainly used to protect and stock food, drinks and pharmaceutical products. Aluminum is a preferred metal due to its chemical inertness, stability, corrosion resistant qualities and impermeability to air, light, ultraviolet rays, water vapour, oils and fats, oxygen and micro-organisms[2,10-12].

II.III Thermal And Electrical Conductivity

The specific electrical conductivity of aluminium makes it indispensable for electronics and electrics. Aluminium cables carry twice as much current as copper of the same weight. High thermal conductivity makes it very suitable for heating and cooling applications.Unalloyed aluminium has a thermal and electric conductivity about 60% of copper, which accounts for its development as a conductor, in the form of bars and tubes which are used in numerous electrical applications, such as connectors and distribution bars[2,10,11].

II.IV WORKABILITY-METAL FORMING OF ALUMINIUM

Aluminium can be formed by all the common metal-working techniques, more easily than most. It is easy to cast, or die-cast to precise and complex shapes. It can be forged, rolled to a superfine foil, and extruded into intricate sections, or pressed. Superplastic alloys can be worked almost like vacuum-formed plastics. Aluminium is also one of the easiest and fastest materials to machine[10,13,14].

II.V VERSATILITY AND ATTRACTIVENESS

Aluminium alloys can be stiff or supple, especially strong or particularly corrosion-resistant. It is easy to tailor the metal, by alloying and heat treatment, to meet a wide range of needs. Aluminium is a clean material. It looks good without further finishing, but takes kindly to a wide range of applied coatings, from paints to coloured anodising[10].

II.VI Recyclability of Aluminium

Aluminium is easily reprocessed using 5% of the energy needed for primary smelting: almost one third of all the aluminium used today is produced from scrap, either from production processes or from recycled products. Aluminum cans are 100% recyclable; there are no labels or covers to be removed. Recycling them reduces waste, saves energy, preserves natural resources and lessens the need for municipal landfill, while offering recycling companies and municipalities a significant source of revenue[10,12].

III. ALUMINIUM USER INDUSTRIES

III.I transportatıon

While transportation has typically represented the largest market for aluminum in North America over the past two decades. The majority of this aluminum was used in automotive and light truck applications, as vehicle manufacturers continue to opt for lightweight aluminum solutions to improve fuel economy, reduce emissions and enhance vehicle performance. Aluminum-intensive automobiles include the Audi A8 and Jaguar XK. As auto manufacturers struggle to meet fuel-efficiency standards, they increasingly turn to lightweight aluminum alternatives for many parts.In addition to auto parts, motorcycles and airplane parts increasingly are

made of aluminum. With trains, boats and cars aluminum is useful for this lightweight property (which gives fuel efficiency) but not essential, in planes however maintaining a relatively low weight is vital and aluminum allows planes to have to this. In modern planes aluminum makes up 80% of their weight, and a normal Boeing 747 contains about 75 000 kg of the metal[11,15,16].

III.II packagıng

Aluminium is probably the most versatile packaging material available today. It makes strong, light, secure shipping containers, and it encapsulates pills. It is probably more commonly seen on supermarket shelves than any other product, and it is equally at home in the heat of oven and the cold of freezer. It is exceptionally homogeneous, so that it can be rolled to the thinnest of foils. Its ductility makes it easy to wrap, and to re-seal once opened.In 2009, containers and packaging regained their position as the top market for aluminum. Aluminum is used in products such as beverage cans and bottles, food containers, and household and institutional foil. Product manufacturers and consumers appreciate foil for its impermeability to light, water, and oxygen - making it a preferred barrier material for beverage, food, and pharmaceutical products. Additionally, aluminum's low weight gives it a competitive advantage over other materials with regard to shipping costs.Aluminum is still used in a very big way in the food packaging industry despite recent health worries linking aluminum to Alzheimer's disease[10,11,15].

III.III Buıldıng And Constructıon

Largely due to products in the residential, industrial, commercial, farm, and highway sectors, the 2009 building and construction market accounted for 2.13 billion pounds of net shipments, good for 11.9 percent of total shipments and the third largest North American market for aluminum.The European building industry uses about 1.2 mill. tons of aluminium every year, making it the second biggest user of the metal. Japanese and American building industry use about 915,000 ton and 1,05 million tons of aluminum per year, respectively. It is found everywhere, in roof and wall cladding, windows and doors, stairs and railings, roof frames, scaffolding, greenhouses and home extensions[10,11,15,16].

III.IV Electrıcal Applıcatıons

Aluminum has many advantages for electrical applications. It is lightweight, strong, corrosion resistant, and a highly efficient conductor (aluminum has twice the conductivity, per pound, of copper)—rendering it the material of choice for transmitting power from generating stations to homes and businesses. It is also infinitely recyclable, making it a perfect fit for today's environment.The North American electrical market was the fourth largest for aluminum, accounting for 7.3 percent of all aluminum shipments during the year. Over the past century, aluminum and certain alloys have gradually replaced the copper wires used to transmit and distribute electric power.Today, almost all the electricity networks in Quebec, Canada and the United States use wire made from aluminum or aluminum alloys, bare or insulated, which carry and distribute electricity at a lower cost than copper. Many underground cables are made from aluminum[12,15].

IV. TRADITIONAL ALUMINIUM ALLOYS FOR SHIP BUILDING

Production of seagoing vessels using aluminium began in earnest after World War II with the introduction of MIG welding technology and the invention of the 5000 alloy series. Arc welding swiftly established itself in the world of shipbuilding as the cheaper, quicker and more effective method for joining panels and extrusions than riveting. Even above the waterline, where steel meets aluminium special measures are required to prevent corrosion, namely protective paint, insulation and explosion-bonded aluminium-steel transition joints[17].

The traditional and the most often used Al-alloys in shipbuilding are 5083 type Al-Mg alloy for plates, and 6082 type Al-Mg-Si alloy for extrusions. These alloys were found to be reliable in marine service as well as during manufacturing.

Aluminium alloy 5083 contains 5.2% magnesium, 0.1% manganese and 0.1% chromium. as in Table 1. In the tempered condition, it is strong, and retains good formability due to excellent ductility. 5083 has high resistance to corrosion, and is used in marine applications. It has the low density and excellentthermal conductivity common to all aluminium alloys.Typical applicationsrequire a weldable alloy of high to moderate strength, with good corrosion resistance. Marine applications, unfired welded pressure vessels, TV towers, drilling rigs, transportation equipment, armour plate are the main areas of usage[18].

Table 1 a.Composition of Aluminium 5083 alloy and b. Physical properties[18].

Element	%	Element	%
Aluminium	Remainder	Silicon	0.40 max
Magnesium	4.0 – 4.9	Iron	0.40 max
Manganese	0.40 – 1.0	Copper	0.10 max
Chromium	0.05 – 0.25	Others, each	0.05 max
		Others, total	0.15 max

a.

Property	at	value	unit	Property	At	value	unit
Density	20°C	2,660	kg/m^3	Melting Range		574 – 638	°C
Weight	20°C	2.66 x thickness in mm		Mean Coefficient of Expansion	20°C	24.2	x 10^{-6} / °C
Modulus of Elasticity				Thermal Conductivity	25°C	120	W / m . °C
Tension	20°C	70.3	GPa	Electrical Resistivity	20°C	59.5	Nano-ohm . m
Torsion		26.4		Electrical conductivity			
Compression	20°C	71.7	GPa	(all tempers)	20°C	29	% IACS

b.

In respect to the Al-Mg alloys with Mg content ≥ 3% wt., the Aluminum Association received the H116 and H321 temper. The H116 products are strain hardened at the last operation in the processing schedule, while the H321 is thermally stabilized. In both procedures the same level of mechanical properties is achieved, meeting the specified levels of corrosion resistance which is assessed in accelerated corrosion tests (NAMLT and ASSET), regarding inter-granular and exfoliation types of corrosion. Those new H116 and H321 tempers are specified in the recently established ASTM B928 standard for "High Magnesium Aluminum Alloy Sheet & Plate for Marine Service"[19].

Table 2 Standard temper and temper definitions for Aluminium 6082 alloy[20].

Standard Tempers	Standard Temper Definitions*
F	As fabricated. There is no special control over thermal conditions and there are no mechanical property limits.
O	Annealed. Applies to products that are annealed to obtain the lowest strength temper.
T4	Solution heat-treated and naturally aged.
T5, T5511	Cooled from an elevated temperature shaping process and artificially aged.
T6, T6511	Solution heat-treated and artificially aged.

The alloy 6082 is a high strength alloy for highly loaded structural applications. Typical applications are scaffolding elements, rail coach parts, offshore constructions, containers, machine building and mobile cranes. Due to the fine grained structure this alloy exhibits a good resistance to dynamic loading conditions. 6082 is certified for use in marine applications[21]. Tempers for this alloy were given in Table 2.

V. CONCLUSION

The usage of aluminium, particularly of Al-Mg types, in the marine environments can be examined in terms of property and cost. The total weight saving is 50% when the constructions are replaced by Al alloys. This makes aluminium advantageous for ship building industry. The advantages of aluminium application in the ship building industry can be grouped as being lightweight, having high corrosion resistance and having low cost maintenance. The traditional and the most often used Al-alloys in shipbuilding are 5083 type Al-Mg alloy for plates, and 6082 type Al-Mg-Si alloy for extrusions. These alloys were found to be reliable in marine service as well as during manufacturing.

REFERENCES

[1] C. J. Altenburg, R. J. Scott, *Design Considerations ForAluminum Hull Structures, Study Of Aluminum Bulk Carrier*, Gibbs & Coxunder Department of the Navy Naval Ship Engineering Center (U.S. Coast Guard Headquarters Washington, D.C., 1971).
[2] http://www.constellium.com
[3] http://www.kmy.nl/info/voordelen-van-aluminium.html
[4] http://www.aluminiumdesign.net
[5] http://www.jefa.com/examples/aluminium.htm
[6] Hull Structure in Naval Applications, Austal Newsletters, 2013.
[7] S.S. Abd El Rahim, H.H. Hassan, M.A. Amin, The corrosion inhibition study of sodium dodecylsulphonateto aluminum and its alloy in 1.0 M HCl solution, *Mater Chem Phys, 78*, 2003, 337-348.
[8] M. Bethencourt, F.J. Botana, M.A. Cauqui, M. Marcos, M.A. Rodriguez, Protection against corrosion in marine environments of AA5083 Al-Mg alloy by lanthanide chlorides, *Alloys Compounds, 250*, 1997, 455-460.
[9] W.B. WanNik, O. Sulaiman, A. Fadhli, R. Rosliza, Corrosion Behaviour Of Aluminum Alloy In Seawater, *Proceedings of MARTEC 2010, The International Conference on Marine Technology*, BUET, Dhaka, Bangladesh, 11-12 December 2010, 175-180.
[10] http://www.aluminyumsanayi.com
[11] http://sam.davyson.com/as/physics/aluminium
[12] http://www.thealuminiumdialog.com
[13] B.D. Danilenko, Workability of aluminum alloys, *Russian Engineering Research, 31(8)*, 2011, 797-799.
[14] B.Ramesh, *Workability Analysis On Aluminium Based Composites And Aluminium Alloys*, Department Of Mechanical Engineering, Pondicherry Engineering College, Pondicherry University, Puducherry, India, September, 2011.
[15] http://www.aluminum.org
[16] http://curiosity.discovery.com
[17] http://www.aluminiumindustry.org
[18] E. Romhanjı, M. Popovıć, Problems And Prospect Of Al-Mg Alloys Application In Marine Constructions, *Journal Of Metallurgy, 298*, 297-307.
[20] http://www.sapagroup.com/us/industrialextrusions
[21] http://www.nedal.com