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ALUMINUM ALLOYS IN SHIPBUILDING INDUSTRY

Introduction

Steel has an extensive account of providing superior mechanical properties to the ship building industry, but with one major disadvantage: weight. Increasing demands for size have forced ship designers to search for alternative materials which will reduce the weight of the ship without compromising strength. When properly designed, aluminum typically reduces the weight of small structures made of low-carbon steel by over 50%. Weight issues have become increasingly important as advanced technology allows us to build larger ships. Since 1910, the maximum weight of ships has more than doubled, increasing from 46,000 tons to 109,000 tons. Increasing demands for size have forced ship designers to search for alternative materials to reduce the weight of the ship without compromising strength. Dramatic technological advances have allowed aluminum to meet or exceed the minimum strength requirements for normal strength steels currently used in the shipbuilding industry. Another advantage of aluminum is its resistance to corrosion, which is superior to steel - it corrodes over 100 times slower than conventional structural carbon steel used to build ships.

This report elaborates the weight reduction, strength, corrosion resistance, and cost of replacing conventional structural steel with lighter-weight aluminum alloys in the shipbuilding industry.

Advantages:

- The structural design of a ship should seek to minimize weight. This will reduce cost and minimize the loss of cargo dead-weight due to structure.
- The weight reduction not also increases fuel efficiency. As a ship gets larger it becomes increasingly difficult to design for fuel efficiency without sacrificing other aspects. In addition, larger ships require larger power plants, which require more fuel. The larger engines and massive quantities of fuel add weight to the already bulky ships. Storage of the fuel also becomes a question. Weight issues have become increasingly important as advanced technology allows us to build larger and larger ships.
- Aluminum has higher corrosion resistance over steel; this results in increased ship life.

Weight:

Impressive technological advances in strength have allowed aluminum to emerge as a possible replacement for ocean-going ships. With a density of 2.70 g/cm3, aluminum is roughly one-third the weight of steel (r = 7.83 g/cm3). The following table gives the strength to weight ratio of different aluminum alloy and carbon steel.

ASTM material code	Material type	Typical Ultimate Tensile Strength, ksi	Density, g/cm3	Strength-to-Weight Ratio
7075-T6	Aluminum	83	2.80	822
2024-T361	Aluminum	72	2.80	713
5056-H18	Aluminum	63	2.66	656
6061-T6	Aluminum	45	2.71	459
3004-H38	Aluminum	41	2.71	418
Fiberglass	Fiber	19	1.43	367
6063-T5	Aluminum	27	2.74	273
1020 Carbon Steel	Steel	60	7.86	211

Corrosion:

Aluminum, as indicated by its position in the electromotive force series, is a thermodynamically reactive metal. Among structural metals, only beryllium and magnesium are more reactive. However, aluminum has excellent corrosion resistance due to an extremely adherent oxide film that forms on the surface whenever it is exposed to air or water. This oxide film is highly protective and because it is more thermodynamically inactive, prevents aluminum from corroding further. When exposed to extremely corrosive materials, such as salt water, the oxide film may break down and further corrosion or pitting may occur but at a much lower rate than carbon steel (please see table given below). In contrast, steel's oxide layer, rust, does not provide a highly protective layer, and as a result, steel continues to corrode. Corrosion behavior of various aluminum and steel alloys in seawater is shown in the table below.

Aluminum Alloy	Corrosion Rate, µm/yr	% Change in Tensile Strength	Steel Alloy	Corrosion Rate, µm/yr
5083-O	0.9	0.0%	Structural Carbon Steel (depending on chemistry & temperature)	120
5086-O	0.9	-2.7%		105
5454-H34	1.0	-0.7%		85
5456-H321	1.6	-1.1		70
5456-O	0.4	-0.4%		

Aluminum can be formed through either casting or wrought processes. The designation "wrought" indicates that the alloys are available primarily in the form of worked products, such as sheet, foil, plate, extrusions, tube, forgings, rod, bar, and wire. The working operations and thermal treatments transform the cast ingot structure into a wrought structure. The structure influences the strength, corrosion resistance, and other properties of an aluminum alloy. This study deals only with wrought aluminum alloys because they possess superior strength and corrosion resistance properties to cast aluminum alloys.

Disadvantages:

Two disadvantages of Aluminum are,

1. The Aluminum alloys cannot meet the maximum yield strengths required in certain Ship building applications—only high-strength, low-alloy steels meet these strength requirements.
2. Aluminum, at about Rs 102.37 per Kg, costs roughly five times more than steel, at about Rs 22.9 per Kg.

Developments in High-Strength Aluminum Alloys for Marine Applications

In recent years, progress has been achieved by aluminum producers in the development of improved aluminum alloys specifically targeted at the shipbuilding industry. In 1995 the aluminum manufacturer Pechiney of France registered the **aluminum Alloy 5383** and promoted this material to the shipbuilding industry as having improvements over **5083 alloy**. These improvements provided potential for significant weight savings in the design of aluminum vessels and included a minimum of 15% increase in the postweld yield strength, improvements in corrosion properties, and a 10% increase in fatigue strength. These developments, coupled with formability, bending, cutting, and weldability characteristics at least equal to that of 5083, made the 5383 alloy very attractive to designers and manufacturers who were pushing the limits to produce bigger and faster aluminum ships. In 1999, the aluminum manufacturer Corus Aluminum, Germany, came out with the aluminum base Alloy 5059 (Alustar). This alloy was also developed as an advanced material for the shipbuilding industry, providing significant improvements in strength over the traditional 5083 alloy. The 5059 alloy is promoted by Corus as providing improvements in minimum mechanical properties over Alloy 5083. These improvements are referenced as being a 26% increase in yield strength before welding and a 28% increase in yield strength (with respect to Alloy 5083) after welding.

Early testing on the 5059 (Alustar) base alloy indicated that problems could be encountered relating to the weld metal not being capable of obtaining the minimum tensile strength of the base material in the heat-affected zone. One method used to improve the weld tensile strength was to increase the amount of alloying elements drawn from the plate material into the weld. This was assisted by the use of helium additions to the shielding gas during TIG welding, which produces a broader penetration profile that incorporates more of the base material. The use of 5556 filler metal rather than the 5183 filler metal can also help increase the strength of the deposited weld material.

Obviously these high-performance vessels require high-quality welding. The training of welders, development of appropriate welding procedures, and implementation of suitable testing techniques are essential in producing such a high- performance product.

The Future

With the increasing demand to create larger and faster ships, particularly for military service and the development of new, improved, high-performance aluminum base materials, it is apparent that aluminum welding has acquired an interesting and important place in ship building industry.

The most popular welding process for Aluminum is TIG. MIG process also is picking up due to increased productivity angle. But in MIG process, the wire feeding is a critical aspect. The preferred method for feeding soft aluminum wire long distances is the push-pull method. Specially designed drive rolls are needed. Drive-roll tension has to be set in such a way to deliver an even wire-feed rate. Excessive tension will

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- M/S MAURIA UDYOG BALLABGARH -FARIDABAD – DELHI AREA - 42 Nos.

Ador Welding Academy (AWA)

Certification Course for Welding Inspector (QC-1) From: 24th to 28th Sept.2012

Skill Courses

deform the wire and cause rough and erratic feeding; too-little tension results in uneven feeding. Both conditions can lead to an unstable arc and weld porosity.

AWL aluminum welding consumables:

Process	AWS classification	AWL brand	Application
GTAW	ER5183	**Tigfil 5183**	For total aluminum ships
GTAW	ER5356	**Tigfil 5356**	For total aluminum ships
GTAW	ER5556	**Tigfil 5556**	For total aluminum high speed ships

Tigfil 5356

Magnesium Aluminum Alloy filler metal that is used to weld Aluminum Alloys 5050, 5052, 5083, 5356, 5454, and 5456. The post-anodizing color tint is white making it a good choice for anodizing applications. The Salt Water corrosion resistance is very good, making it an ideal choice for many marine applications. Average tensile strength of weld is 38,000 psi.

Tigfil 5183

5183 is an aluminum filler that has improved strengths on alloys sush as 5086 compared to 5356 that may not meet the needed tensile. Commonly used for welding of marine components, drilling rigs, cryogenics, railroad cars, storage tanks - base metals of 5083, 5086, 5456, to each other or to 5052, 5652 and 5056.

Tigfil 5556

5556 is an aluminum filler that has good ductility and improved crack resistance due to the content of manganese, magnesium and zinc. Commonly used for welding of base materials 5154, 5254, 5454 and 5456.

Conclusion:

The feasibility of replacing steel with aluminum in the shipbuilding industry depends primarily on the application and cost constraints. Demands for greater ship size have forced designers to search for alternative materials to reduce ship weight while maintaining strength. Aluminum alloys meet or exceed the minimum yield strength requirements for normal strength steels and have superior corrosion resistance (steel corroded at a rate of 120 micrometer per year, while in a similar study, aluminum corroded at a rate of only 1 micrometer per year). However, because of higher costs, aluminum may not be always economical. For high-strength applications, ship builders sacrifice corrosion resistance and weight reduction in favor of the greater strength provided by HSLA steels. When normal strength materials are adequate, ship builders are going in for using aluminum alloys to reduce ship weight and improve corrosion resistance.

Please contact cmo@adorians.com or visit our website www.adorwelding.com for assistance in selection of suitable processes, consumables and training of welders for defect free welding of Aluminum alloys.