AUSTAL

ALUMINIUM
DELIVERING SPEED & STRENGTH IN NAVAL APPLICATIONS

ALUMINIUM HULL STRUCTURE

Aluminium is increasingly replacing Steel as the preferred hull material in naval applications, offering more capability and reduced operating costs.

Aluminium has a density one third that of steel. A ship designed and built with aluminium will have a lower lightship displacement when compared to the steel equivalent, requiring smaller engines, reduced fuel and maintenance cost as well as permitting additional mission capability, weapons and sensors to be accommodated.

This substantial difference in structural weight more than offsets the weight of additional structural fire protection material and active fire suppression systems that may be required to be installed on an aluminium platform.

Austal has performed a detailed analysis on two equivalent 56m patrol vessel designs in steel and aluminium to establish the difference in annual operating fuel costs. The aluminium hull offers significantly better fuel economy, with savings in the order of 21%, or around 150,000 litres of fuel per ship per year.

Aluminium is also non-magnetic reducing susceptibility to mines and eliminating the need for costly and heavy degaussing systems. Analysis and testing performed for the Littoral Combat Ship (LCS) Program has also verified that the aluminium hull structure can withstand significant underwater blast loads without losing hull watertight integrity. The ductile nature of the aluminium structure ensures that significant plastic deformation can be tolerated before structural failure.

The corrosion resistance of marine grade aluminium alloys ensures that protective coatings are not required on all hull surfaces. The protective aluminium oxide layer that forms on the material surface ensures that bilges, tanks, voids and other interior spaces do not require annual maintenance and coating. A number of naval platforms such as the LCS have been manufactured with no topside paint which further reduces the ship weight and maintenance cost.

Littoral Combat Ship "Independence" is an all aluminium combatant with no exterior hull coating above the waterline, dramatically reducing maintenance costs.

THE MYTH

Aluminium & the Falklands Task Force

Of the 100 ships in the Royal Navy Falklands Task Force, nine were sunk. Of these nine only three, the frigates HMS Antelope, HMS Ardent and the support ship Sir Galahad had aluminium superstructures. All three vessels had steel hulls and in each case the damage inflicted was significant enough to result in sinking regardless of the material used in the superstructure. HMS Ardent was hit by seven 500 and 1000 pound bombs, plus at least two more bombs which failed to detonate and sank some six hours after the attack. Any warship of this size, regardless of aluminium or steel construction, would have been sunk under these circumstances. There was no evidence that aluminium burnt.

HMS Sheffield was the first British vessel sunk during the conflict. It caught fire when an Exocet missile penetrated deep into the control room. The blaze generated poisonous smoke and most of the crew abandoned ship. Although Sheffield was widely reported to have an aluminium superstructure she was an all steel ship with both a steel hull and a steel superstructure.

▲ THE ALL STEEL HMS SHEFFIELD SANK ON 4 MAY 1982 WITH THE LOSS OF 20 MEN AFTER BEING HIT BY AN ARGENTINE EXOCET MISSILE FIRED FROM AN AIRCRAFT.

"There is no evidence that it (aluminium) has contributed to the loss of any vessel."

As quoted in the Falklands Defence White Paper 14/12/82

THE HISTORY OF ALUMINIUM

The aluminium industry is just over 100 years old and has developed to the point where many companies in some 35 countries are smelting aluminium and thousands more are manufacturing the many end products to which aluminium is so well suited.

For the first half of the 20th century the aluminium industry pursued improvements in the production processes to reduce the price of the metal. Constant research and product development throughout the 1950s, 60s and 70s led to an almost endless range of consumer goods incorporating aluminium. Its basic benefits of lightness, strength, durability, formability, conductivity and finishability made it a much sought after product.

Aluminium is relatively unique in being highly economic to recycle. Metal can be reclaimed and refined for further use at an energy cost of only five per cent of that required to produce the same quantity of aluminium from its ore. In 2003, the European Union produced 9.8 million tonnes of aluminium products of which 3.6 million tonnes of castings, wrought aluminium (rolled and extruded products) and deoxidation aluminium were produced from scrap.

Some of the important physical properties of aluminium are listed below:

	ALUMINIUM[1]	STEEL[2]
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

Notes: (1) Min. values for 5083 H116 Aluminium Alloy
(2) Min. values for Ordinary strength hull structural steel (ABS grade B)

THE ALUMINIUM DESIGN & CERTIFICATION APPROACH

There are now High Speed Craft Rules published by many Classification Societies including Det Norske Veritas, The American Bureau of Shipping, Lloyds Register, Bureau Veritas, Germanischer Lloyd and RINA.

From these Rules the vertical design acceleration can be established. It is this design acceleration that has a profound effect on both the local and global loads that are applied to a design. The use of physical model testing and seakeeping computer simulations helps provide a comprehensive set of accelerations, pressures and global loadings to be applied to a particular vessel design, which are both accurate and acceptable to the relevant Aluminium patrol boats for the Trinidad and Tobago Coast Guard and Armed Forces of Malta are in Det Norske Veritas classification.

Classification Society. As vessel designs increase in size, the effect of global hull girder loads on the local structures must be considered. In the slamming regions of a vessel, the local pressures are used to size the plate and stringers, but the longitudinal stresses as a result of the global bending must not be overlooked.

These global loads include longitudinal crest landing and hollow landing dynamic moments, hogging and sagging bending moments and for multi-hull craft transverse bending, split moment and the pitch connection moment. In addition to the global loads discussed above, the local scantlings must also be sized using the static and dynamic sea pressures defined by the Rules.

Once all aspects of the design have been assessed by the plan approval department within a Classification Society, the vessel must then be surveyed during construction. The material properties used in the design process are typically based on the welded strength of the material. Typically vessels are fabricated from 5083 and 6082 marine grade material. Each of the individual welded joints are qualified by the attending classification society, using visual inspection, non-destructive and destructive testing.

The individual welding technicians are also certified before they are able to carry out structural welds on a certified vessel.

"SACAL BORINCANO"40 YEARS IN SERVICE

Sacal Borincano" is an all aluminium Ro-Ro trailer ship designed to carry 40 highway trailers between Miami and San Juan. The vessel is 226ft (69m) in length and has a displacement of 2000 tonnes. South Atlantic and Caribbean Line operated the vessel which was constructed by American Marine in 1967, with support from Reynolds Metal Company.

The vessel was constructed in aluminium to achieve an economical operating speed of 14 knots with a total installed power of only 3000hp (2240kW). On May 29, 1967 the "Sacal Borincano" performed her acceptance trials in the Gulf of Mexico and achieved a speed of 15.7 knots.

The vessel was constructed in accordance with the American Bureau of Shipping +A-1E classification requirements. The vessel was maintained in classification for its entire operating life. In 1979 the vessel was renamed "Siboney" and commenced service with Ferry Lineas. At that time she was reflagged in Argentina. Siboney ceased operation in 2007.

The material used in the construction of the vessel was 5086 H34 plate and 5086 H111 and 6061-T6 extrusions. The MIG welding process used an argon shielding gas and 5356 welding wire. The vessel exterior remained unpainted (except below the waterline) without any corrosion issues.

This ship operated for more than 40 years, predominantly in South America. While the material and welding technology available at the time of construction was relatively immature compared with today, the vessel proved that an aluminium hull can operate successfully for as long as any steel hull.

ALUMINIUM PATROL BOATS FOR THE TRINIDAD AND TOBAGO COAST GUARD AND ARMED FORCES OF MALTA ARE IN DET NORSKE VERITAS CLASSIFICATION.

ALUMINIUM CORROSION RESISTANCE

In addition to the lightweight and high strength of aluminium, the key reason why its use has become so widespread is the excellent corrosion resistance. The corrosion resistance of aluminium results from the presence of a strong and adherent layer of aluminium oxide which forms on the surface when the bare metal is exposed to the atmosphere. This behaviour is in contrast to steel where the oxide/hydroxide corrosion products are loose and powdery, and afford no protection to the metal surface.

5000 series shows the best overall resistance to corrosion in marine conditions. Alloys in the range of 2.5% to 5% Mg show negligible thickness loss due to general corrosion, and their weight loss in sea water of about 0.2 mils per year is 1/20th that of mild steel. 6063, 6082 and 6061 also show good resistance to sea water and their weight loss is about 0.5 mils per year.

Aluminium is susceptible to galvanic corrosion as many metals are cathodic to aluminium. In order for bi-metallic (galvanic) corrosion to occur three conditions are required:

1. Presence of an electrolyte (e.g. seawater)
2. Dissimilar metals
3. Electrical continuity between these metals

Galvanic corrosion is prevented by isolation of aluminium from other metals, good design practices and the painting of submerged surfaces. Where it is impossible to achieve isolation (in areas such as the water jets) sacrificial zinc anodes are used routinely.

AUSTAL USES PASSIVE ZINC ANODES TO PROTECT THE HULL FROM GALVANIC CORROSION. THEY ARE MOUNTED IN RECESSED ANODE POCKETS (PICTURED) ALONG THE HULL TO LIMIT ANY FLOW DISCONTINUITY IN WAY OF ANODES.

FIRE SAFETY

The key difference between aluminium and steel is that aluminium alloys lose strength at a lower temperature than steel. Both materials are non-combustible and do not burn.

Aluminium conducts heat more effectively than mild steel. This thermal conductivity assists in the dissipation of heat during a fire and allows rapid boundary cooling of exposed structures.

The mechanical strength of aluminium alloys starts to degrade at temperatures between 150 and 180 degrees C. This susceptibility to fire damage, results in the need for structural fire protection in areas of fire risk. A standard fire protection system employed by Austal is a ceramic fibre wool system which has been shock and furnace tested in accordance with the requirements of MIL-S901D and IMO A.754(18).

Fire risk can be evaluated using a formal safety assessment process. This rational approach ensures that the installed passive and active fire protection systems, provide an equivalent level of safety to a conventional steel ship.

Passive and active fire protection systems include the following:

- A60, A30 and smoke boundaries
- Fire main and hydrants
- Remotely monitored addressable fire, smoke and flame alarms
- Remote actuation of mist systems
- Remote actuation of AFFF and drencher systems
- Remote monitoring and actuation of bilge systems
- Smoke control, with remote damper actuation
- Last resort damage control would still involve damage control teams

This automated approach reduces the demand for damage control teams, while achieving an effective and light weight fire safety solution.

THE AUSTAL DESIGNED AND BUILT 127M ALUMINIUM LITTORAL COMBAT SHIP, LCS 2 “INDEPENDENCE”

Aluminium conducts heat more effectively than steel. Thermal conductivity assists in the dissipation of heat during a fire and allows rapid boundary cooling of exposed structures.

WESTPAC EXPRESS

"WestPac Express" is the longest serving high speed vessel for the US Department of Defense, with fourteen years of continuous service in support of the US Marine Corps 3rd Marine Expeditionary Force in Okinawa, Japan. This all aluminium 101m catamaran has been so successful that it has led to the Joint High Speed Vessel (JHSV) program for the US Navy; comprising ten (10) vessels designed and constructed by Austal in Mobile, Alabama.

The US flagged "WestPac Express" operates for up to 3,500 hours per year and transports up to 19,000 personnel and 15,000 tonnes of cargo annually, at 35 knots. The ship is operated in accordance with the IMO High Speed Craft

(HSC) Code, USCG and the Classification society regulations. All of the officers and crew are type rated as per the HSC code.

During her fourteen years of service "WestPac Express" has demonstrated a technical reliability of 99.7% (ie: less than 10 hours per year operational delays for technical reasons). There have been no reliability issues associated with the primary aluminium hull structure. "WestPac Express" has been involved in various Theatre Support Missions during her time in Okinawa including:

- Humanitarian Assistance
- Disaster Relief
- Support of training operations
- Transport & pre-positioning of personnel & equipment
- Emergency preparedness exercises

All of the advantages of an aluminium vessel have been realised on "WestPac Express".

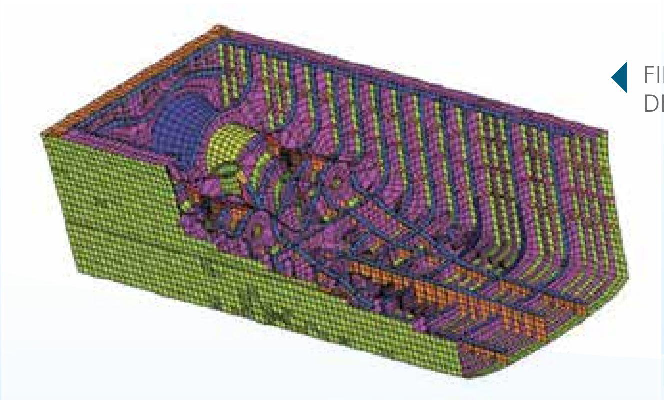
THE ALL ALUMINIUM 101M "WESTPAC EXPRESS" REMAINS IN SERVICE WITH THE US MARINE CORPS IN OKINAWA, JAPAN AFTER MORE THAN FOURTEEN YEARS.

FATIGUE PERFORMANCE

Structural fatigue is an issue which must be considered in the design of any structure. Aluminium is more sensitive to detail design and workmanship than an equivalent steel structure.

The global and local loads imposed on ships are specified with the aid of numerical analysis, tank testing and full scale measurement. A number of international design codes exist which characterise the fatigue performance of various typical joint configurations. Provided that the design process uses a rational approach for areas where cyclic loads shall be experienced, there is no reason why the fatigue life of an aluminium ship should not be in excess of 30 years.

The Littoral Combat Ship design is certified by the American Bureau of Shipping with the SFA(30) notation. This notation indicates that the ship structure has been reviewed using a Spectral Fatigue Analysis approach to verify that the primary structure is adequate for the intended 30 year service life of the vessel. In areas where high cyclic loads are experienced it may be necessary to increase local scantlings, introduce local reinforcements, modify the design arrangement or use an alternative connection method. A typical watertight bulkhead arrangement is shown below, and demonstrates the care taken to eliminate stress raisers in the structure.



FINITE ELEMENT DESIGN MODEL

The classification society Det Norske Veritas maintains statistics for high speed aluminium vessels in service, which reflect the following :

Damages per year:

- More than 70% of the HSLC have no damages
- 6% have < 1 damage
- 7% have 1.5 damage

ALL AUSTAL'S WELD PROCESSES AND WELDERS ARE CERTIFIED IN ACCORDANCE WITH CLASSIFICATION SOCIETY REQUIREMENTS TO GUARANTEE THE WELDED STRENGTH OF ALL STRUCTURAL ELEMENTS.

Certain areas of all vessels, such as those in way of the propulsion machinery, are subject to significant cyclic loads over the vessel's life. The detailed structural analysis of these areas is essential to ensure that the design stress values do not exceed an acceptable fatigue stress range. This type of analysis allows the cumulative effect of low cycle steering and reversing loads to be considered, as well as the high cycle blade pass frequencies. As a result of this type of analysis, Austal has an unparalleled track record in the design and manufacture of reliable aluminium structures.

Aluminium structures which are designed correctly will operate effectively for up to 30 years without any structural issues or the need for a single coat of paint.

Correctly designed aluminium structures will operate effectively for up to 30 years without any structural issues or the need for a single coat of paint.

COMPLETED STRUCTURE

"SOFT TOE BRACKET"

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