Running a tight ship: Stainless steel can be cost-effective for the construction of ships and boats

Because of exposure to saltwater, rust and corrosion are a constant preoccupation for both shipbuilders and sailors. Shipbuilders use several methods to reduce the risk of corrosion, including the use of corrosion-resistant metals. One of the most reliable and cost-effective of these is stainless steel, which offers strong corrosion resistance at a price that is competitive with other materials. It is ideal for ship components exposed to saltwater and moist sea air and obligatory for chemical tanker containment when hazardous chemicals are being transported. And duplex grades are increasingly being used, especially for the inner hulls of chemical tankers.

By James Chater
Rust in peace
Canada is at peace with most countries in the world, but its navy faces a formidable enemy: rust. In June 2014, one of Canada’s three destroyers succumbed. HMCS Iroquois had to be laid up indefinitely after patches of rust were found on its hull. Half a dozen rust spots were found on the exterior of the ship and inside in an area behind the solid ballast tanks. The hull plates have undergone an average thickness loss of 30%, whereas the allowable loss amounts to only 20%. Of the entire Canadian navy of 33 ships and submarines, only 17 are currently fit for service.

Corrosion
This example illustrates the running battle waged by shipbuilders and sailors against corrosion. This corrosion can take various forms. Pitting corrosion occurs when a metal is exposed to too high a concentration of chloride (salt); temperature also plays a role. Crevice corrosion can attack any ship part where crevices exist, such as propeller shaft glands and bearings, or places where barnacles grow. Stress corrosion cracking can occur in stagnant, aerated seawater, necessitating the use of grades higher than 304 and 316. Also frequent is galvanic corrosion, because most ships use a variety of metals in their construction. Fittings, deckhouses, fasteners, hull plating, propellers, shafts, valves, condensers and piping are all vulnerable. It can occur whenever two different kinds of metal are in electrical contact with seawater. The corrosion is likely to be severer if one of the metals is much “nobler” than the other, i.e. occupies a much higher position in the galvanic series than the other. For instance, if an aluminium hull comes into electrical contact with a bronze propeller, the hull will fail as the aluminium becomes an anode to the bronze. The same problem can occur with such corrosion-resistant alloys as cupronickel and Monel. Monel is used for water and fuel tanks, underwater applications, propeller shafts and keel bolts. However, not only is it expensive, but it also has to be carefully insulated from other metals such as steel, or else electrolytic action will cause the steel to disintegrate.

Swedish Steel Yacht, manufactured entirely from Sandvik’s super duplex grade SAF 2507™. Photo: Sandvik

This boat was built using Sandvik’s super duplex grade SAF 2507™. Photo: Stainless Steel Yacht

Since corrosion is such a persistent problem, why are more ships not made of highly corrosion-resistant alloys or special metals such as titanium? The answer is that some are, but it is a costly option. Occasional attempts have been made to construct boats and yachts using stainless steel structurally, especially in the hull. Recently a new prototype, the Swedish Steel Yacht, was manufactured entirely from Sandvik’s super duplex grade SAF 2507™. This grade, originally developed for the offshore oil and gas industry, was selected because it resists salt corrosion more than other duplex grades. It is lighter than an aluminium boat and consumes only half the fuel because of the thin gauge of its hull. All metal below the waterline is mirror-polished to facilitate the removal of marine organisms. The prototype is likely to interest police, navies and sea-rescue services throughout the world. For larger boats, mild steel continues to be the standard option for the welded plates that make up the hulls of most ships. Corrosion prevention can take various forms. Specialized polymer-based paints can prevent the spread of ions along the steel surface, thereby inhibiting corrosion. Cathodic protection can be obtained through hot-dipped galvanized steel, or by attaching blocks of “sacrificial” anodes – aluminium, magnesium, zinc or alloys of these – to the ship in order to protect its hull. In short, the usual form of corrosion protection is some combination of coating and cathodic protection.
Stainless is cost-effective
Yet the use of stainless steel and CRAs in ships is growing. Apart from corrosion resistance, some forms of stainless steel, especially duplex grades, offer favourable strength-to-weight ratios, allowing thinner gauges which translate into greater fuel efficiency. Yachts, marine structures and on-board fittings mostly use aluminium alloys or stainless steel. Aluminium, though light, has limited corrosion resistance in seawater, so requires a lot of maintenance. Stainless, on the other hand, offers superior corrosion resistance and strength.

For onboard fixtures above the water line, grades 304 and 316 are usually sufficient. These grades are commonly applied to fasteners, rigging, fittings such as pulley blocks, rails, ladders, hatches, window frames and fittings. Type 304 can be applied to fully exposed components as long as they are frequently washed with fresh water. In all other cases, 316 is to be preferred. For permanent contact with seawater (permanent immersion), superaustenitics (6%Mo), duplex and superduplex grades are recommended. These grades can be found in engine parts, grills, pumps, propeller shafts, exhaust piping, winches and heat exchangers. Standard duplex grade 2205 can also serve as an alternative to mild austenitics in rigging and certain fittings.

Duplex
A special use for duplex has been found in the construction of the cargo tanks – effectively the inner lining of the hulls – of chemical tankers. Chemical tanker construction is mainly concentrated in China, Japan and South Korea. Chemical tankers can carry up to 50 tanks, each with its own pump and piping system to avoid cross-contamination. Whenever hazardous chemicals are involved, the tanks are made of stainless steel. In the past, austenitics such as 316LN and 317L were used, but gradually duplex (mainly type 2205) was introduced and is now the clear favourite because the thinner gauges reduce weight and therefore save fuel. Outokumpu has been supplying duplex plates for use in chemical tankers for several years. In the mid-1980s the Italian naval architect Leonardo Acciarri was the first designer to recognize the potential of duplex 2205 for the tanks of chemical tankers. Outokumpu supplied the duplex for several of the ships he designed. Recently, when Acciarri was designing chemical tankers constructed in the Far East, he turned to another Outokumpu product, LDX 2101®. In 2013 Outokumpu received a large order for duplex 2205: 12,250 tonnes for five tankers that Stolt is building in China. Meanwhile, NSSC has developed NSSC®2120, another lean...
Special uses

Various types of stainless steels and special alloys find specific uses in various types of ships:
- Some icebreakers are equipped with an explosion-welded abrasion-resistant stainless-steel ice belt that reduces friction and protects the ship’s hull from corrosion.
- Ships that transport gases such as ethylene feature cylindrical, insulated, stainless-steel cargo tanks.
- A special type of gas transporter is the LNG carrier. These transport methane in liquid form at a temperature of -163°C. This requires cryogenic-standard grades that are ductile and resistant to embrittlement and cracks. Therefore nickel steel, high-nickel alloys or aluminium is used. The two main families of LNG carriers are those of the Moss design, with storage tanks made of aluminium, and those of the membrane design, which use stainless steel or nickel alloy. Storage tanks of the membrane type are made either of 1.2 mm thick walls made of 304L corrugated stainless steel or Invar nickel alloy (36%Ni), which is only 0.7mm thick, allowing considerable weight saving. Cryogenic valves are often made of 304LN and 316LN. The welding consumables for stainless steels in cryogenic service are invariably nickel alloys.

The Estonian multipurpose icebreaker Botnica has an explosion-welded stainless steel ice belt and “reamers”.

Conclusion

The use of stainless steels, especially duplex, is likely to increase in ships and boats because of the favourable strength-to-weight ratio, corrosion resistance and ease of maintenance. The extent of its use may depend on fuel costs. The more they increase, the more shipbuilders will be attracted to duplex grades as a way to reduce weight and save fuel.

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