Stainless Steel

More than a hundred different versions of stainless steel are available. But some are more suitable than others for marine applications.

Text & Photos By
Jonathan Klopman

It's no surprise to almost anyone in the boat business that stainless steel, at times, ain't so stainless. Rigger Frank Culanari of Bay Sailing (Fall River, Massachusetts) put it best: "Remember, they call it stain*less*, not stain*proof*."

Stainless steel is often employed in structural applications, where unexpected corrosion or cracking can result in dismasting, sinking, and perhaps personal injury. Avoiding such catastrophes demands an understanding of the properties, limitations, and failure mechanisms of stainless alloys.

Background

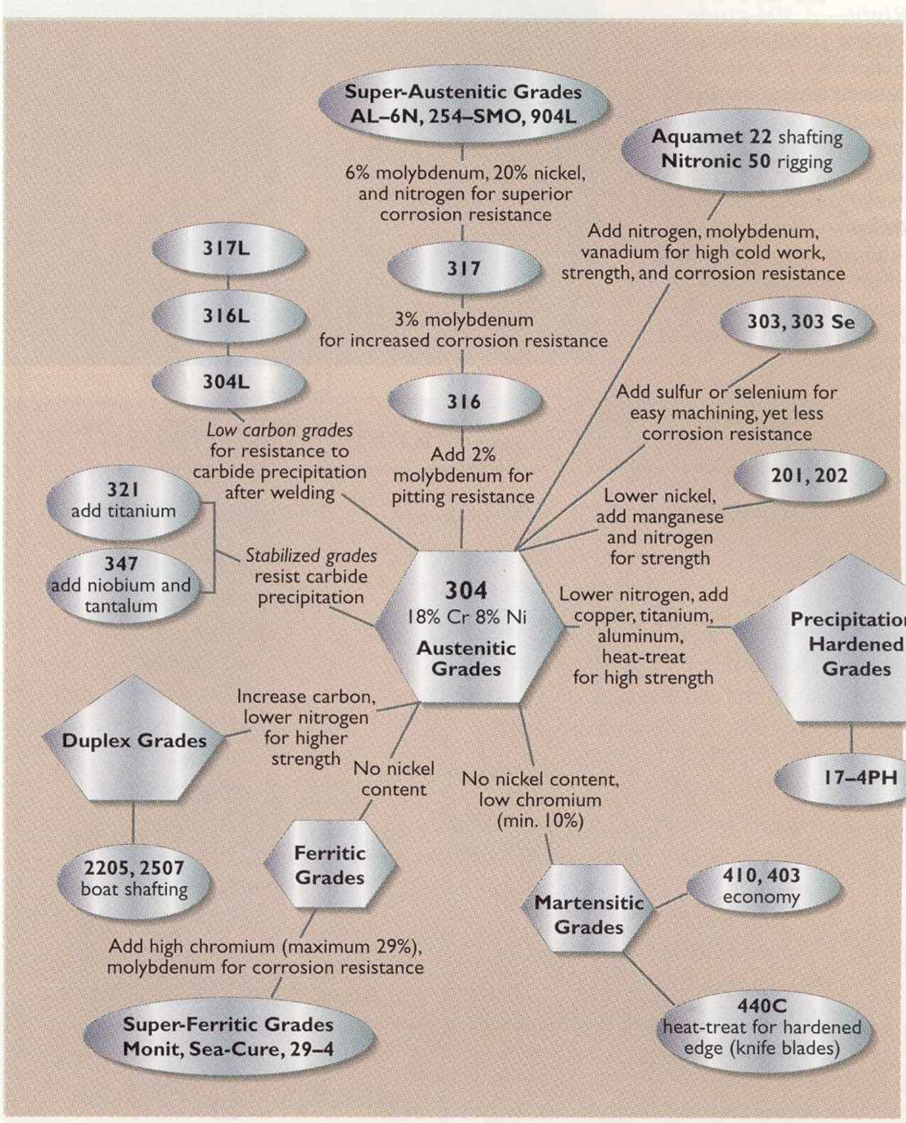
Stainless steel is a relatively new alloy, having been around for only 80 years. The impetus for inventing the alloy, predictably, was to develop a maintenance-free material that would resist rusting. Whereas iron oxide on steel is a permeable membrane (air and water can penetrate the surface and attack the underlying steel), stainless steel is protected by a microscopic self-healing layer of chromium oxide.

By definition, stainless steel is a ferrous alloy that is at least 50% iron. A steel alloy can be termed "stainless" after the addition of a minimum of 10% chromium. In fact, with 11% chromium and few additional elements, 410-grade stainless can be considered the most basic stainless, and has the lowest corrosion resistance of all grades. Corrosion resistance increases with chromium content, but is limited practically to a maximum of 30% chromium.

Although chromium is considered the alloying element that defines stainless steel, it is by no means the only one that affects corrosion resistance. Myriad other elements are added to enhance the working or fabricating properties of a specific alloy.

The best way to gain an understanding of stainless steel is to look at it as an

Facing page*—An overall view and detail of stress-corrosion cracking in a stainless steel swage fitting, taken from the tuned rig of a sailboat. This type of failure is initiated by parts being under a tensile load in the presence of chlorides. The chloride element here is visible as salt crystals inside the crack. Note how the scratches and pits on the surface of the stainless become apparent at 100x magnification.* ***Right****— The 300-series austenitic grades of stainless are typically found in marine applications. For general service, the most common grades are 304 and 316.*



engineered material. Composite laminates are designed, optimized, and employed for different applications; the same is true of the more than 100 stainless alloys currently in production. Understanding the properties and limitations of a specific grade is really a matter of knowing how the alloying elements will react within the operating environment. (For more on corrosion, see PBB No. 32, page 36 and PBB No. 33, page 28.)

GRADES AND GRAIN STRUCTURE

The families of stainless steel alloys are grouped according to grain structure. The consitituent elements in a particular alloy will determine how the grain structure forms as the molten metal cools. These structures are *martensite, ferrite, austenite*, and *duplex*—a combination of austenite and ferrite. (See the illustration of basic alloying elements and properties on this page.) The principal alloying element in martensitic and ferritic alloys is chromium. With the possible exception of some high-chromium "super ferritics" such as Sea-Cure and Monit, neither martensitic nor ferritic grades are considered suitable for marine service. As you might guess, the ferritic grades have a high iron content; they can be identified in the field with a magnet. (Some austenitic alloys can develop a weak magnetic attraction after they have been drawn or work-hardened.)

The introduction of nickel defines austenitic-grade stainless. According to the International Nickel Company (Suffern, New York), two-thirds of all the nickel refined goes into the production of stainless steel, and 75% of all stainless production today is in manufacturing austenitic grades. The 300-series austenitic grades are those most commonly employed in the marine industry.

Before we continue, a brief note on the three-digit grading system is in order: It is not arranged according to nobility or alloy content. The 400 series spans both martensitic and ferritic grades. Although 316 and 317 are more noble than 304, they are not superseded by 321 and 347. Some proprietary alloys bear trade names and not a number grade, such as Nitronic 50 and AL-6N.

Most of the stainless produced today is grade 304. Also termed "18–8" for its nominal content of chromium and nickel, 304 is available in a wide variety of suballoys, so it can be adapted for different applications. For example, one mill offers more than 30 types of 304-based products. Type 304 strikes a good balance between performance and price. But, there are a number of situations in the marine environment where this base metal will prove inadequate.

The general approach of producers has been to analyze failures and tailor new alloys to meet specific conditions. An interesting—if not confounding—factor to keep in mind is that alloying elements in even minute quantities can affect each other. An additive that improves strength, for instance, could adversely affect corrosion resistance.

The following sections outline the major corrosion and failure mechanisms of stainless steel in the marine industry, and products that have been developed in response.

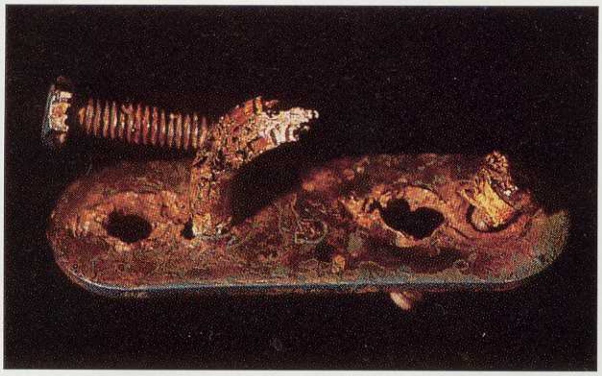
GALVANIC CORROSION

Stainless steel depends on oxygen to maintain its protective layer of chromium oxide. A clean, uninterrupted stainless surface in an aerobic environment, where the metal is able to maintain a uniform biofilm, is extremely noble. Under these favorable conditions, the alloy is termed "passive."

But, if stainless steel is subjected to an *an*aerobic environment, it will not be able to generate chromium oxide, and thus turns "active." This passive-to-active shift is illustrated in the accompanying list of the Galvanic Series of metals in seawater (see page 64).

Although most marine professionals

Right—*A 304-grade padeye used below the waterline. Extensive pitting over its entire surface indicates that a more noble form of stainless, such as type 316, would be better for this application.* ***Below***—*Note how the nobility of stainless steel shifts from passive to active when immersed in the anaerobic environment of salt water.*



Galvanic Series in Flowing Seawater*

CATHODIC (MOST NOBLE)	Potential in Millivolts
Graphite	+200 > +300
Platinum	+190 > +250
Hastelloy C (Nickel based, 16% Mo)	–30 > +80
Titanium	–50 > +60
Aquamet 22/Nitronic 50 S.S. shafting	– 250 > +60
316 S.S. (2% Mo) passive	–100 > 0.0
Monel (70% Ni, 30% Cu)	–140 > –40
304 (18–8) passive	–100 > –50
Inconel (78% Ni, 13.5% Cr, 6% Fe)	–170 > –140
Copper Nickel (70% Cu, 30% Ni)	–230 > –180
Lead	–250 > –190
Silicon Bronze	–290 > –260
Bronze (through-hull 85% Cu)	–310 > –240
Manganese Bronze	–340 > –270
410 S.S. (11% Cr) passive	–350 > –260
Admiralty Brass	–360 > –280
Red Brass	–400 > –300
Nibral (Nickel/Aluminum/Copper prop)	–420 > –310
Inconel *active in still water*	–460 > –350
316 S.S. *active in still water*	–540 > –430
304 S.S. *active in still water*	–580 > –460
410 S.S. *active in still water*	–580 > –460
Iron/Steel	–710 > –600
Aluminum	–1000 > –760
Zinc	–1030 > –980
Magnesium	–1630 > –1600
ANODIC (LEAST NOBLE)	

* Abbreviated list from the American Boat and Yacht Council's *Standards and Recommended Practices for Small Craft*, standard E–2, *Cathodic Protection.*

are aware of this phenomenon, it's worth taking a closer look at the chart to see precisely how stainless steel shifts in its relative nobility to other metals. The numbers can be judged in roughly 200 millivolt chunks to determine a significant difference between two metals.

In their active states, there is barely any differentiation between alloys 316, 304, and 410. They all become anodic to the copper alloys as well as to lead. In fact, they are barely more noble than iron and mild steel.

The severity of the corrosion depends on the masses of coupled metals involved. The fastener must always be more noble than the "fastenee." A bronze (more noble) screw attaching a stainless steel trim tab will not cause significant problems. But, a lower-grade stainless bolt connecting a large bronze casting could ultimately lead to failure.

At the top of the Galvanic Series, graphite/carbon forms a very efficient cathode that will cause virtually any other metal to corrode preferentially. Early failures of aluminum hardware on carbon spars are fairly well known. While not as dramatic, stainless in combination with graphite seals, packing, gaskets, and lubricant will pit. In these cases, a relatively small amount of deterioration could cause an expensive leak.

Experience tells us that the stainless steel bolt won't simply fizz away like zinc. Nevertheless, the electromotive force of current going from the stainless to a cathode can trigger other problems. For example, the galvanic couple would prevent the stainless from forming a protective biofilm, which in turn could accelerate pitting or crevice corrosion.

PITTING

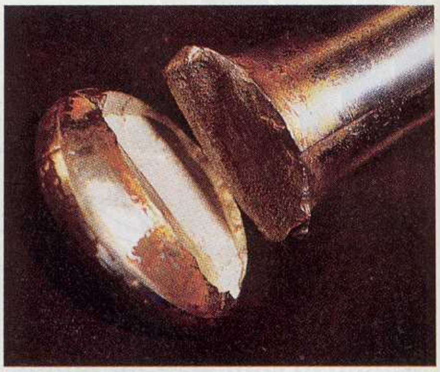
Pitting is caused by a local break in the protective chromium-oxide coating. On a molecular scale, the coating film is made up of a lattice of oxygen and hydrogen sheathing the part. As metal ions leave the surface of the part, they bond with the hydroxide to form chromium oxide. If there is a slight gap in the hydroxide layer, a metal ion will release from the metal and "heal" the discontinuity in the surface film.

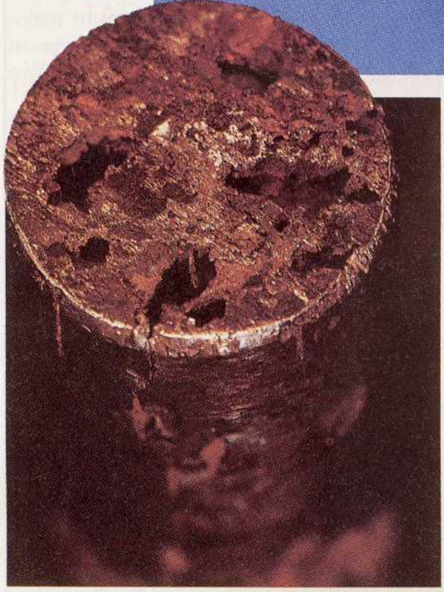
A problem arises in a chloride-rich, oxygen-starved environment. If there is a break in the hydroxide film, chloride ions will bond with the free oxygen sites and will not close the gap. Metal ions are then free to release from the surface and into solution. The reaction continues until what was once a break in the film turns into a pit on the surface of the metal.

The pH level in these charged concentration cells is extremely low, sometimes dropping down to pH 1. One of the byproducts of the free hydrogen and chloride ions is actually concentrated hydrochloric acid! This reaction explains why some corroded stainless steel parts appear to have been eaten away: they have been.

The oxygen-starved microenvironment within the concentration cell causes the pit to grow deeper into the body of metal, rather than to spread out along the surface. So, the process is inherently different from the gradual and predictable nature of simple scaling on mild steel. Once it has begun, pitting in stainless steel has a tendency to penetrate deep into the part and eventually cause structural failure.

Molybdenum has been found to be





Crevice corrosion in stainless is often found in areas hidden from view. Some examples: a rudder pin that looks as if it was attacked by teredo worms ***(below, left)****, a keelbolt from a wooden boat* ***(above, left)****, and a rod-rigging cold head from a large yacht* ***(right)****. In all cases, the corrosion could only be observed by disassembly.*

the most beneficial alloy for preventing pitting. Grade 316 stainless is essentially the same as 304, but with the addition of 2%–3% molybdenum. Grade 317 was developed as an alloy even more resistant to pitting, with the addition of only 1% more molybdenum than 316. It's notable that the performance difference between these alloys and common 410 or 304 is logarithmic—a little bit of moly goes a long way.

Sulfur is extremely detrimental to pitting resistance. Modern production techniques are able to refine virtually all sulfur out of new stock. Still, sulfur is added to some grades (such as 303) to improve free-machining properties of the material.

One example is domestically produced swage fittings. The military specification for such fittings calls for 303. Unfortunately, the military spec was written in the 1940s, and was geared toward aircraft. It's ironic that, instead of being a rigid standard of compliance, the stamp "mil spec" is a guarantee that the part is not well suited for a marine application. Manufacturers in England and Australia do offer swage fittings in 316 grade.

CREVICE CORROSION

While the term "pitting" usually describes corrosion on the exposed, or "bold," surface of a part, *crevice* corrosion refers to damage at the back, or faying, surface. Especially in the case of fittings below the waterline, the installation of the part itself creates oxygen-starved nooks and crannies that can initiate pits.

Crevice corrosion is common under the heads of fasteners, on chainplates where they pass through the deck, and on sailboat rudder stocks inside a fiberglass shell. The probability of corrosion depends on the gap and depth of the crevice (narrow, deep cracks are a bad thing), as well as on the grade of alloy.

One way to prevent crevice corrosion is to engineer the part to avoid crevices. Yeah, right. In boatbuilding, just as in life, many crevices are unavoidable.

Nevertheless, this remedy does point out an important general fact about corrosion: it needs water to grow. Getting rid of the crevice could be as simple as rebedding a fitting. For example, most rotted-out chainplates are the result of long-term deck leaks; corrosion-inhibiting compounds and pastes, as well as bedding, can prevent many of these kinds of problems. Some sailboat manufacturers will protect keelbolts by sealing the nut in a glob of gelcoat.

Crevice corrosion of the stock and web frame inside sailboat rudders is very common. Due to the mechanics of the joint where the stock passes into the blade, most rudders are bound to collect water. It's hardly worth tearing into a rudder to dry it out if this entry point can't be sealed off. One approach would be to feather the joint and lay in a bead of methacrylate adhesive; some formulations are designed specifically for bonding metal to plastic.

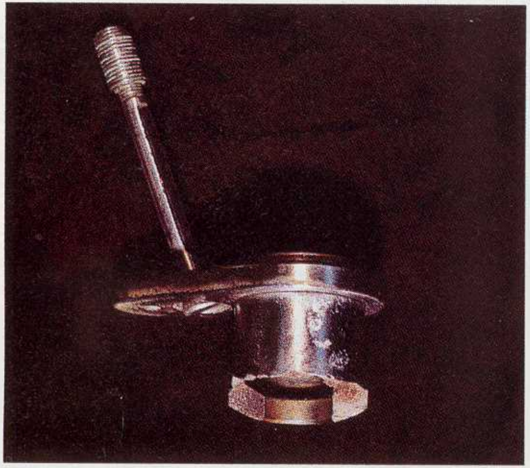
Keelbolts can present one of the most challenging crevice-corrosion problems. In production fiberglass boats, the only saving grace has been that the keel-to-sump joint is usually well bedded in resin or goop. Yet typical hairline-cracking at the sump joint could allow water to get at the bolts. In this event, that huge mass of lead would be more noble than the active stainless keelbolts (assuming they are 304), which in turn would accelerate crevice corrosion. The situation with wooden boats is much worse, as the plank keel is invariably saturated with saltwater electrolyte.

Cathodic protection definitely aids in preventing crevice corrosion. Once again, if a galvanic current is impressed in the right direction, then there will be less impetus for the pits to form in the first place. It's interesting to note that stainless propeller shafts rarely show signs of damage, in part because they are routinely protected with zincs. For this reason, it would be worthwhile to bond a stainless steel rudder stock to the zinc anode with a shaft brush. (Another equally—if not more—important factor in this lack of crevice corrosion on shafts is that most shafting for pleasure boats seems to be specified for superior alloys such as Crucible's nitrogen/manganese-enriched Aquamet 22.)

Immersion service in salt water is one of the most demanding environments for stainless steel, and calls for a superior alloy. Several manufacturers have developed a new class of stainless, called "super austenitics," specifically for the offshore oil-drilling industry. Two such examples would be Allegheny-Ludlum's AL-6N and Avesta Sheffield's 254-SMO. Both alloys have high chromium content (20%), high nickel content (~20%), and very high molybdenum content (6%). The corrosion resistance of the "6 mollies" has proven to be superb, and well worth the added material cost. One interesting note is that the German navy is reported to have commissioned a patrol-boat hull to be plated with super-austenitic stainless.

CORROSION FATIGUE

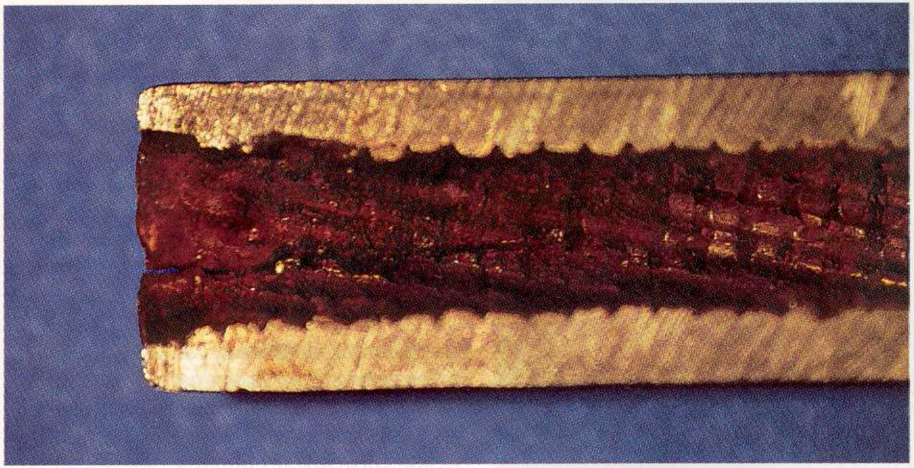
Surface irregularity in a stainless part



can promote corrosion, which will dramatically lower its fatigue resistance. Normal fatigue studies plot stress levels against a given number of cycles to failure. The same method is employed in testing for corrosion fatigue, but the part is tested in a caustic atmosphere.

The difficulty with such tests comes in interpreting the data. How can lab studies be extrapolated to predict actual service life? This is a difficult question that even metallurgists will shy away from. The responsible answer probably is that, in a corrosive atmosphere, the part cannot be expected to hold up to optimum life-cycle expectations.

Rod-rigging failures are one case study of stainless steel fatigue. The Nitronic 50 stainless in rod rigging is chosen principally for its ability to be cold-drawn to extremely high strength: 190,000 psi ultimate tensile, vs. 84,000 psi for 304. (Nitronic 50 is actually a trade name for Crucible Service Center's identical alloy, Aquamet 22. Its content is 22% chromium, 12% nickel, 4% manganese, 2% molybdenum, and nitrogen.) Although the longevity of rod rigging on the whole is excellent, experience is beginning to show that it might have a more finite life span than was originally thought. Stress will naturally concentrate at a discontinuity in the part—in this case, at the rod head. Fatigue cracks will initiate halfway up the rod head and run around the circumference of the rod.



Facing page—*A spreader-tip cup, manufactured from 17–4PH (precipitation hardened) stainless steel. The material is highly susceptible to chloride-induced stress-corrosion cracking. When it failed, the lower portion of the tip cup tore off perpendicular to the tension load on the part. In the closeup, salt deposits are visible along the lip of the fitting.* ***Left***—*Old-style swage fittings were threaded to give them a better grip on the wire. In practice, though, this allowed water to run down the inside of the fitting, leading to corrosion that would expand to eventually crack it.*

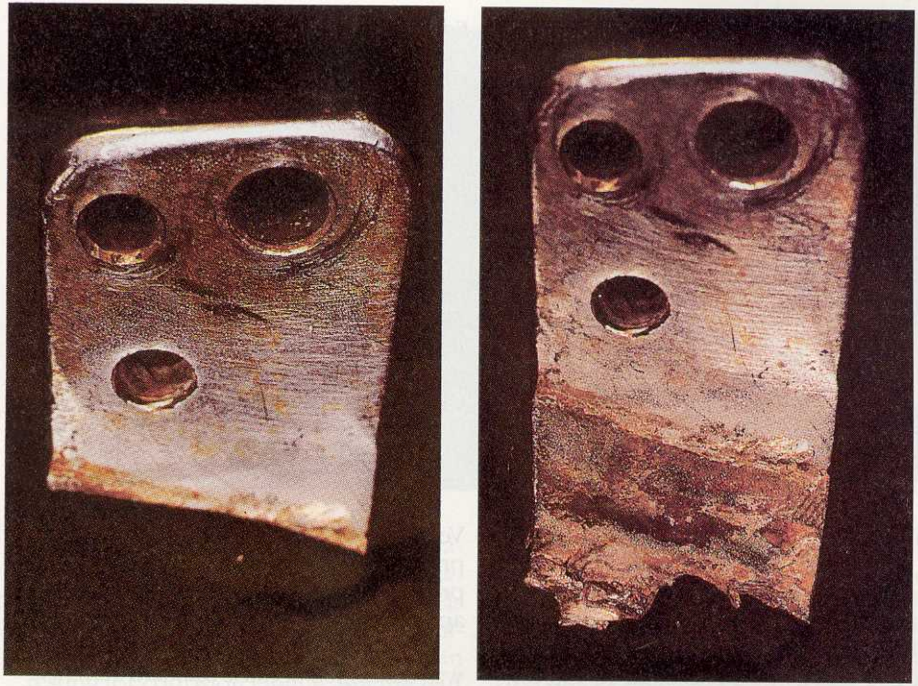
The problem, once again, is in predicting such fatigue. Will a C&C 35 sailed five months a year require the same attention as a maxi bluewater cruiser? What if the rod was originally spec'd oversize? When do you tell the owner of a 130′ sloop that the rig has to be pulled and the standing rigging stripped so the rod heads can be inspected? These and other questions are at the center of a continuing controversy that has yet to yield firm answers.

STRESS-CORROSION CRACKING

Stress-corrosion cracking is the premature failure of a part, initiated by tensile stress in a chloride-rich environment. The failures are typically fine, jagged-edged cracks perpendicular to the tensile load. Elevated temperatures (generally over 2,500°F) as well as low pH are known to exacerbate the problem.

Alloying elements that help prevent this phenomenon are nitrogen, titanium, vanadium, tungsten, and phosphorus. Very high-strength alloys tend to be more prone to stress-corrosion cracking, and precipitation-hardened stainless steels appear to be particularly susceptible.

Precipitation-hardened stainless steel was developed because standard austenitic grades cannot be hardened by heat treatment. Manufacturers dropped the nickel content and perfected a special hardening process to create this new family of alloys. Precipitation-hardened stainless steels can have tensile strengths of as



A broken stemhead fitting from a sailboat. ***Left***—*The fitting looks as it did on deck, with no discernible corrosion. But once torn out, evidence of heavy corrosion and stress cracking becomes visible. The cause of failure is a combination of poor bedding at the deck and a bad weld. Improper welding technique leads to carbide precipitation, where the heat from welding leaves the alloy chromium-poor and susceptible to intergranular corrosion.*

high as 200,000 psi without being cold-worked. Although it appeared that this new material would be ideal for high-strength applications (such as standing rigging), it since has proven to be somewhat unpredictable in the marine atmosphere. Since a sailboat rig operates under constant tensile force and salt-spray exposure, these are ideal conditions to initiate stress-corrosion cracking.

Although no studies have replicated stress-corrosion cracking in austenitic grades of stainless steel, I still suspect that it does occur. Any rigger can confirm that swage fittings at deck level tend to crack, and that the problem seems to be far worse in tropical climates. The greatest worry, though, is not the crack in the fitting but the condition of the wire in the swage. (See my article "Analyzing Failed Metal Parts," PBB No. 51, page 56.)

Wire failure in standing rigging is typically attributed to crevice corrosion. Broken strands, however, do not show signs of pitting. Close inspection will reveal that the strands actually crack clean across. The damage is concentrated in the core of the wire, where salt water can dry and build up a concentration of chlorides.

Some early swage fittings, notably those marked "Acco," were manufactured by drilling and actually tapping the hole for the wire. It was thought that the threaded hole would provide better mechanical "grip" to the wire. In fact, the tapped threads seem to act as a conduit to funnel salt water down into the fitting. For this reason, *any* old rigging fittings should be considered suspect.

CARBIDE PRECIPITATION

Carbide precipitation, also termed "sensitization," is a condition resulting from poor welding practice—specifically, when excess carbon remains in the alloy.

Austenite grain structure will only retain a maximum of .03% carbon at room temperature. Therefore, when a piece of higher-carbon stainless is superheated during welding and then cooled slowly, the excess carbon will precipitate out of the heat-affected zone next to the weld bead. The free carbon will take chromium with it to form chromium carbide. This leaves the area adjacent to the weld bead depleted of chromium. The vulnerable area then can be attacked by intergranular corrosion, which can lead to a fine series of cracks in the heat-affected zone, and eventual failure of the weldment. (For more on this type of corrosion, see PBB No. 52, page 18, "Tank Choices.")

Carbide precipitation can also compound other problems: it drastically lowers the metal's resistance to stress-corrosion cracking. This is yet another reason to be wary of poorly welded chainplates and rigging fittings.

Since carbon is the source of the difficulty, the following are ways to assure trouble-free weldments:

- The precipitated carbides can be brought back into solution by reheating the part to 20,000°F, and then quenching it. Rapid cooling will lock the carbon in the grain structure before it has a chance to re-precipitate. Of course, this approach may not be practical, depending on the size of the part and the availability of an appropriate furnace.
- Make sure that the plate and welding rod are low-carbon grades. An "L" grading indicates low-carbon alloys.

Quality Control vs. Quality Assurance

One often hears the lament that the boat business is being driven by lawyers, rather than by engineers. In the unfortunate case of personal injury due to gear failure, the plaintiff will attempt to prove defective/improper materials, design, or advice. A boatbuilder conceivably could be held liable for choosing poor-quality or inappropriate hardware. For the equipment manufacturer, the standard of proof may hinge on which measures the company took to assure the quality of the product, or to select the proper grade of alloy.

Some critical pieces of hardware may have zero tolerance for defects. That's why Schaefer Marine (New Bedford, Massachusetts), for instance, chooses to X-ray every padeye and snap shackle as it comes off the line. If you subcontract out parts, or order raw material, you might want to ask for the materials to be certified. —*Jonathan Klopman*

Always use 316L stick—even with 304—to assure that the weld bead itself is noble.

Actually, modern stainless production uses a refining process called Argon Oxygen Decarburization. AOD percolates oxygen and an inert gas through the molten charge of steel to draw out excess carbon. Most stainless produced today begins as low-carbon grade. Since carbon is an inexpensive way to increase strength and act as an austenite former, it may be added back into certain grades.

- Special welding grades of stainless, the "stablized" grades, can be used for fabrication. Type 321 contains titanium, while 347 uses niobium and tantalum. The trace elements in these grades will bond with carbides to prevent the weld area from becoming sensitized.

HYDROGEN EMBRITTLEMENT

Hydrogen embrittlement is a form of intergranular cracking. In the marine environment, the condition requires an oxygen-rich atmosphere, which can be generated by cathodic overprotection. A byproduct of "overzincing" is the breakdown of water molecules into hydrogen and hydroxyl ions. The low molecular weight of the hydrogen ion can allow it to pass between the grains of more complex metal grains to initiate cracking.

Ferritic grades of stainless—including the high-chromium super ferritics—are generally susceptible to hydrogen embrittlement. The grain structure of the austenitic grades makes them, for the most part, immune.

One interesting new family of stainless steel is duplex—a combination of austenite and ferrite grain structure. The advantage of duplex is that the alloys combine the high strength of the ferritics with the corrosion resistance of the austenitics. Duplex has been used in large-boat shafting. Regarding hydrogen embrittlement from overzincing, the unique grain structure of duplex means that while the trace ferrite grain may succumb, the layers of austenite act as barriers to halt crack growth.

VELOCITY EFFECTS

Most grades of stainless steel are resistant to erosion from water velocities of up to 50 m/sec—higher than can reasonably be expected in the marine environment. The following velocities form a basis of comparison:

- hydrofoil, 40 m/sec
- pump impeller, 25 m/sec
- piping system, 5 m/sec.

Similarly, stainless is resistant to cavitation erosion. Martensitic stainless is most resistant, followed by the austenitics, with the ferritics least resistant. This performance explains the choice of stainless for high-speed propellers and jet-pump impellers. It's interesting to note that 304 is almost twice as resistant to cavitation erosion as 316.

But, if a propeller material were chosen for ultimate resistance to cavitation erosion, its *corrosion* resistance could be compromised. One manufacturer in particular has had a problem with pitting on the blades of its stainless steel propellers. While this manufacturer would not release the information regarding materials selection, I suspect the company made a choice without considering that a propeller might sit for extended periods in stagnant, polluted water.

MAINTENANCE AND CORROSION PREVENTION

Maintaining a clean surface finish on stainless steel is crucial to good cosmetics and long-term performance. Take a 50x pocket microscope and look closely at an older piece of stainless. It's shocking how scratched and fouled the surface appears.

Surface imperfections, biofouling (barnacles), and trace iron oxide on the surface of the part can create localized galvanic cells that in turn are subject to pitting attack. In particular, stainless parts that are fabricated in a shop that welds both mild steel as well as stainless can become contaminated with weld spatter and bits of steel filings from grinders.

The proper post-fabrication cleanup of stainless surfaces is termed "passivating," in which the surface of the stainless is etched with a nitric acid solution. The acid dissolves any ferrous oxide impurities and cleans the surface on a micro level. In some cases, the parts are immersed in an acid solution, or "pickled." (For more on passivating, see the Nickel Development Institute publication 10004, *Fabrication and Post Fabrication Cleanup of Stainless Steel.*)

The benefits of proper cleaning can be dramatic. For example, Wichard Inc. (Simsbury, Connecticut) is well known for the superior luster and finish of its marine hardware. Although the company uses a good alloy (305Cu), it is not an extraordinarily noble metal. Wichard's Jack Dunn proudly states the company's secret: "We take the time to tumble-polish our parts twice as long as anyone in the industry."

Wichard also markets a nitric-acid-based paste, "Wichinox," that can be used to clean the rust stains from older hardware. This process of "repassivating" can clean the surface of a troublesome part that might have been considered a poor grade. Neutralizing the surface with the acid paste and then cleaning off with a 3M scrub pad and water can dramatically lengthen finish life.

Some studies have shown that the best finish process is electropolishing, a procedure that adds an electrical charge to the part as it is being etched. On a micro level, the charge will tend to knock off the rough tips ("asperities") of scratches on the surface. So, the method smooths as well as cleans the surface.

By contrast, aggressive buffing of a rough casting or fabrication alone can tend to roll the asperities over, trapping contaminants below the surface. This in turn can lead to long-term leaching of rust stains—a common complaint about hardware on a lot of older production boats from the Far East.

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Jim Jenkins of the Nickel Development Institute has said, "There are no bad grades of stainless steel, only poor selection of material." This seems to me a very important point. The discussion about different grades is invariably one of balancing corrosion resistance against physical properties—all within a budget.

Because stainless is still 50% steel, the per-pound cost of even the exotic alloys is relatively reasonable. In specifying a stainless rudder tube for a 50′ custom sailboat, designer Jay Paris found that outfitting the boat with a super-austenitic 254 SMO would be $170, vs. $80 for 316. Not a difficult decision, considering that the super-austenitic might keep the rudder from falling off in the Azores.

Although there are some impossibly demanding situations (hot, wet, caustic diesel exhaust, for one), many operating environments have already been studied and mated with an optimized alloy. With the increasing availability of superior stainless alloys for marine applications, the responsibility will fall on us to seek out the best shiny stuff for the job. PBB

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