Rusting of Stainless Steel Castings

Identifying and eliminating sources of free iron keep stainless stain-free

Almost everyone who makes stainless steel products finds that they rust occasionally. That upsets users since they have paid for "stainless." A good question for designers, then, is "How and when are stainless steel castings vulnerable to corrosion and how can they be protected?" To address that question, Hitchiner has tested various conditions that cause stainless steels to rust. This update provides a synopsis of the factors at play in stainless steel corrosion and the results and conclusions that can be drawn from Hitchiner's testing program.

Stainless Steel Corrosion

There are two basic types of stainless steel—highly corrosion resistant, nickel-chromium austenitic steels and less corrosion resistant ferritic and martensitic steels. For special purposes, there are also duplex stainless steels, a mixture of the two structures. Basically, the formation of a passive surface layer of chromium oxide protects the metal from corrosive media in everyday usage and surroundings—as golf irons, hand tools, machine parts. The alloys' resistance to various chemical solutions is too complex to cover fully here; if you have a chemical solution you need to contain, there are extensive tables of corrosion rates that you can use.

The American Society for Testing Materials has tested most stainless steel alloys extensively in atmospheres around the United States. Some of these test environments—large city seaports and the bumpers of trucks driven on salty roads—have the worst corrosive qualities. These tests show that, in a few years at most, both rust and white corrosion products form on all stainless steels, even those that were perfectly clean at the beginning of the tests. If the stainless steel is kept clean, it will not form either corrosion product for many, many years. Many different mechanisms can play a role in forming these corrosion products.

In some cases, redeposition after dissolution from the alloy surface leaves ions on the steel's surface. With the right conditions of heat and humidity, these ions combine with oxygen and develop a corrosion product. Redeposition of iron ions leads to rust spots; redeposition of chromium ions leaves a deposit of chromium oxide, indicated by white spots having a matte finish on the polished steel.

Contamination by environmental iron is, however, the most common cause of rust on stainless steel. Because it does not come from the alloy itself, such iron is normally called "free iron." Almost every environment contains non-stainless steel that can yield free iron. If you drive behind a truck on a wet day, for example, the water from the rusty underbody that sprays onto your car's bumper will contain free iron. All machine tools are made of non-stainless metals, so cutting fluids contain free iron. Dust in the air, particularly in manufacturing plants, contains free iron. If you pick up a plain steel bar, your fingers will pick up free iron ions. Water flows through non-stainless pipes, so it contains free iron.

Free Iron Testing Methods

Because it is so common, Hitchiner tested golf club heads to show the effects of free iron in a more quantitative way.

Humidity Test. Depending on the type of alloy, there are various methods for testing for free iron. They are described in SAE AMS STD 753. Some tests are very corrosive and cannot be used on all types of stainless steel. While useful for process control, none of the short-time tests have ever correlated with the long-time tests run by ASTM.

The simplest and easiest test to control calls for dipping the sample into distilled water and putting it in a closed container with excess water at 75° F (24° C), giving 100% relative humidity for 12 to 24 hours. Any free iron converts to rust. It is a very sensitive test, as will be seen. All results described in this update are from the humidity test.

Quantification. To quantify the occurrence of rust, rust spots were counted and a count of one was given for each 1/16 inch (1.5 mm) of size or length. The letters, grooves and backfaces of the golf club heads received a maximum count of 100 each; thus the maximum count for rust for one head was 300.

Test procedures and results

Finished (Polished) Castings. We first ran the humidity test on three each of six golf club head styles of two alloys, 431 and 17-4PH stainless steel taken from finished goods inventory. The results were not too bad (Table 1. Rust Counts of 431 and 17-4PH stainless steel Finished Golf Club Heads, Uncleaned).

After dipping them in acetone to remove oily shop residues, we then retested these samples and an additional three for each style (six per style total). We did not retest Style C because it was chrome plated. (Table 2. Rust Counts of 431 & 17-4PH stainless steel Finished Golf Club Heads, Acetone Dipped.)

The data indicated the problem was not confined

to one golf club head alloy or style, that polishing residues gave the heads some degree of protection and that the drilled hosels had extensive rust, indicating free iron pickup from the drilling bits. This was shown on the chromium-plated head as well.

Unfinished (Unpolished) Castings. We also tested Type A 431 stainless steel golf club head castings at various stages in process (Table 3. Rust Counts of Type A 431 stainless steel Unfinished Golf Club Heads).

The effectiveness of the last treatment—pickle, dry air sand blast, ultrasonic Deoxidine, rinse and fan dry, yielding zero rust counts on 160 castings total—shows that shop compressed air used for sand blasting was the principal cause of corrosion. The air caused the corrosion because its lines carry condensed water that has free iron ions in it.

Shop Atmosphere as a Free Iron Source. To further investigate shop atmosphere as source of iron, we took a finished golf club head that had zero rust counts in the test and placed it on a table in the finishing department, leaving it for three hours before retesting it for rust. Exposed to settling dust, the top face had a count of 20 in small spots of rust. This shows that rust-free heads must be protected from shop atmospheres if they are to pass a rust test later on.

Summary

Cast surfaces are rough and free iron is hard to remove from the texture without ultrasonic cleaning. Cast surfaces, therefore, are likely to rust more than machined or polished surfaces. Any contact with shop dust, non-stainless steel tote pans, dirty gloves, dirty hands, etc., after cleaning will easily cause clean parts to rust in the rust test. After cleaning, all surfaces will have to be protected by oil or by placing in a plastic bag or plastic sealing to prevent recontamination and rust later. In short, free iron ions are everywhere and must be protected against.

Rust Counts of 431 & 17-4PH SS Finished Golf Club Heads, Uncleaned				
Club Type	**Letters**	**Grooves**	**Backface**	**Total Count**
A	1	2	18	21
B	4	9	0	13
C	1	0	0	1
D	2	0	0	2
E	4	6	1	11
F	0	5	0	14
				Total 62

Table 1

Rust Counts of 431 & 17-4PH SS Finished Golf Club Heads, Acetone Dipped				
Club Type	**Letters**	**Grooves**	**Backface**	**Total Count**
A	15	46	68	129
B	26	125	100	251
D	5	11	15	31
E	3	13	2	18
F	13	206	6	225
				Total 654

Table 2

Rust Counts of Type A 431 SS Unfinished Golf Club Heads	
Process Stage	**Rust Count on Three Castings (900 max.)**
After pickle	900+
After pickle and sand blast with shop air	800+
Pickle and sand blast with dry nitrogen	50
Clean castings that passed the humidity test reblasted with shop air	173
Pickle, shop sand blast, ultrasonic Deoxidine treat, rinse and Rustlick treat	3
Pickle, shop air sand blast, ultrasonic Deoxidine, rinse and shop air sand blast	20
Pickle, dry air sand blast, ultrasonic Deoxidine, rinse and fan dry	0*
*On 160 castings total	

Table 3