BOEING®
A&M ENVIRONMENTAL TECHNOTES
FEBRUARY 2000 VOLUME 5, NUMBER 1

CORROSION AT SEA

Why are hazardous materials required to produce an F/A-18? One big driver is corrosion control. If it flies in the air, where does all the corrosion come from? The problem is usually not in the air, but on the ground, or in the case of the F/A-18, in the middle of an ocean.

Observations have been made that would indicate corrosion rates are quite significant for a U.S. Navy aircraft carrier operated aircraft.

F/A-18 Operational Environment

Severity of environmental exposure does play its part, but this has to be coupled with the time an aircraft is on the ground (or on the aircraft carrier hangar deck, as the case may be). The average U.S. Navy aircraft flies 4-5 hours per day, however, corrosion is a process which is most active during non-operating periods. Thus the Navy carrier operated aircraft at rest is exposed to the severest of corrosive environments for 19-20 hours per day. This would appear to account for the amount and severity of corrosion experienced by aircraft carrier operated Navy aircraft. Thus not only the climatic factor enters into the corrosion equation, but also the duration and type of exposure.

The combined action of wind and water is instrumental in the generation of sea water spray, which in the case of aircraft carriers and low freeboard ships, is carried to the flight deck, and hangar deck, when the steel curtains (doors) are left open for personnel comfort. At times this spray appears as a fog of droplets or mist, with size depending on the prevailing weather conditions. If you add in exhaust gases, salt fog can be acidified to a pH of 2. It is not unusual to find this mist condensing on stowed aircraft to the extent that the aircraft surfaces drip sea water. This is a very corrosive environment.

Upon evaporation solid salt particles remain that may accumulate in aircraft crevices and joints. Subsequently, in the presence of moisture (even if not sea water), a salt water condition can be produced in the crevice or joint, simply because the deposits attract moisture to metal surfaces and provide the electrolyte.

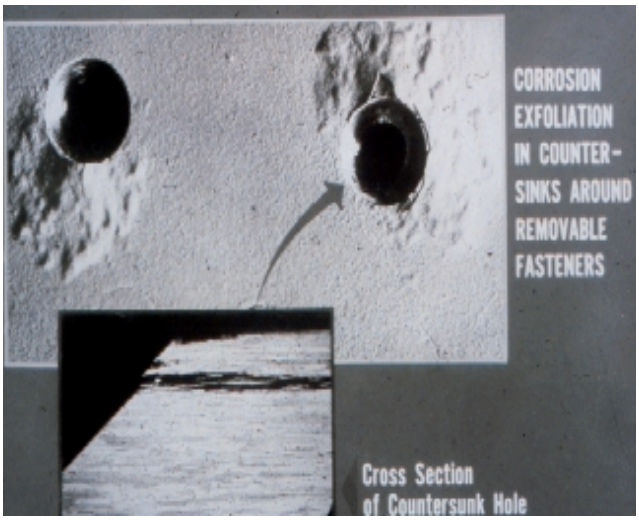
Corrosion is a chemical reaction similar to a battery. Electrons flow from one surface to another. For corrosion to occur you need three conditions to occur simultaneously. 1. The presence of an anode (the material most likely to corrode) and cathode (the material least likely to corrode). 2. An electron conductor between the

anode and cathode. 3. An electrolyte. On an aircraft the anode and cathode could be an aluminum spar and a composite skin. The electron conductor is the metal fastener that fastens the skin to the spar. The electrolyte is salt water from a wave that just crashed over the bow of the aircraft carrier. Since the anode and cathode materials are selected by design criteria (weight, strength and performance), the common way to stop corrosion is to seal out the water (electrolyte). This is done with coatings and sealants.

There are several types of corrosion that occur on aircraft. A common type of corrosion experienced on the F/A-18 aircraft moldline is filiform corrosion. Filiform corrosion typically occurs on painted aluminum substrate.

Filiform Corrosion

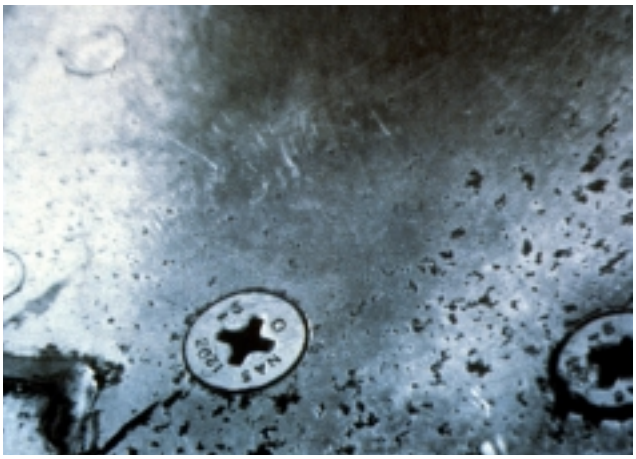
The majority of filiform corrosion initiates around fasteners and at the edge of skins where the coating system has been breached. High relative humidity, chloride ions (sea salt) and oxygen accelerate filiform corrosion growth. Repairing the corroded area typically consists of removing the corrosion with localized sanding. The exposed aluminum is then chromate conversion coated, primed with a chromated epoxy primer and coated with a polyurethane topcoat. The Navy has developed a self-priming topcoat for corrosion repair in the field. It contains non chromate corrosion inhibitors and eliminates the need for the primer coat.



Exfoliation Corrosion

Exfoliation corrosion, causes the formation of flakes or layers of aluminum. This type of corrosion is also known as layer corrosion. Imagine a solid piece of aluminum turning into multiple sheets of aluminum foil. This type of corrosion is highly visible, and can lead to a significant loss in the strength of the aluminum structure.

Exfoliation corrosion is rarely if ever seen on an F/A-18, and has for the most part been completely eliminated with newer aluminum alloys and improved heat treatments.



Pitting Corrosion

Pitting corrosion is a localized corrosion that results in small pits in the aluminum. Once pitting corrosion is initiated, it can propagate and form in deep holes in the aluminum. Pitting can

be initiated and accelerated by the presence of chloride ions, low pH and water, all of which, as mentioned earlier, are characteristics of the aircraft carrier environment. Pitting type corrosion has been seen on F/A-18 aircraft.

Intergranular corrosion occurs at the boundaries between the grains in certain aluminum alloys. This type of corrosion is microscopic. Severe intergranular corrosion results in a loss of ductility of the aluminum alloy, and can lead to exfoliation corrosion. Intergranular corrosion can lead to a fracture failure of a critical load bearing aircraft structure. F/A-18 aircraft experience severe loading during catapults off the aircraft carrier as well as trap landings on the carrier. Severe loads are also put on the aircraft during high g-force maneuvers.

Intergranular Corroded Aluminum Alloy

Stress corrosion cracking (SCC) can be one of the most damaging types of corrosion. Like intergranular corrosion, SCC also follows the grain boundaries in the aluminum alloy. It occurs when there is a sustained tensile stress, and exposure to a corrosive environment (sea salt). SCC, again like intergranular corrosion, can produce a fracture failure of a critical load bearing aircraft structure. There are many ways to prevent SCC. Design loads on the aircraft must not exceed material threshold stress levels for SCC. During manufacture of the aircraft, installation and assembly stresses should also be avoided. Material selection and processing can also prevent SCC. Selection of aluminum alloys that are less prone to SCC is critical. Over aged, stretched and stress relieved aluminum alloys must be used. Also it is important to use the correct aluminum heat treat tempers that were developed to reduce stress corrosion cracking.

Stress Corrosion Cracking in a 7079 Aluminum Alloy Fitting

Several other materials are used to combat corrosion on the F/A-18. Alclad skins are used on the aircraft to reduce corrosion tendencies. In alcladding, a thin sacrificial layer of relatively pure aluminum protects the underlying high strength aluminum alloy. Chromate conversion coating and anodizing aluminum provide corrosion resistance as well as improving paint adhesion. Galvanically dissimilar metals are coated with organic coatings in order to isolate the anode and cathode materials. Chromated epoxy primers provide a large portion of corrosion protection for aluminum substrates. Polyurethane topcoats are used for their excellent flexibility and durability. Polysulfide sealant and chromated primers are used for wet fastener installations for corrosion protection. Polysulfide sealants are also used for fay surface and fillet sealing to reduce the likelihood of water intrusion, which prevents certain types of corrosion.

In addition to selecting the correct materials for corrosion protection, it is also important to insure that these materials are being properly manufactured and applied by Boeing qualified vendors and subcontractors. Maintaining the concentration and temperature of metal chemical processing baths, proper mixing and control of

paints and sealants, checking paint and sealant adhesion, measuring hardness and electrical conductivity after aluminum heat treatment, passing hydrogen embrittlement tests, and passing monthly salt spray tests are all important steps to verify that the maximum corrosion resistance for our aircraft is being obtained. Boeing relies on their vendors and subcontractors to do their very best because corrosion of aircraft is probably the greatest enemy that will confront our military aircraft when they are deployed.

Specialty coatings used on new aircraft pose an additional challenge to Navy maintenance personnel with respect to corrosion control. Coatings used for aircraft signature control sometimes accelerate the corrosion process. Extensive work is being done with suppliers to minimize the effect these materials have on corrosion. Improved corrosion resistant specialty coatings have been developed.

Proposed OSHA regulations may pose an additional challenge to corrosion protection. OSHA is considering significant reductions in the permitted amount of worker exposure to hexavalent chrome. Chrome has been the workhorse in aluminum aircraft corrosion protection. Non chromated primers are in development and are currently being field evaluated on the F/A-18 and other aircraft moldline surfaces. Field evaluations show that the non chromated primers are approaching the corrosion resistance of chromated primers, but a solution still needs to be developed for internal structures.

Designing future aircraft to minimize corrosion is a challenge with the ever-changing environmental regulations. New materials such as appliqué paint films may reduce the amount of corrosion on the F/A-18 moldline.

F/A-18 B with JPAP Appliqué on Deck

Minimizing dissimilar metals and limiting the number of fasteners can reduce the potential for corrosion, while also reducing assembly time and costs. New materials are needed that can provide improved corrosion resistance while also meeting the strength and weight requirements of high performance aircraft.

Carrier based aircraft experience one of the most severe environments with respect to corrosion. While all these corrosion control measures may appear tedious and lengthy, rest assured that the overall objectives are to keep the F/A-18 fleet at a high state of readiness to protect our nation's and allies' interests. Changing environmental, occupational safety and health regulations continually challenge suppliers to develop greener and safer materials. A strong relationship between Boeing and its suppliers is needed to develop creative solutions to these problems.

For more information contact;
John DeAntoni at (314)-232-2198, e-mail:
john.r.deantoni@boeing.com *or*
Sharon Sofian at (314)-234-5996, e-mail:
sharon.sofian@boeing.com