SIEMENS
Ingenuity for life

Aerospace and defense

Corrdesa

U.S. materials provider uses Siemens solutions to combat damaging effects of corrosion

Products

Simcenter, Teamcenter

Business challenges

Offset costs of equipment corrosion

Replace materials that accelerate equipment failure

Meet performance and environmental requirements

Keys to success

Implement a corrosion-free design approach using Simcenter STAR-CCM+ and Teamcenter

Use 1D design approach to analyze corrosion threats from simple geometries

Deploy 3D CAE with Simcenter STAR-CCM+ for complex components and high-risk areas

Results

Modified bushing to reduce oxidation

Improved prediction for thin electrolyte films

Used CFD to predict and suggest solutions for high-risk areas of complex products

Corrdesa, Simcenter STAR-CCM+ help U.S. military save millions on corrosion costs

The cost of corrosion

Corrosion is costing the U.S. $25 billion per year, or 4 percent of the U.S. Department of Defense (DoD) budget. Corrosion costs the U.S. Navy (Navy) and U.S. Marine Corps (Marines) $3.6 billion annually and accounts for approximately 30 percent of maintenance costs.

Aside from the significant economic impact, corrosion from environmental interaction puts military equipment, mission readiness and even lives at risk. The cost of corrosion is analyzed annually by a DoD corrosion office, and a Corrosion Prevention Advisory Board exists for all new military systems. NACE International, the global corrosion authority, estimates the annual cost of corrosion is $2.5 trillion worldwide and $250 billion in the U.S.

Harsh naval environments are prone to corrosion, and the cadmium and chromates that were previously depended upon to provide corrosion protection are being phased out due to environmental concerns. Using dissimilar materials such as carbon fiber composites and aluminum in the presence of electrolytes creates galvanic corrosion, a problem that causes approximately 80 percent of the structural failure in military aviation. This results in aircraft being out-of-service for 25 to 30 days annually.

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Corrosion on an F-18 wing and airframe.

It is estimated that 25 to 30 percent of these corrosion issues could be avoided with improved corrosion management practices and material selection. But current design guidelines and military standards are based on outdated science and data that are inadequate for addressing modern materials and their corrosive behavior.

On the frontlines of corrosion

Founded in 2011, the vision of Corrosion Resistant Design by Environmental Stress Analysis (Corrdesa) was to develop a corrosion simulation tool chest for the materials community. As a result, the eight-person company from suburban Georgia has been instrumental in transitioning corrosion simulation analysis into the military and commercial design sectors.

Corrdesa boasts years of corrosion and computer-aided engineering (CAE) expertise. The company is helping the Navy implement a corrosion-resistant design approach using Siemens Digital Industries Software’s Simcenter™ STAR-CCM+™ software and Teamcenter® software.

Corrdesa’s corrosion analysis workflow provides instantaneous material selection to resist galvanic corrosion, saving the Navy thousands of testing hours and millions of dollars.

Fighting the good fight

Degrading materials such as air, water, salt water and/or other materials reacting with their environment results in corrosion. Military assets are most susceptible to corrosion as they operate in harsh environments. These environments include freshwater, salt water and oceanic moisture. In the presence of these liquid electrolytes, dissimilar materials with differing electric potentials in contact (either directly or indirectly) are prone to galvanic corrosion, also known as electric corrosion. One metal acts as an anode corroding quickly while the other acts as a cathode with slower corrosion.

Most corrosion resistant design is done using the galvanic series: tables and charts ranking materials by their electric potential based on half-century old materials and data. The galvanic potential difference between the materials causes one to act as

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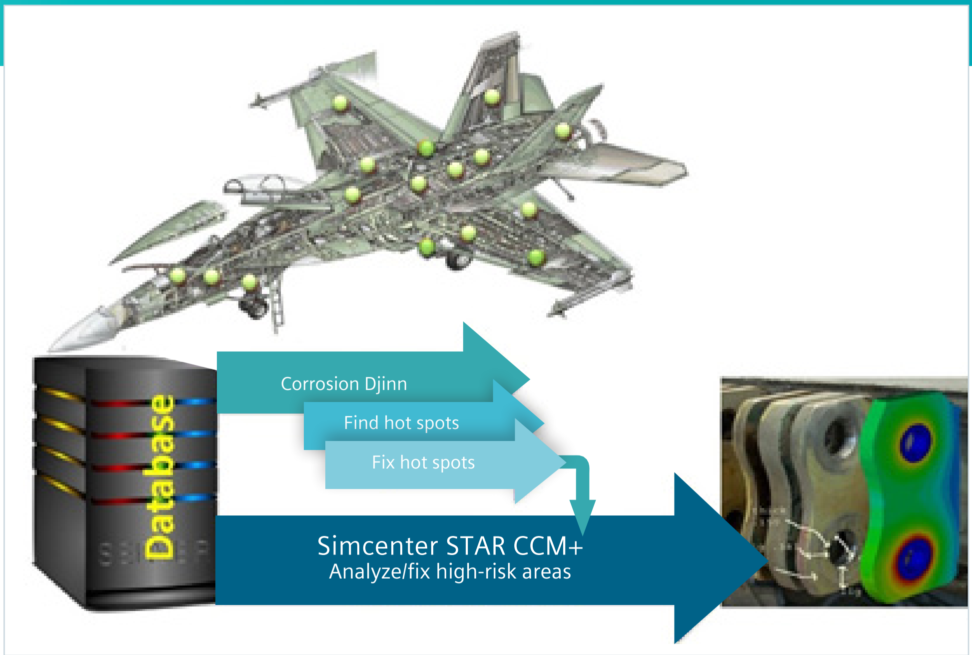

The Corrdesa corrosion analytics engineering workflow.

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an anode, accelerating corrosion. Designers use tables to choose materials and coatings based on their potential to corrode. But the data from these tables are less science and more of a suggestion because the potential is measured only for individual metals and does not account for other metals in proximity. The electromechanical kinetics, electrolyte composition and temperature are not considered. Meanwhile, aerospace materials and coatings are constantly evolving to meet performance and environmental requirements.

The galvanic series was adopted as U.S. military standard (MIL-STD) and detail (MIL-DTL) documents standardizing design specifications and requirements. MIL-STD-889 for galvanic compatibility assessment is required for all military aircraft programs. But the outdated standards, even when applied correctly, can still result in poor material choice and oversight: for example, the $228 million bill for repairs and retrofits related to corrosion on the F-22 fighter jet.

"The root cause of this problem lays within the galvanic couple between the conductive gap filler and aluminum skin panels," says Daniel Dunmire, Director, Corrosion Policy and Oversight Office, DoD.

To its credit, the DoD has updated MIL-STD-889C to propose an approach using galvanic current instead of potential. The Office of Naval Research has initiated a Sea-Based-Aviation (SBA) program, involving Corrdesa, to develop computational methods for corrosion analysis and prediction.

Science-based corrosion analysis with simulation

"I've been kicked out of meetings in the past for saying you can simulate electroplating and corrosion," says Alan Rose, chief executive officer (CEO), Corrdesa. "But acceptance is growing. Today, electroplating simulation is a requirement in many OEMs. With the right verification, validation and accreditation, it is common to use simulation tools for corrosion prediction."

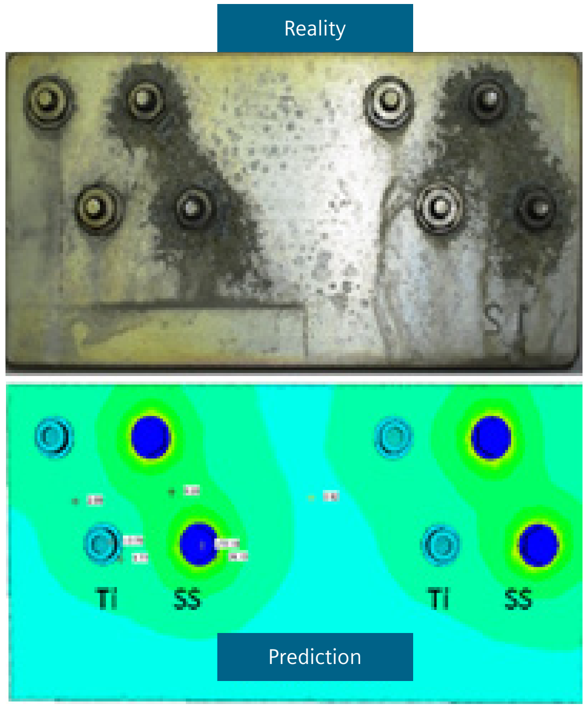
Rose's 25 years of CAE experience shines through when he talks about corrosion simulation. Meanwhile, Keith Legg, chief technology officer (CTO), is a world-renowned expert on corrosion and coatings. Led by Rose and Legg, Corrdesa leads the way in marrying corrosion and CAE.

Corrdesa's corrosion analysis method is a three-step process that features an internationally recognized electrochemical database; Corrdesa's 1D Corrosion Djinn™ tool that analyzes 80 to 90 percent of corrosion threats from simple geometries; and 3D CAE with Simcenter STAR-CCM+ for complex components and high-risk areas.

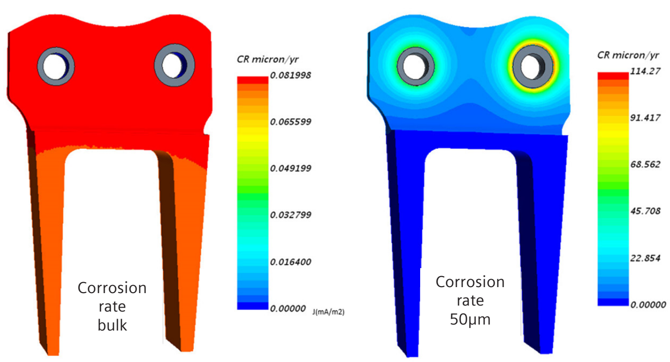
As part of the SBA program, Corrdesa worked with the Navy to create a standardized electrochemical database. The new database in Corrosion Djinn comes with data for modern alloys, coatings and surface treatments, and is constantly updated with polarization curves, showing current density and electrode potential for new materials and coatings. With the updated data, the Corrosion Djinn tool calculates galvanic current and corrosion rate between dissimilar materials, coatings and treatments for simple geometries.

For complex geometries, computational fluid dynamics (CFD) simulations with Simcenter STAR-CCM+ predict the changes in corrosion rate that come with variations in film thickness and show where corrosion is likely to occur. The CAE approach can take from hours to days per interface to predict and suggest solutions for high-risk areas of complex products.

"Instead of having our customers waste thousands of hours testing materials and trying coatings, they can characterize them in one day in the lab," says Rose. "Combine that with science-based corrosion modeling and you can quickly assess different materials and choose the best one. Testing materials to make them corrode takes time. With CFD, it's non-destructive and you can virtually test again and again."



A test versus Simcenter STAR-CCM+ prediction for NAVAIR Galvanic coupons.



The corrosion rate on uncoated lug/bushing in an F-18 aircraft.

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Solutions/Services

Simcenter STAR-CCM+
siemens.com/simcenter

Teamcenter
siemens.com/teamcenter

Customer's primary business

Corrdesa was established in 2011 with the aim of developing a corrosion simulation tool chest for the materials community. The company's unique approach combines 25 years CFD simulation experience with expertise on materials, coatings and corrosion. Corrdesa has been instrumental in transitioning corrosion simulation analysis into the military and commercial design communities. The company's methodologies and best practices have been influential in steering revised military standards, such as MIL-STD-889. www.corrdesa.com

Customer location

Tyrone, Georgia
USA

Is the simulation science solid?

In a strict military design environment, verification and validation is required. The updated military standards and Corrdesa's involvement in the SBA program have opened the door for greater acceptance of corrosion simulation. In addition, Corrdesa's design method was validated against many existing cases.

When compared against test data from accelerated tests for NAVAIR galvanic coupons, the 1D method gave acceptable predictions for bulk electrolyte conditions. The 3D CAE approach, accounting for film thickness and fluid film, improved the prediction of thin electrolyte films. Both quantitatively and qualitatively, satisfactory predictions were achieved with different test chamber results to validate the approach. But would it work in a real-life scenario?

On many of the Navy's F-18 aircrafts, fastener holes suffer sever corrosion. Repair involves inserting a stainless-steel bushing in the fastener hole or replacing a smaller bushing with a larger one. Galvanic tables point to 15-5 PH/Bare Al coupled fasteners as the answer. However, corrosion analysis by Simcenter STAR-CCM+ and Corrosion Djinn tell a different story. Simulation shows that not only is Ti6Al4V/anodized Al a better chemical solution combination, but that the best solution is to modify the bushing to reduce oxidation.

Recently, an electrical connector manufacturer couldn't meet the contact resistance requirements while using a new material (a zinc-nickel combination). To meet requirements, manufacturers were using polytetrafluoroethylene-filled electroless nickel (EN-PTFE) on aluminum because it met conductivity requirements. But corrosion analysis and Navy testing showed EN-PTFE connectors corroding cadmium from mated connectors and accelerating galvanic corrosion of aluminum electrical boxes.

A perfect fit for Siemens

"We selected Simcenter STAR-CCM+ because of its multiphysics capabilities to model corrosion, fluid film, thin film, condensation and more," says Rose. "I can quickly and accurately calculate electrolyte thickness, choose the correct polarization, material data and calculate corrosion rate distribution. By using a well-respected, verified and validated code like Simcenter STAR-CCM+, which our customers already use and have paid for, I can quickly assess the materials, choose the best option and minimize testing. Everyone wins."

On average, there are thousands of bushings and fasteners just in the airframe, and there are potentially thousands more in other aircraft systems. Finding problematic interfaces, bushings and fasteners among these is a difficult, if not impossible, task.

The answer, according to Rose, is Siemens' Teamcenter, which is being widely adopted by the Navy and U.S. Air Force. Teamcenter is an end-to-end product lifecycle management (PLM) software that integrates information, data, processes and people throughout a product's life. Teamcenter can identify and document thousands of interfaces and materials. Designers and maintainers can also access all electrochemical data, Corrosion Djinn and Simcenter STAR-CCM+ within Teamcenter. Corrdesa's corrosion resistant design philosophy and Siemens' solutions offer a blueprint to tackle the enormous problem of corrosion.

Siemens Digital Industries Software

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