USN Tie Down Redesign

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No Loose Ends

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Background

Due to corrosion and mechanical degradation, tie downs used for securing aircraft on platforms such as DDG/CGs and LHA/LHDs have faced life-span and effectiveness issues. A critical component to these ships, tie downs are required to secure million-dollar assets on surface warfare ships; replacement of these pieces are frequent and expensive.

The tie downs installed on Destroyers and Aircraft carriers are constantly exposed to seawater and jet fuel. This exposure results in corrosion induced material loss, eventually requiring their replacement. The replacement cost per tie down is approximately $30,000 due to the amount of manpower and specialty systems needed for removal and reinstallation. During this process, all the piping below the deck needs to be moved before the old tie down can be cut out of the flight deck and a new one welded in.

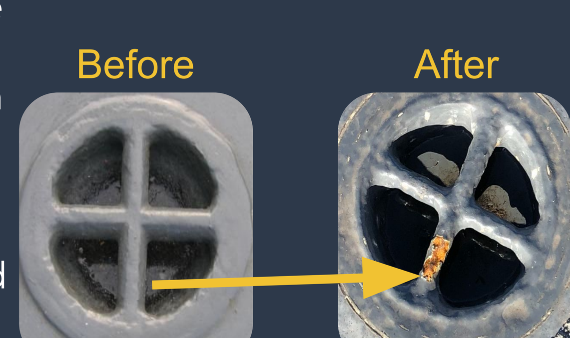
$2,105,400,000

Estimated tie down removal cost for the current commissioned fleet

Abstract

With the issues presented in the current tie downs, our team was tasked to ***redesign and test a DDG tie down that can withstand 16,000 lb of static force total, and is potentially made of a new material that extends the lifespan of the current tie downs.***

This new design includes a threaded joint, eliminating the need to weld the entire tie down to the deck during replacement. A single sailor can replace the tie downs without hindering flight operations. In addition, the removal and reinstallation of the tie down no longer requires the ship to be in drydock. With the ability to replace the tie downs underway, The ship can remain operational and continue to execute the mission. What used to be a major and long process could be accomplished in minutes.



Design and Fabrication Process

There are 5 major components. The crossbars, cup, threads, and receiving fixture are all made of 4130 Chromoly steel. The crossbars and threads are welded to the cup. The copper gasket you see there is used to provide a watertight seal between the threads and the receiving fixture. If that seal were to fail, the copper still provides anti-corrosive properties for the threads.

Crossbars — 4130 Steel welded to the cup portion of tie down

Cup — 4130 Steel cup portion of the tie down

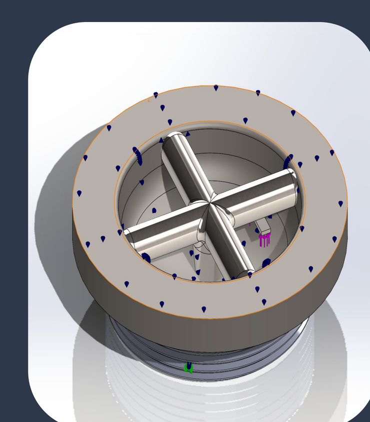
Threaded Joint — 4130 Steel threaded joint machined onto cup portion of tie down

Nut — 4130 Steel nut welded into flight deck and receiving end for the threaded joint

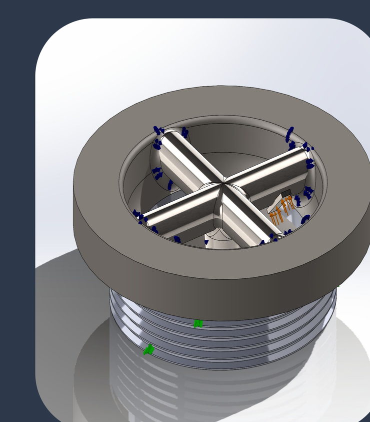
Gasket — Annealed copper gasket used as the sacrificial anode

Testing Methods

The first step in the testing process was creating a SolidWorks file of our new design. Once this CAD model was completed, a simulation known as a Finite Element Analysis was run in order to determine the stresses on the tie down during what would be considered normal operation conditions.



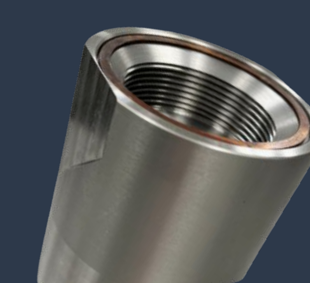
90° Pull



45° Pull

The FEA was run at 10000 lbs (the maximum predicted load of the chains that secure the aircraft) and 16000 lbs (the Navy's required maximum applied load). In order to meet the warrant holder's needs, the same test where conducted but at a 45 degree pull. In addition to running the simulation with 4130 chrome moly steel, the same tests were also performed with A375 stainless steel as the tie down material to compare the results.

90° Pull



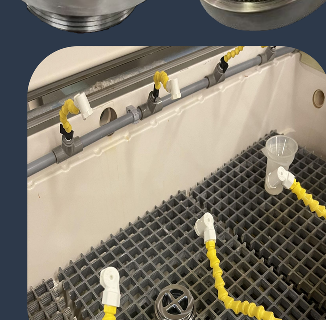
45° Pull

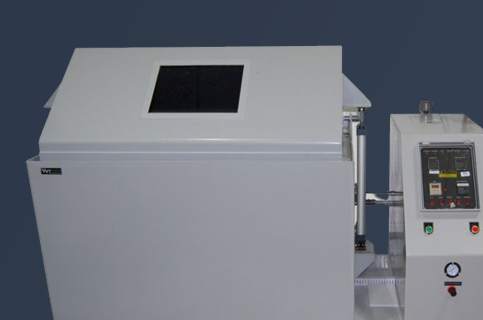
A real world tensile test was performed on a half scale model. A 90 degree pull was done through the fabrication of a hook to pull on the bar and a threaded portion to hold the tie down to the bottom of the Instron tester. The same standard procedure was performed in the 45 degree test but with a different fixture this one fabracted to hold the tie down at a 45 deg angle.

The corrosion testing consisted of a cycle that was 16 hours wet followed by 8 hours dry. This cycle was done 7 times on each of the models we had. One was on of our redesigned models and the other was coated with NRLs diamond like ceramic coating which is ment to reduces the corrionson the tie down,. Both tie downs were fixed in a moch holder to simulated being threatened in on a ship with an annealed copper gasket. This was to simulated the effects of being at sea and see how the tie downs would hold up a corrosive environment.

Pre-corrosion Uncoated

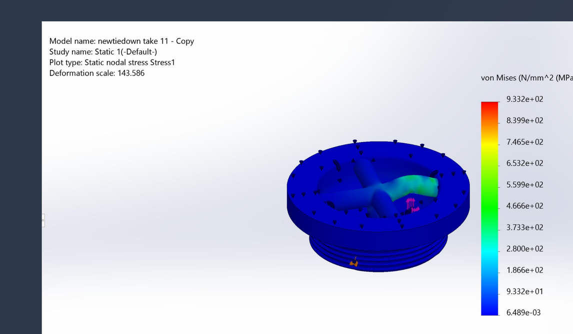
Pre-corrosion Coated

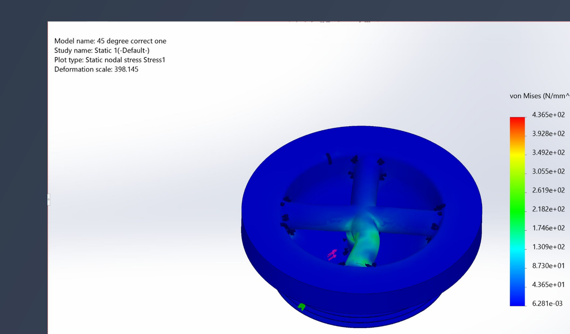




Results

We also applied a Finite Element Stress Analysis to a full scale, 3D model of our design in order to compare the stresses experienced by our tie down to the Navy requirements. We then scaled the same model down by ½ so that we could compare the results of that FEA to our live testing. Here you can see that the stresses are localized to the bars alone with minute stresses on the treads of the tie down.





We determined from our models that the stainless steel would not be a suitable replacement because of its low yield strength and decided to continue using the current 4130 Chromoly steel. A modeled 2000 lb test was used to compare our half size load to our full scale by using a 1/8th rule.

FULL SCALE	Yield Strength	Max Stress 10,000 lbs, 90° pull (252 MPa)	Max Stress 16,000 lbs, 90° pull (403 MPa)	Max Stress 10,000 lbs, 45° pull (113 MPa)	Max Stress 16,000 lbs, 45° pull (180 MPa)
4130 Steel	460 MPa	54.8% of yield	87.6% of yield	24.6% of yield	39.1% of yield
347 Annealed Stainless Steel	275 MPa	91.6% of yield	147% of yield	41.1% of yield	65.5% of yield

The max stress on the full scale would be about 88% of the overall yield strength. The 16000 lbs is the requirement given by the navy and our design has an additional factor of safety of 1.15.

After completing the test, we determined the factor of safety for the half scale model is approximately 2.4 based on the operational requirements for the Navy and a 1/8th scaling factor. The load was approximately 4800 lbs for each of the tests surpassing our goal of 2000 lbs. The tests were called due to noticeable defamation in the hook without any plastic deformation in the tie down

½ Scale	90° pull	45° pull
Max Load	21,351 N (4,800 lbs)	21,209 N* (4,768 lbs)
Factor of Safety	2.4 (relative to operational requirements)	2.4 (relative to operational requirements)

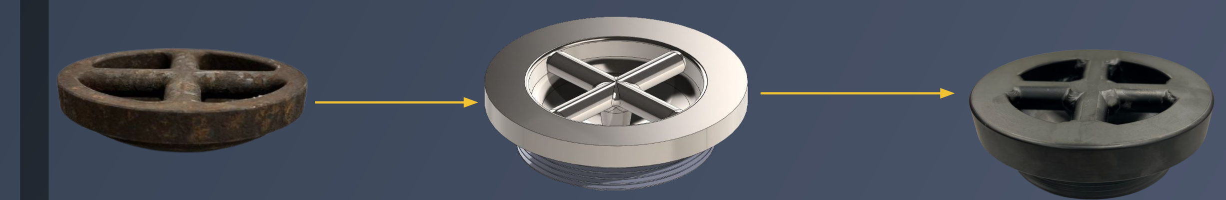
On the uncoated tie down, the lip of the cup and crossbars were the only parts of the tie down that were exposed to the spray. These parts displayed uniform corrosion whereas the threads on the joint show have no corrosion on at all. The coated tie down has no noticeable corrion present.

Post Corrosion Testing

Uncoated

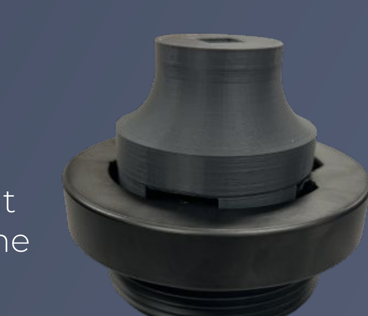
Coated

Conclusion



Our sponsor for this project NRL has been looking at different coatings for Navy tie downs in conjunction with our redesign. NRL coated one of our models with a Diamond like carbon coating they have been testing in order to increase corrosion protection.

We also took into consideration the need for enlisted personnel to easily install and remove the tie downs from their receiving fixtures. Because of this, we modeled a bung wrench which is designed to be compatible with half inch torque wrenches and could be made available to all deck divisions.



At the end of the day, the problem with the current tie down design is that it is costing the Navy an outrageous amount of money. If the Navy continues with the old tie down design on all of its newly contracted DDGs and carriers, it would cost almost 1.5 billion dollars when the tie downs need to be replaced; and statistically speaking, each tie down will need to be replaced at least once before these new ships will be decommissioned. With our new design however, it would only cost the navy approximately only $42 million when those tie downs need to be replaced. This would lead to a savings of $1.4 Billion, which is a 97% cost percentage decrease.

$1,457,391,820

Estimated savings if every tie down on newly built ships need to be replaced after implementing the threaded tie down design

References

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