Good Grease, Good Landing

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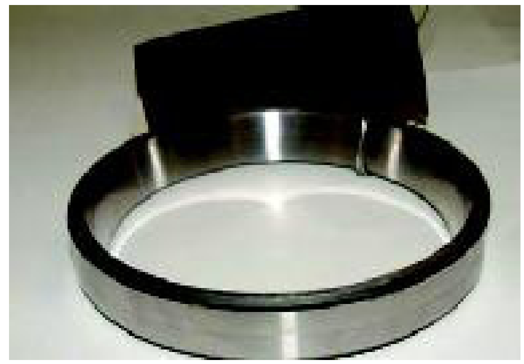
The C-5 galaxy military transport when fully loaded weighs up to 380 tons.

Tests reveal that a new lithium-soap-thickened, synthetic grease may help mission-critical aerospace components keep rolling under extreme loads and corrosive environments.

The landing gear of the massive C-5 Galaxy military transport airplane is a feat of heavy-load engineering. The plane's paint alone weighs 2,600 lb. Fully loaded, its maximum weight tops 380 tons, and it can land that load in just 4,900 ft of runway, even on substandard surfaces.

The force exerted on the C-5's landing gear makes its gears mission-critical components. But the wheel assemblies, all 28 of them, regularly see moisture, rain, seawater, dust, dirt, and other corrosion-causing elements. Corrosion weakens parts, shortens operating life, and jeopardizes basic functions such as raising and lowering the landing gear and wheels turning on axles.

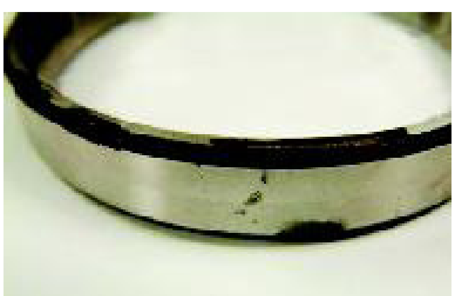


E-2C bearing cone ring (top) lubricated with MIL-PRF-81322 grease after a 300-hr saltwater bath and subsequent cleaning shows extensive corrosion and pitting. The part was deemed unserviceable by the Navy. In contrast, the E-2C bearing cone ring (bottom) lubricated with MIL-PRF-32014 grease after a 300-hr saltwater bath looked like a brand new part.

Further corrosive complications come from cleaning agents and bacterial decontaminants used in aviation maintenance. High-pressure washing can push out protective greases and drive water into the inner workings of the landing gear, possibly inviting further environmental attack. The C-5 suffered costly maintenance and expensive part replacement, a problem that the Air Force Research Laboratory (AFRL) Materials and Manufacturing Directorate at Wright-Patterson Air Force Base (WPAFB) in Dayton, Ohio, resolved to solve.

The AFRL began testing a synthetic grease called Rheolube 374A to meet MIL-PRF 32014 grease specifications. Rheolube 374A is a lithium-soapthickened, polyalphaolefin (PAO) grease with antiwear and anticorrosion additives. It has an operating range of 54 to 175°C.

PAO is a synthetic hydrocarbon fluid widely used as a lubricant. The molecular structure of a PAO is simple and resilient, providing reduced friction, wear protection, and low-temperature serviceability. The previously specified grease on the C-5, MILPRF-81322, is also PAO-based, but is thickened with organic clay rather than lithium soap.



Following lab tests, the new grease was subjected to more than two years of flight testing in the landing gears of the C-5, where it logged 2,725 flight hr, 1,217 total landings, 609 full stop landings, and 1,263 gear cycles. The landing gear components underwent a complete tear down and inspection following the 2-yr test. The results make the Air Force think Rheolube 374A will reduce maintenance, minimize part replacements, and reduce system failures.

With the success of the new grease on the C-5, the Navy also wanted to take a hard look at Rheolube 374A (MIL-PRF 32014) to see whether or not the synthetic grease can address similar corrosion problems in E-2C Hawkeyes. The Hawkeye is the Navy's all-weather early-warning and command aircraft for carrier battle groups. It has a 24-ft-diameter rotating antenna mounted atop its fuselage that lets the E-2C act as a forward radar scout.

Of primary concern for maintenance technicians are bearings in the E-2C's landing gear and rotodome. The latest versions of the E-2C first flew in 1973 and haven't been produced since the 1980's. Wear and environmental corrosion on these components are of exceptional concern because part replacement calls for custom fabrication.

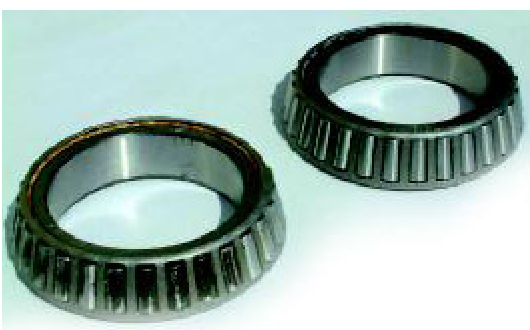
A high-pressure wash test was designed to flood bearing seals to test for corrosion resistance in the test greases. Wheel assemblies were exposed to a far more aggressive wash than what is considered standard procedure.

The Navy made detailed comparisons of the PAO-based grease MIL-PRF 32014 (Rheolube 374A) used in the C-5 tests and MIL-PRF 81322, the Hawkeye's previous grease. E-2Cs see extreme environmental conditions, flying in severe weather and from an aircraft-carrier flight deck where saltwater intrusion is a constant reality. Key components put under stringent saltwater-immersion and wash-rack tests were the aircraft's bearing cones and wheel assemblies.

In the saltwater immersion test E-2C bearing cones were coated with the test greases and suspended in a seawater tank for 300 hr. Additionally a small pump circulated the seawater to better expose the cones.

An inspection of test parts after the 300-hr immersion revealed the bearing cone coated with the original MIL-PRF 81322 grease had obvious oxidative discoloration. After cleaning it showed deep corrosion. Corrosion pits in the outer rim were 0.020 to 0.040-in. deep. Damage was so bad the part was no longer serviceable.

The MIL-PRF 32014 (Rheolube 374A) greased cone also emerged from the same saltwater bath with discoloration. But after cleaning it had no corrosion pits and was still serviceable. The discoloration came from the MIL-PRF 81322 sample's residue that settled on the cone lubricated with MIL-PRF 32014. And thus MIL-PRF 32014 did not oxidize. Engineers at the Naval Aviation (Navair) Depot in San Diego, where testing took place, reported the bearing cone lubricated with MIL-PRF 32014 looked like a brand new part.



E-2C wheel assembly bearings after the wash test. The bearing lubricated with MIL-PRF-81322 grease (left) shows corrosion on all the rollers. The bearing lubricated with MIL-PRF 32014 grease (right) is in like-new condition with no visible corrosion

Navair also tested a bearing cone that serves as a control piece, submerging it in saltwater for 300 hr with no grease at all. It showed less damage from corrosion than the cone lubricated with MIL-PRF-81322. While there was obvious surface corrosion, there was no deep pitting as observed on the MILPRF-81322 test part. When the control piece came out of the saltwater bath it had a gray surface. Materials analysis found the coating to be a calcium formation, which potentially limited the corrosion on the control bearing. Researchers speculate that the clay thickener in the MIL-PRF-81322 grease, which can be hydroscopic, apparently locks in water, forming the deep corrosion pits on the MILPRF 81322-test part.

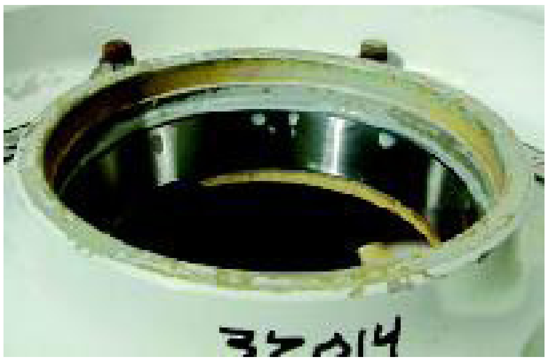
Other Navair tests subjected two new wheelbearing assemblies to high-pressure spray washes. The wheels were rotated to ensure total water intrusion during the 100-psig, three-day test. A cleaning solution, Turco 5948R, used by the Navy was also added to the wash. Water was forced through the axle, flooding the bearing seal area for 10 continuous minutes. After each wash cycle, technicians poured seawater over the assemblies. The assemblies then stood overnight before seeing another wash cycle.
This high-pressure wash is more rigorous than typical aircraft washes. The goal was to replicate a worst-case scenario where water would mix into the grease as the bearing rollers rotated in the grease lubricants. Both wheels were mounted on the same caster barrel so each grease would see the same test conditions.

A high-pressure wash test was designed to flood bearing seals to test for corrosion resistance in the test greases. Wheel assemblies were exposed to a far more aggressive wash than what is considered standard procedure.

The wheel assemblies stood for 10 days before being torn down and inspected. Technicians reported that both wheel cavities contained large amounts of water, but the water in the MIL-PRF-32014-lubricated wheel was milky white. This indicates some degree of grease washed out of the assembly in the water. In contrast, the technicians noted that water from the MIL-PRF-81322-lubricated wheel remained clear, suggesting less washout.

Technicians reported that the wheel lubricated with MIL-PRF-81322 had seized on to the axle, while the MIL-PRF-32014-lubricated wheel rotated freely. The caster barrel on which the wheels were mounted showed significant rusting after the 10-day trial, indicating how unlubricated parts may have fared in this same environment.

The wheel-bearing cup assembled with MILPRF-81322 showed extensive corrosion after the 10-day test. The corresponding bearing roller also had broad corrosion. While less MIL-PRF-81322 grease washed out of the bearing, it reportedly absorbed water and changed color. As seen with the saltwater bath test, the tendency for the MIL-PRF-81322 grease to absorb water may have compounded corrosive damage, rather than prevent it.



Bearing cup assembled with MIL-PRF-81322 grease (top) showed extensive corrosion after the 10-day wash test and actually seized on the axle, while the bearing cup assembled with MIL-PRF-32014 grease (bottom) is free of corrosion and still serviceable after the 10-day wash test. It is as clean and smooth as a new part

The teardown inspection on the wheel assembly lubricated with MIL-PRF-32014 showed the high pressure had washed out more grease. But there was less corrosion. After the 10-day test the bearing cup assembled with MIL-PRF-32014 was in excellent condition and still serviceable. The roller bearings had little to no corrosion and were also considered serviceable. Despite the washout of the grease during the test, the remaining film of grease was still able to provide good corrosion resistance.

Navair also conducted other tests to ensure the new grease would function mechanically as the original MIL-PRF 81322. Grease chemistry can also affect machine torque, particularly at low temperatures. A cold-soak-bearing test showed the two greases have comparable cold performance. MILPRF 32014 added a few inch-pounds of difference, but wasn't considered significant enough by Navair to require any power increase.

The Navy's extensive testing demonstrates the vast difference among greases, even those formulated with some of the same basic ingredients. The idea that a grease is a grease doesn't necessarily apply when considering performance. There are a wide variety of oils, thickeners, and additives that can be combined into an expanding array of grease formulations. Every new recipe can deliver wide or slight variations in performance depending on the specific ingredients and ratios. In the case of the two greases compared by Navair, both greases were based on synthetic hydrocarbon oil, but used different thickeners and additives, which accounts for the difference in performance.

While the clay thickeners used in MIL-PRF 81322 generally have a good resistance to water washout, there are some issues with solubility. Clays, as demonstrated in both the soaking and wash tests, can absorb water. In some applications this may not be problematic, or even relevant. But it's possible that the clay thickener was the root of corrosion problems in the case of the Air Force and Navy landing gears.

Lithium soaps, in contrast, are not water soluble or hydroscopic. Therefore lithium-soap-thickened grease can create a better barrier against environmental intrusion than a thickening substance that absorbs water. Though the overall resistance to washout might be lower in lithium-soap grease, the remaining lubricant film provides an elemental barrier sufficient to prevent corrosion.

A grease can be as much of an engineered material as the parts it's lubricating. It is a design element that can be used to improve the overall performance of a mission-critical application like the landing gear in a 380-ton airplane. Grease should be a carefully considered component of any mechanical design.

RHEOLUBE 374A PROPERTIES

BASE-OIL PROPERTIES	TYPICAL VALUES	TEST METHOD
Recommended service range, °C	54 to 175	
Thickener	Lithium	
Base oil	Polyalphaolefin (PAO)	
Kinematic viscosity, cSt (mm2/sec), 100°C	16.9	ASTM D-445
Kinematic viscosity, cSt (mm2/sec), 40°C	121	ASTM D-455
Viscosity index	153	ASTM D-2270
FORMULATED GREASE PROPERTIES	**TYPICAL VALUES**	**TEST METHOD**
Penetration, 1/10 mm, Unworked	244	ASTM D-217
Penetration, 1/10 mm, Worked 60X	267	ASTM D-217
Penetration, 1/10 mm, NLGI Grade	2	ASTM D-217
Oil separation, 24 hr, 100°C	3.3	FTM 791B, 321.1
Evaporation, 24 hr, 100°C	0.29	ASTM D-972
Water washout, 60 min, 40°C	3.2%	ASTM D-1264
4 Ball wear, 60 min, 1,200 rm (40-kg load), 75°C	0.44 mm	ASTM D-2266

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