UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio **Spring 2004**

Engineers Develop Grease Recommended For C-5

(U.S. Air Force photo by Tech. Sgt. Justin D. Pyle)

A low-cost, multi-purpose grease developed by the Air Force Research Laboratory received a positive evaluation from Air Force maintainers following nearly 1,529 airframe hours, which adds up to roughly 11 months of operation, on the C-5 aircraft.

Equipment specialists from Dover AFB, Del., who evaluated the grease's performance during a rigorous inspection of the aircraft in December 2003, recommended that the C-5 convert to the new moisture-resistant and high-load carrying grease pending review of an Interim Status Report and approval by the C-5 System Program Office. According to Ms. Lois J. Gschwender, an engineer from AFRL's Materials and Manufacturing Directorate's Nonstructural Materials Branch, final approval from the SPO was given in a meeting February 17.

In September 2002, two C-5 landing gears were greased with the multi-purpose grease, MIL-PRF-32014, and two landing gears, which were packed with the current grease, were identified as control gears. To date, the new grease has acquired 1,529.6 airframe hours, 351 total landings, 299 full-stop landings and 360 gear cycles. "By incorporating the stable, low-cost, rust-inhibiting grease, the Air Force could solve several challenges related to wear, corrosion and rust in the landing gear assembly of the C-5 aircraft," said Ms. Gschwender. "During testing conducted by the University of Dayton Research Institute on-site contractors at the directorate, the grease demonstrated water washout resistance, high-temperature and high-speed performance. During flight testing, the new grease has proven that it provides superior anti-wear and anti-rust performance and will provide a significant cost advantage due to reduced maintenance, part replacement and system failures."

According to Ms. Gschwender the directorate, led by Mr. Ed Snyder, first began working with grease companies to develop the multi-purpose grease in the late 1980s. Their goal was to find a commercial source of grease to replace the mineral oil sodium soap thickened product used in cruise missile engines. The mineral oil product reacted negatively to air moisture and was bleeding out of bearings while in storage.

"Greases are used in military applications to improve and ensure the performance of moving parts," said Ms. Gschwender. "When compared to liquid lubricant systems, grease systems provide significant advantages in the design of a system. Greases are self-contained, which eliminates the need for pumps, tubing, heat exchangers and other extra hardware that increase the weight and design requirements of a system." Because no appropriate greases were commercially available, and only a small volume of grease was required for the missiles, ML researchers and contractors from AMOCO designed a unique lubricating grease, which was ultimately assigned the MIL-PRF-32014 military specification. The rigorous performance requirements in the specification require the grease composition to include anti-oxidant, anti-wear, and anti-rust ingredients.

Following validation testing by several military agencies and by Williams Engine Company, the grease was adopted for the cruise missile with great success, said Gschwender. When the original supply of grease was used up, still no commercial supply was available because the usage volume of grease for the cruise missile was very small. AMOCO again custom made and delivered the second batch of the lubricant to the Air Force in 1994.

Mr. David Marosok, a lead C-5 landing gear engineer at Ogden Air Logistics Center, Utah, approached AFRL to solve a dilemma resulting from the implementation of a very expensive grease ($5,000 per gallon) that had been recommended by a contractor to solve corrosion and rust problems. This grease had in fact aggravated the problems, Ms. Gschwender said.

Following collaboration with AFRL, where participants analyzed wear and (continued on page 3)

Powerful Ultrasonic and Eddy Current Capability for Nondestructive Inspection Transitioned to Air Logistics Center

Engineers from the Materials and Manufacturing Directorate of the Air Force Research Laboratory (AFRL) and the Aeronautical Enterprise Program Office (ASC/AAA) recently transitioned enhanced ultrasonic and eddy current capability to the Oklahoma City Air Logistics Center's (OC-ALC) Nondestructive Inspection (NDI) Production Team (OC-ALC/MAB). This capability was integrated into the Boeing Mobile AUtomated Scanner (MAUS), which is a large area automated inspection system currently used by OC-ALC.

Funded by ASC/AAA, the system's new features will be used to automate additional time-consuming manual inspections and broaden detection capabilities for multi-layer structures on the B-52, E-3 and the KC-135 aircraft. This new capability of the fifth generation MAUS (MAUS-V) is the result of a new system architecture that provides greater depth resolution and higher data processing speeds. In comparison to the previous MAUS (MAUS IV), the MAUS-V has improved software features such as data filter algorithms to highlight corrosion, and a new software database system to reduce inspection setup times. The enhanced architecture also provides a platform to support many other capabilities that require faster rates of data processing, such as linear and phased ultrasonic arrays and multi-frequency eddy current.

Under contracts with ASC/AAA, the Materials and Manufacturing Directorate's Nondestructive Evaluation Branch (AFRL/MLLP), and the NDI Program Office (AFRL/MLS-OL), the Boeing Corporation was tasked to upgrade the existing MAUS inspection units used by OC-ALC for Periodic Depot Maintenance (PDM) cycles. In addition, the Boeing Corporation was tasked to develop new automated inspection procedures for the B-52 spanwise splice structure taking the place of a labor-intensive manual inspection. Additionally, Boeing developed procedures for mapping skin thickness on the E-3 wing skins, as well as procedures for KC-135 splice inspections by utilizing the upgraded architecture and software features of the new MAUS-V configuration.

In October 2003, ASC/AAA and AFRL/ML engineers transitioned the first MAUS-V unit to OC-ALC for use on the E-3 aircraft. Since then, the MAUS-V has been used in PDM cycles on the KC-135 and B-52 aircraft. OC-ALC is upgrading their remaining MAUS-IV units to capitalize on these new features.

The MAUS-V software features allow operators to rescan ambiguous areas at higher resolution during inspections, allowing operators and engineers to make better decisions regarding structural disassembly and repair. In addition, new c-scan algorithms were incorporated to remove geometric feature effects and highlight areas of corrosion. The new database system uses scaling factors to reduce system setup and calibration time for operators, which used to take up to six hours for some inspections. The improved MAUS-V hardware also provides better surface contouring around discontinuities, such as button head fasteners.

The enhanced ultrasonic and eddy current circuitry of the MAUS-V yields faster data processing capability and better depth resolution to assist operators in distinguishing near surface anomalies from surfaces. The advanced ultrasonic capabilities result from greater ultrasonic pulsing power then previous MAUS configurations. This feature allows operators to inspect components with low sound attenuation properties and gives a better signal to noise ratio while improving resolution. The successful transition of this automated ultrasonic and eddy current inspection technology demonstrates AFRL/ML's and ASC/AAA's dedication to improving the performance of aircraft inspection technologies. The system's transition also marks the completion of major milestones in the Enhanced Equipment for Material Thinning (TCORR) and MAUS Wiring Implementation (MAUS Wing) Programs. The TCORR and MAUS Wing programs are managed by AFRL/MLLP and AFRL/MLS-OL respectively, in conjunction with ASC/AAA and OC-ALC/MABPI (NDI production). The TCORR and MAUS Wing programs focus on improving NDI depot production capabilities and productivity by upgrading existing equipment and adding new features to improve data reliability.

The transition of the new MAUS-V system provides ALC personnel with new capabilities to map skin thicknesses throughout wing and fuselage surface structures. This feature allows engineers to record and monitor changes in structural integrity based on changes in skin thickness, when such things as corrosion or patch repairs are made throughout the life of the component. The new depth resolution ability will assist production personnel and engineers in distinguishing material anomalies from adjacent near and back surfaces on complex composite and metallic aircraft structures. The faster data processing capability of the MAUS-V will reduce some KC-135 inspection times up to 50 percent. In addition, the new database features of the MAUS-V will reduce some system calibrations and setups by 60 percent over the previous MAUS-IV. All of these new features equate to large maintenance cost avoidances for OC-ALC during aircraft PDM cycles.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 03-201.

ML Scientists Conduct Biomineralization Research

Scientists at the Air Force Research Laboratory Materials and Manufacturing Directorate (ML), working with research associates at Genencor, Inc., and Trinity University in San Antonio, Texas, have made significant advancements in the quest for new materials for advanced structures using processes borrowed or adapted from living organisms.

One of their principal areas of concentration is "biomineralization," the biological process by which organisms form minerals used to make hard tissues such as bone, teeth and shell. Working at the billionths-of-a-meter scale, the researchers have successfully demonstrated that various types of minerals can be created via laboratory experimentation (*in vitro*) and that the size, shape and other defining characteristics of the crystals that form them can be partially controlled.

A mineral is a naturally-occurring homogeneous inorganic substance with a specific chemical composition and a characteristic crystalline structure, color and hardness, like gold or silver, or a mixture of inorganic compounds, like granite. In living organisms, minerals make up the hard tissues, including bones and teeth and for some organisms, a protective shell.

The mineral crystals ("biominerals") formed by living organisms are created at physiological temperatures; hence, the ability to mimic the transformation of inorganic molecules into nano- and micro-structured components *in vitro* at low temperatures provides a critical incentive for the Air Force materials science research community.

Research at the ML Survivability and Sensor Materials Division supports the notion that biomineral properties such as particle size, shape, crystal orientation, polymorphic structure, defect texture, and particle assembly can be controlled or at least partially controlled. This control is exercised through specialized proteins that recognize specific crystal surfaces during the growth of the crystals. Recognition is based on complementarity at the molecular level between the protein and the crystal structure on defined planes.

Duplicating complex cellular processes would be extremely difficult. Fortunately, the materials chemistry aspects of biomineralization can be studied using model systems. One particular aspect of interest to the materials chemist is the means by which these organisms use organic constituents to mediate the growth of the mineral phase. Examples are macromolecular templates, used to direct the nucleation event, vesicular compartments that delineate particle size and shape, and solubilized proteins that help regulate the kinetics of crystal nucleation and growth.

Scientists have capitalized on some of these concepts to produce novel materials. The self-organizing ability of amphiphilic molecules, for example, has been used to direct the nucleation and growth of inorganic materials precipitated in their presence, such as in the fabrication of mesoporous ceramic thin films, organized arrays of nanoparticles, and microlaminated structures. Biopolymers and their synthetic analogues are used in industrial processes requiring water treatment and particle manipulation. Examples are polypeptides, used as biodegradable dispersants, flocculents, absorbents, anti-scalants, and crystal growth modifiers.

The current biotechnology effort within ML began with funding in 1998. Initially focusing on snake-based infrared detection, the effort has grown to encompass the broader potential that biotechnology possesses when integrated with materials science. This growth has been incremental, beginning with expansion into other biological models of infrared detection. In 1999, it became essential to begin work in polymeric micro-fabrication so that proteins uncovered in the infrared portion of the work could be maintained and presented *in vitro*. Also that year, a proposal was submitted to begin examining biological chromophores. Finally, in 2000, work was initiated in the area of biological inorganics.

The understanding of biomineralization processes is highly relevant to research on advanced materials. Biology provides an insight into unconventional strategies of a degree of sophistication yet unconceived in man-made materials, and continued research in these and related fields could lead to significant advancements both in the understanding of the nature world and of direct benefit to the Air Force and national defense.

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Grease (continued from page 1)

rusting challenges that plagued the landing gear of the C-5, ML researchers, including Gschwender, Snyder and Dr. Shashi Sharma, determined that a MIL-PRF-32014 qualified grease could offer improvements in the landing gear. "The C-5 landing gear is regularly exposed to moisture and rain, air, bacterial decontaminants, and other corrosion and wear encouraging phenomena, which at times cause significant problems for operators, and challenges for systems maintainers," Gschwender said. While AMOCO was unavailable to manufacture the grease, Nye Lubricants, a small business that specializes in specialty lubes, commercialized a qualifying grease called Rheolube 374A.

AirBP also has a grease qualified to the MIL-PRF-32014 specification they call Aeroplex 3214. The two current suppliers were attracted to the potential larger volumes offered by use in the C-5 aircraft, Ms. Gschwender said. "MIL-PRF-32014 is expected to cost less than $100 per gallon and to provide the desired improvement in performance over both the original grease and the contractor recommended grease," she added.

In late November and early December 2003, experts at Dover's Equipment Maintenance Squadron, who provide maintenance to the C-5 fleet beyond normal flight line servicing, conducted an isochronal inspection of the C-5 aircraft where the ML-developed grease was in use. The parts were observed and grease samples were taken for analysis by ML personnel at their facilities at Wright Patterson AFB.

After examining the parts, and showing maintenance specialists test coupons with differing greases to demonstrate how they perform, aircraft authorities agreed to change the technical orders for the C-5 to enact conversion to the new grease in all grease lubricated aircraft applications.

"The consensus of Dover's maintenance operation specialists was that the conversion to MIL-PRF-32014 should occur as soon as possible," Ms. Gschwender said. "We also expect the grease to improve performance in other areas of the aircraft, and to replace many currently used military greases. This grease has demonstrated the potential to become 'near-universal.'"

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 03-559 .

Materials, Manufacturing & Enabling Technology Series (MMETS)

April 8, National Composites Center, 4 p.m.

Dr. Edwin (Ned) Thomas, MIT Institute for Soldier Nanotechnologies, will address how advanced nanotechnology research will improve the survival of the soldier of the future, at the next meeting

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