Thermoplastic Powder Coating Hits the Beach

by **Fred Allen,**
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A recently developed coating repair method has been accepted by the United States Marine Corps as a means of saving millions of dollars in remanufacturing costs. The Light Armored Vehicle (LAV) is an eight-wheeled amphibious reconnaissance vehicle used by the United States Marine Corps for a variety of functions, including security, command and control, reconnaissance, and assault (*Figure* 1). The LAV operates on land and in water, carries communications equipment, and provides a weapons platform.

Considering the demanding operating conditions of LAVs, these vehicles require coating materials that can withstand humidity, temperature, impact, wear, and corrosion. The drive shaft, for example, is coated with Nylon 11, a material known for its toughness and weatherability.

Figure 1—Marine Light Armored Vehicle.

In 2004, 80% of the LAV drive shafts were being scrapped at the Marines' Albany Maintenance Center because of the Nylon 11 coating disbonding from the metal. A team from Rochester Institute of Technology (RIT) led by Prof. Michael Haselkorn developed a remanufacturing process using a novel thermoplastic powder to repair the damaged Nylon 11 coating,[1] enabling the drive shafts to be reused and saving the Marines $1.5 million each year.

Remanufacturing the drive shafts using Nylon 11 coating was not feasible because the drive shaft contains a U joint which could not be removed and a Nylon 11 coating on the inner diameter spline. Reapplying the Nylon 11 was not an option, because the Nylon 11 coating will not melt and flow evenly unless it is applied at temperatures above 365°F. At those temperatures, both the U joint and Nylon 11 coating on the ID will be damaged. Abcite®[2], an Alternative Thermoplastic Powder (ATP) was selected for this remanufacturing application because it melts at a significantly lower temperature (183°F) than the Nylon 11 and has similar or better physical and mechanical properties. Accordingly, it could be applied

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[1] Haselkorn, M., "Remanufacturing," Presented at 2007 Defense Manufacturing Conference, Sustainment/Readiness Technical Session, December 4, 2007.

[2] Abcite is a thermoplastic powder coating product made by Axalta Coating Systems, Houston, TX.

to the outer diameter of the shaft without damaging the U joint or existing Nylon 11 coating on the spline.

In the remanufacturing process developed by Prof. Haselkorn and his team at RIT, the Abcite ATP was deposited on the outer diameter of the drive shaft using a flame spray process (*Figure* 2). In this process, the ATP was fed into a flame, where it was melted and applied to the surface. Once applied to the surface, the ATP quickly cooled and hardened. After application, it was machined to the proper print dimensions.

By developing tests to simulate real life conditions, the Center for Remanufacturing and Resource Recovery (C3R) at RIT was able to demonstrate to the Marines that the wear, corrosion, and impact resistance of Nylon 11 and the ATP coating are very similar.

The wear resistance of the ATP coating on the remanufactured LAV drive shafts was determined using a special fixture, designed and built at RIT (*Figure* 3). The test fixture simulated the movement of the drive shafts by opening and closing the coated shafts 3.25 in. using an air cylinder. The wear resistance of the coating was determined by opening and closing the drive shafts in sand, and corrosion resistance was determined by actuating the shafts in a mixture of water and sand. During each test, three ATP-coated and one Nylon 11-coated drive shafts were tested in the fixture. The performance of the ATP coating was then compared to the performance of the Nylon 11 coating when applied and tested separately.

Two wear tests were run. One test consisted of opening and closing the shafts for 26,000 cycles in sand, while the second test actuated the cylinders 25,000 cycles in sand. Wear measurements were taken after every 6,000 cycles (first test) and 5,000 cycles (second test). These wear measurements consisted of measuring the outer diameter of the shafts coated with the ATP coating and with Nylon 11. The results of these wear tests are shown in *Figures* 4 and 5.

The wear test results show that the ATP coatings suffered less or equal wear compared to the Nylon 11 coating. In Trial 1, the ATP-coated shafts recorded approximately half the wear of the Nylon 11-coated shafts. In Trial 2, the amount of wear for the two coatings was essentially equal. Thus, these two limited trials showed that, at the very least, the ATP coating had wear resistance in sand equal to or better than the Nylon 11.

Photomicrographs of the Nylon 11 and ATP coatings after 25,000 cycles in sand are shown in *Figures* 6 and 7, respectively. The images show abrasive wear on the coated shafts caused by sand

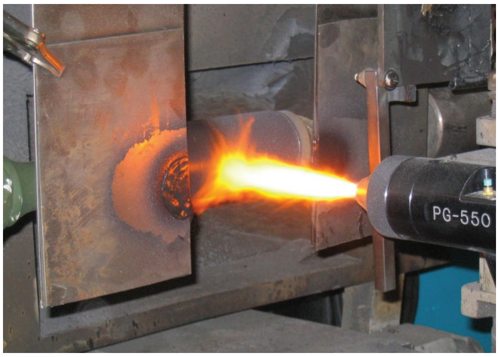

Figure 2—Flame spraying Abcite ATP coating.

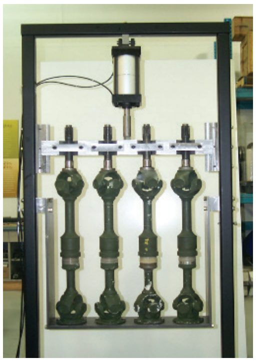

Figure 3—Drive shaft test fixture.

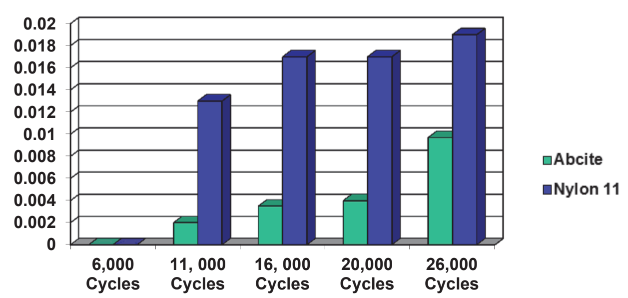

Figure 4—Wear of ATP coating and Nylon 11 coating in sand: Trial 1.

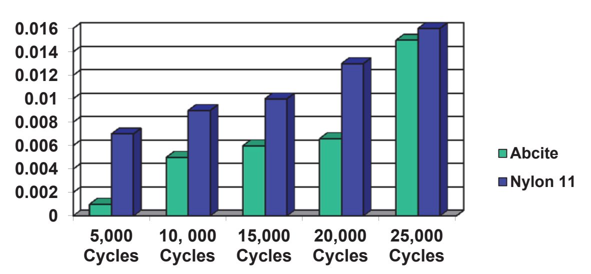

Figure 5—Wear of ATP coating and Nylon 11 coating in sand: Trial 2.

The U.S. International Trade Commission defines remanufacturing as an industrial process that restores end-of-life goods to original working condition or better (Investigation 332-525, USITC Pub 4356, Oct. 2012). The remanufacturing process consists of complete disassembly of the product. Each part is then cleaned and inspected. If required, each part is reconditioned or replaced. Next, the product is reassembled and tested to ensure it meets or exceeds the original product's specifications.

particles being trapped in a seal and damaging the coated surface. While both the Nylon 11-coated shafts showed coating striations caused by the abrasion (*Figure* 6), this type of wear was not typical for the ATP-coated shafts and was observed on only one of the six ATP-coated shafts tested. *Figure* 7 shows an undamaged ATP-coated shaft after 25,000 cycles and *Figure* 8 shows striations confined to a small region on one ATP-coated shaft. These results indicate the superior wear resistance of the ATP coating.

The corrosion resistance of the ATP coating was further evaluated by actuating two remanufactured cylinders in water for 40,000 cycles and then keeping the coated shafts submerged in water for an additional 50 hr. *Figure* 9 shows that after the testing there was no disbonding or rusting beneath the ATP coating. Any rust observed on the ATP coating, which was caused by rub-off of the rust on the test fixture, was easily removed by wiping the coating with a dry cloth (see inset images in *Figure* 9).

The impact resistance of the ATP coating was determined by hitting the coating with a hammer and then actuating the drive shaft 120,000 cycles. One of the affected remanufactured shafts is shown in *Figure* 10. This figure shows that even through striking the coating with the edge of a hammer (hitting the coating with the flat face of the hammer had little effect), the coating did not disbond or spall from the surface of the driveshaft either during impact or after being actuated for 120,000 cycles.

Abcite thermoplastic powder is based on high performance ethylene-based resins with chemical compositions specifically designed to provide outstanding durability and lasting adhesion to metal and other substrates. Coatings made from this material provide excellent corrosion, UV, chemical, impact, and chip resistance.

Typical uses of Abcite coatings include protection of automotive components, road signs and light poles, offshore and seaside structures, and battery boxes. Other applications involve demanding environmental or operating conditions. These coatings contain no volatile organic compounds (VOCs) and require no primer, making them a sustainable alternative to liquid coating systems and galvanized steel. Examples of other remanufacturing opportunities for which these coatings can be considered include replacement of solvent-based coatings (to reduce VOCs) and replacement of waterborne coatings (to reduce drying time and cost). CT

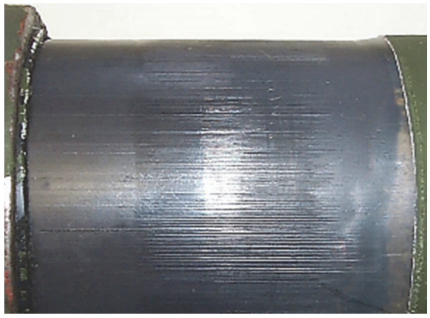

Figure 6—Damaged Nylon 11 coating after 25,000 actuations in sand.

Figure 7—Undamaged ATP coating after 25,000 actuations in sand.

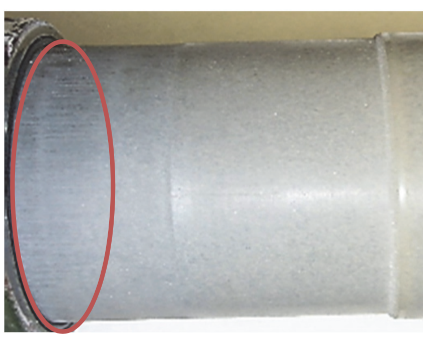

Figure 8—Slightly abraded ATP coating after 25,000 actuations in sand.

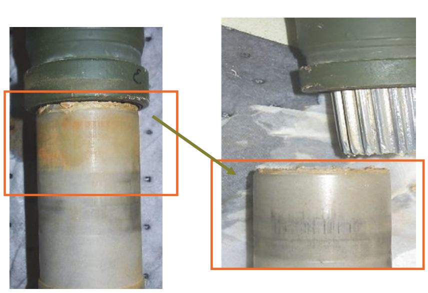

Figure 9—Repaired drive shaft after actuation and soaking in water.

Figure 10—ATP coating after impact and testing.

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