COLD SPRAY REPAIR SERVICES
Moog Inc. is best known as a worldwide designer, manufacturer, and integrator of precision motion control products and systems. While very proud of the core business that we’ve built, our capabilities go well beyond servo-valves and hydraulic actuation – expanding to cold spray repair, additive manufacturing, integrated logistics services, reverse engineering and more, and benefiting military and commercial aircraft customers, defense manufacturers and other industries.

COLD SPRAY REPAIR CAPABILITIES

For decades, both new part manufacturers and end users have tried to find repair solutions for corroded and damaged parts. Replacement parts are expensive and usually have long lead times. As a result, maintainers often prefer repairing versus replacing.

Many processes have been developed to repair damaged parts, but these may induce undesirable thermal stresses that can result in premature failure. Over the past several decades, experts from around the world have been looking for alternatives. One innovative solution is a process called Cold Spray – an additive manufacturing process that uses metal powders accelerated to supersonic speeds to restore the original substrate without inducing thermal stresses. This process is being widely used in the automotive, industrial, and industrial marketplaces and is ideal for aerospace materials like magnesium, aluminum and titanium, as well as other alloys.

BEARING SUPPORT COVER

Top: as received
Top: repaired & machined
Bottom: as received
Bottom: repaired & machined
WHAT IS COLD SPRAY?

Cold Spray is an advanced additive manufacturing process for metal surfaces that does not induce thermal stresses into the parent or deposited material. Its unique properties are compatible with many aerospace materials.

What makes Cold Spray so unique? Unlike other repair processes that use heat to fuse materials together, Cold Spray uses a compressed gas to accelerate metal powders to supersonic speeds and impinge them onto the substrate. The resulting surface can be made comparable in strength to the original substrate.

Cold Spray is a material deposition process in which relatively small particles (ranging in size from approximately 5μm to 100μm in diameter) in solid state are accelerated to a critical high velocity (typically 300-1400m/s), and are subsequently plastically deformed to develop a deposit on a metallic substrate.

HOW COLD SPRAY WORKS

Cold Spray repair is generally performed using low or high pressure systems, through the use of a handheld, portable system or a stationary system in a ventilated work chamber.

Low Pressure Systems: These systems are used in the application of lighter materials. Low pressure Cold Spray systems are typically much smaller, portable, and are limited to 300-600 m/sec particle velocities. Metallic powder is injected after the nozzle throat (diverging section). Low pressure systems generally utilize readily available air or nitrogen as propellant gases. Low pressure Cold Spray is typically used to repair minor surface defects, blemishes, etc.

High Pressure Systems: These systems provide significantly enhanced capabilities, enabling the use of additional materials and provide dramatic improvements in process characteristics and performance. High pressure Cold Spray systems utilize higher pressure gases, are stationary, and typically generate particle velocities of 800-1400 m/sec. Metallic powder is injected before the nozzle throat after which the gas is expanded through a converging/diverging nozzle. Lower weight gases, such as nitrogen or helium, are the preferred propellant gases. High pressure Cold Spray is used for more complex repairs and/or where increased deposition adhesion and elongation properties are required.
For nearly a decade, Moog has worked closely with the US Army Research Lab (ARL), which is designated as the DoD’s expert in Cold Spray. Moog has extensive experience using Cold Spray to repair commercial and military aerospace components, and is uniquely positioned as the technology leader, having successfully demonstrated repairs to corroded areas, wear damage and manufacturing defects on hard-to-repair magnesium and aluminum parts including: transmission gearboxes, sump housings, engine components, flap transmission housings, nose wheel steering actuators, landing gear components, and more. Moog is currently approved by OEMs including Boeing, Bell Helicopter, and Sikorsky Aircraft to provide component Cold Spray repairs, as well as by other customers such as Heli-One, Hawker Pacific, and Lufthansa Technik.

COLD SPRAY IS IDEAL FOR MANY SITUATIONS:

- Repairing corrosion damage
- Recovering mis-machined parts
- Improving wear resistance
- Restoring worn/damaged features
- Preventing corrosion damage
- Surface build up
- Providing conductive properties
- Improving dielectric properties
- Thermal management coatings
- Enhancing surface conductivity
MOOG PROVIDES COMPREHENSIVE COLD SPRAY SERVICES

Moog is actively involved in continually advancing Cold Spray technology and applications. We continue to develop, qualify, certify and acquire approval of Cold Spray repairs for both fixed and rotary aircraft components for commercial and military customers. Repairs are developed and conducted by skilled and experienced personnel. Our material specialists are ASM International Certified Thermal Spray Operators in Cold Spray. Moog also has available metallurgical engineers and can establish FAA Designated Engineer Representative (DER) approved Cold Spray repairs.

Actual testing has demonstrated that Moog meets or exceeds all current Cold Spray testing criteria, as shown in the table below for Aluminum 6061 on magnesium substrate.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Minimum Success Criteria</th>
<th>Actual Moog Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro examination</td>
<td>No excessive or massive oxides or voids</td>
<td>Negligible oxide (powder remains solid state)</td>
</tr>
<tr>
<td>Porosity</td>
<td>&lt; 2% when viewed at 100x</td>
<td>&lt;0.50% porosity</td>
</tr>
<tr>
<td>Bond Strength (per ASTM C633)</td>
<td>10 ksi minimum</td>
<td>&gt;20 ksi</td>
</tr>
<tr>
<td>Elongation (per ASTM E8)</td>
<td>3% minimum</td>
<td>3-5%</td>
</tr>
<tr>
<td>Triple Lug Shear (per MIL-J-24445A)</td>
<td>N/A</td>
<td>20 ksi</td>
</tr>
<tr>
<td>Ultimate Tensile Strength of Bulk AA 6061 Cold Spray</td>
<td>Cast magnesium</td>
<td>38-41 ksi</td>
</tr>
<tr>
<td></td>
<td>UTS 20-41 ksi</td>
<td></td>
</tr>
</tbody>
</table>

MOOG OFFERS AN ARRAY OF COATING POWDERS

As one of the only commercial facilities operating both high pressure and low pressure systems, Moog has the ability to spray a wide array of coating materials. With a variety of materials comes a variety of critical velocity requirements... the more pressure, the more velocity. Our wide array of equipment coupled with our extensive range of coating materials ensures we meet your unique repair requirements. Moog has the capability to spray numerous types of powders, some of which are listed below:

- Aluminum
- Brass
- Bronze
- Copper
- CRC-NiCr
- Inconel
- Monel
- Nickel
- Niobium
- Silver
- Steel
- Stainless Steel
- Tantalum
- Tin
- Titanium
- Zinc
- Zirconium

MOOG OFFERS VALUE-ADDED COLD SPRAY SERVICES

Moog operates two state-of-the-art Cold Spray facilities, one in West Fargo, North Dakota and the other in Webster, Massachusetts, both of which are FAA Part 145 Repair Stations, with ISO9001 certification and an AS9100 certificate. Moog can offer a range of services from the simplest Cold Spray applications to complete “turnkey” component repairs which include:

- Surface preparation/pre-machining
- Cold Spray application
- Post machining
- Surface finishing
- Anti-corrosion coating
- In-house metallurgical material analysis
- Final inspection
- DER Approved; Repair Substantiation
COLD SPRAY EXAMPLES

CORROSION REPAIR TO PT-6 REDUCTION GEARBOX HOUSING

**Challenge:** The reduction gearbox housing experiences widespread corrosion on the outer wall and the mating surfaces, resulting in it being taken out of service.

**Solution:** Moog used Cold Spray technology to repair the corroded wall and sealing surfaces of the reduction gearbox housing including a corrosion through-hole.

**Customer Benefit:** Repairing this part with Cold Spray ensured that the coating is more corrosion and wear resistant. The customer saved a significant amount of lead time and the potential cost savings can be in excess of 70% of a replacement part.

CORROSION REPAIR TO S-92 SUMP HOUSING

**Challenge:** Corrosion caused severe surface pitting in several areas on the magnesium sump housing. Normally these castings would be scrapped.

**Solution:** Moog repaired the magnesium surfaces using a Cold Spray aluminum alloy.

**Customer Benefit:** Repairing this part with Cold Spray ensured that the coating is more corrosion and wear resistant. The customer saved a significant amount of lead time and the potential cost savings can be in excess of 70% of a replacement part.

KC-135 INTEGRATED DRIVE GENERATOR HOUSING

**Challenge:** The integrated drive generator housing experiences extreme corrosion damage in multiple locations, which is a major maintenance problem that requires constant and costly attention.

**Solution:** Moog used Cold Spray technology to repair the corroded zones on the IDG housing, thus salvaging the component and expediting the process of installment. Tinker Air Force Base has approved Moog's Cold Spray repair procedure for the IDG housing.

**Customer Benefit:** The benefit is the ability to salvage corroded and damaged components that are beyond serviceable condition. Cold Spray can be utilized to repair the corrosion and damage found during periodic maintenance and evaluation. Salvaging the parts utilizing Cold Spray will reduce the need to purchase new components and decrease the downtime of the aircraft due to the long leads times associated with producing complex and expensive magnesium housing.
REPAIR OF CASTING DEFECT FOR HELICOPTER TRANSMISSION HOUSING

**Challenge:** A magnesium casting suffered manufacturing defects (casting porosity) during the casting process.

**Solution:** Moog restored the part using a Cold Spray 6061 aluminum powder.

**Customer Benefit:** The approach repaired a previously unidentified void between manufacturing steps and salvaged an expensive part that otherwise would have been scrapped.

AIRCRAFT WHEEL REPAIRS – NUMEROUS TYPES

**Challenge:** Aircraft wheels experience corrosion and wear damage, primarily to the mating surfaces of the inboard and outboard halves of the wheel assembly. This wear or corrosion will result in wheels being removed from service.

**Solution:** Moog uses Cold Spray technology to repair the corroded or damaged mating surfaces, or other damaged features on the wheels to restore to serviceable condition.

**Customer Benefit:** Utilizing Cold Spray to damaged wheels identified during normal service activities provides an approved repair that recovers wheels that would have been scrapped.

T700 ENGINE FRONT HOUSING

**Challenge:** The T700 particle separator and UH-60 sump front frame experiences corrosion and wear to the mating surface resulting in the part being removed from service and requiring a replacement part.

**Solution:** Moog used Cold Spray technology to repair the corroded sealing surface of the sump housing, thus salvaging the component. The U.S. Army approved this Cold Spray repair via MEO B 1671 with Moog as the only approved Cold Spray source.

**Customer Benefit:** Utilizing Cold Spray to repair corrosion found during periodic maintenance and evaluation provides the ability to salvage parts that have been corroded or worn beyond standard maintenance limits.