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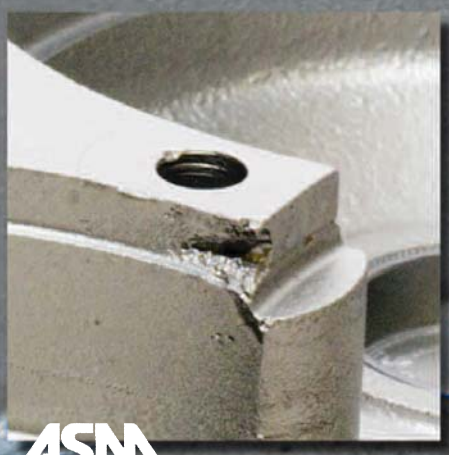
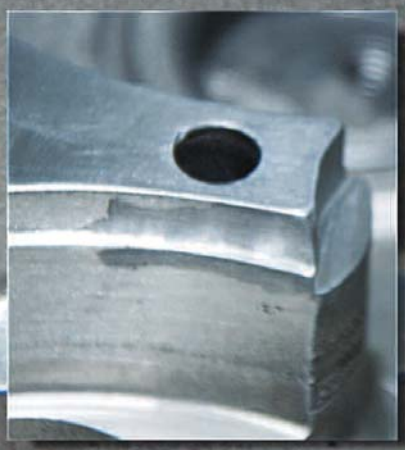
THE OFFICIAL NEWSLETTER OF THE ASM THERMAL SPRAY SOCIETY

Thermal Spray's Role in Emerging Technologies

Aircraft Part Restoration via Cold Spray

JTST Highlights Society News





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Practical Cold Spray Success: Repair of Al and Mg Alloy Aircraft Components

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Cold spray is one of the many names for describing a solid-state coating process that uses a high-speed gas jet to accelerate powder particles toward a substrate to form a coating or deposit. The term "cold spray" refers to the relatively low process temperature involved in the process, which is typically much lower than the melting point of the spray material. Although the concept of cold spraying metal powders onto substrates goes back to the early 1900s, it was not until the 1980s that the applicability of this technology was demonstrated and patented by the Institute of Theoretical and Applied Mechanics of the Academy of Sciences in Novosibirisk[1] (high-pressure cold spray) and then by the Obninsk Center for Powder Spraying (OCPS)[2] (low-pressure cold spray) in the former Soviet Union.

In traditional cold spray equipment, pre-heated air, nitrogen, or helium at a certain pressure is injected into a converging-diverging (DeLaval) nozzle to allow the conversion of enthalpy into kinetic energy and produce the acceleration of the gas to supersonic speeds. The powder feedstock can be introduced upstream in the case of high-pressure cold spray, or downstream into the diverging section of the nozzle in the case of low-pressure cold spray (Fig. 1).

Every material displays a critical minimum level of kinetic energy above which acceptable bonding occurs. Typically, the higher the melting point and mechanical strength of the powder, the more kinetic energy is required to produce acceptable bonding. The type of gas, gas pressure, and gas temperatures determine the amount of energy available to accelerate the feedstock powder. High gas pressures and temperatures with helium provide maximum energy levels. However, there are economic implications as well as equipment portability limitations. Low melting-point and ductile materials, such as aluminum, copper, zinc, and others, can be successfully cold sprayed using lower pressures, gas temperatures, and less expensive carrier gases including nitrogen or air. Low-pressure cold spray equipment enables the ability of spraying these materials at low cost and with high flexibility.

Because adhesion of the metal powder to the substrate and deposited material is achieved in the solid state, the characteristics of cold-spray deposits are quite unique, making cold spray a suitable process for depositing a wide range of materials on many types of substrates, especially in non-traditional applications that are sensitive to the temperature of the process. Some of the characteristics of cold sprayed deposits include extra low oxygen content, no residual tensile stresses, no grain growth, and no phase change. Certain materials may even experience extreme grain refinement at the nanometer scale. These attributes make cold spray uniquely suitable for depositing a range of advanced and temperature-sensitive materials.

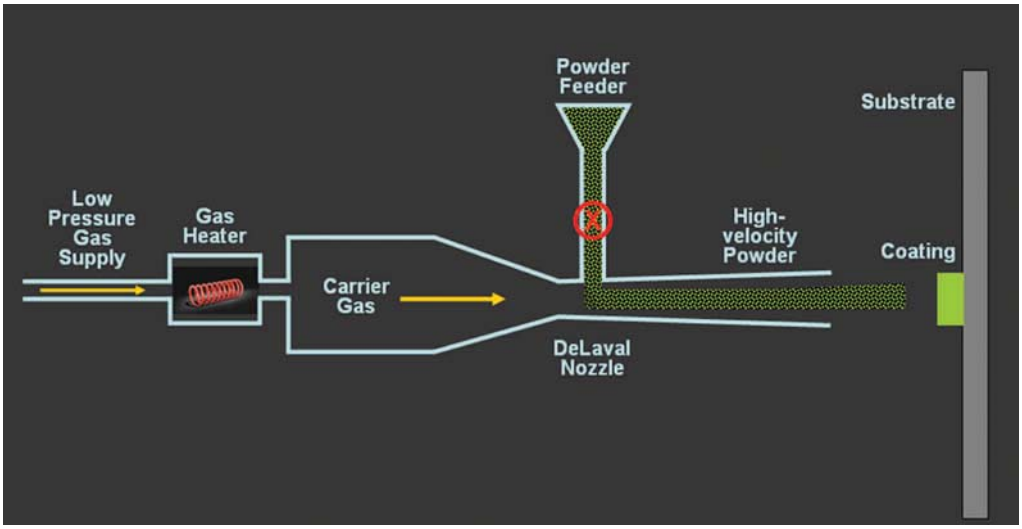

Fig. 1 — *Schematic of the low-pressure cold-spray system.*

Aircraft Practical Applications: Mg and Al Challenges

Magnesium is the lightest of all structural metals, being 35% lighter than aluminum and 78% lighter than steel. Aluminum and magnesium casting alloys are widely used in aircraft components because of their inherent weight advantages over other metals. Premature failure due to corrosion is one of the main challenges associated with these alloys, which affects the safety and readiness of aircraft. Examples of these components include rotorcraft transmission, gearbox housings, mast supports for helicopters, and control comfort actuators (Gimbals), to name a few. Most of these parts could not be reclaimed adequately because, although there is existing technology that could somewhat restore them, these repairs are often inappropriate

due to excess porosity, oxidation, and thermal damage. Because part replacement is often the only option, the cost of aircraft maintenance has significantly increased over the years. As an example, one common repair technique is the use of aluminum shims, which are adhesively bonded over ground down areas affected by corrosion. In response to this problem, the U.S. Army Research Laboratory (ARL) Center for Cold Spray has qualified cold spray as the process of choice to reclaim a number of magnesium components, which demonstrated significant technical and economical advantages over existing methods[3,4].

Aluminum-based metallic coatings for corrosion mitigation and restoration are some of the most common applications of low-pressure cold spray systems, given the favorable economics and portability of these systems. Because of its passivation behavior, pure aluminum provides superior general corrosion resistance compared to aluminum alloys and magnesium alloys. Cold spray represents an effective way to produce thick dense aluminum coatings onto a variety of substrates, including aluminum alloys, magnesium alloys, and steels, using minimum surface preparation, and without mechanically or thermally compromising the substrate properties (Fig. 2).

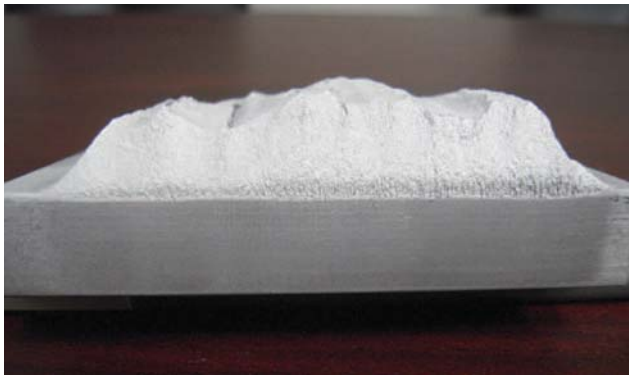

Fig. 2 — *Thick cold-sprayed deposit of aluminum on 6061 aluminum-alloy substrate.*

Fig. 3 — *Various stand-alone configurations of low-pressure cold-spray equipment including auxiliary components. Courtesy of CenterLine Windsor Ltd.*

Commercial Shop Takes the Lead for Cold Spray Repair of Aircraft Components

Working with large aerospace suppliers such as Honeywell, a thermal spray shop in Arizona has taken the industry lead to qualify cold spray as an adequate repair methodology for high value aircraft components made of aluminum and/or magnesium alloys, including gear box housings, inlet housings, and aircraft actuators. The shop uses commercially available low-pressure cold spray equipment (Fig. 3) to perform mechanical and corrosion repairs of these components following FAA-approved procedures. The components are then machined to required dimensional specifications. After machining, protective finishes, primers, and top coats can be successfully applied to the required areas.

One example of such repairs is the restoration of critical aircraft engine components, such as the one illustrated in Fig. 4. Many of these engine designs are used for propulsion, as well as APUs (auxiliary power units) and comfort support in commercial aircraft. These components are made of a variety of aluminum alloys including 6061, 7075, and other more exotic aluminum alloys. Frequently and during routine service they can experience corrosion damage that can be economically repaired using low-pressure cold spray (Fig. 4a). After basic surface preparation, the corroded area can be successfully restored using cold spray (Fig. 4b). This can include robotic motion to evenly apply a repair layer to the damaged surfaces. Thereafter, the affected area(s) can be machined and finished using standard shop methods (Fig. 4c and 3d). The density and bond strength of the repair typically exceed the minimum specifications for a metal repair. Currently, a military standard specification[3] and other private specification endeavors are developed to capture the benefits of this cold-spray application. Generally, thermal spray and welding techniques can be too intrusive to complete a repair reliably and economically. Therefore, in the case of aluminum, low-pressure cold spray has become a reliable repair technique that yields outstanding accuracy and economics.

Summary

Cold spray constitutes a family of emerging processes that expands on the capabilities of traditional thermal spray

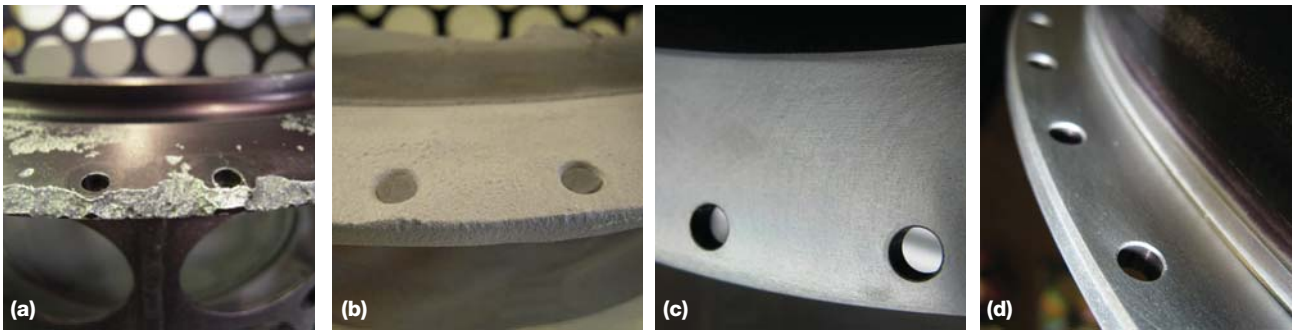

Fig. 4 — *Repair of an aluminum component in a utility engine for a private jet; (a) before with extensive corrosion damage; (b) as sprayed with aluminum; (c) as machined; (d) finished part.*

by going beyond into unique applications that are either technically or economically prohibitive using thermal spray. Cold spray can produce high quality thick metallic deposits of pure metals, alloys, and composites having extra low oxide content and negligible or no porosity. The commercial implementation of cold spray for repair of high-value aircraft components is undoubtedly a positive indication of the benefits of this novel technology, and will inevitably lead the way to further optimization of the process. **iTSSe**

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