Boeing 787 Dreamliner. Courtesy of Boeing.

NEW TRENDS IN AEROSPACE:

SAVING THE BOTTOM LINE WITH COLD SPRAY REPAIRS

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Cold spray is an effective method of depositing a variety of temperature-sensitive materials in specialized applications, such as high-value aerospace component repair.

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Cold spray is a solid-state coating process that uses a high-speed gas jet to accelerate powder particles toward a substrate where metal particles plastically deform and consolidate upon impact. The technique got its name from the relatively low temperature involved in the process, which is typically much lower than the melting point of both the spray material and substrate. The concept of "cold spraying" metallic materials onto substrates dates to the early 1900s. However, 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 Novosibirsk[1] (high pressure cold spray) and then by the Obninsk Center for Powder Spraying[2] (low pressure cold spray) in the former Soviet Union.

In cold spray equipment, air, nitrogen, or helium at prescribed pressures and temperatures is injected into converging-diverging (de Laval) nozzles to accelerate the gas jet to supersonic speeds. The spray material, in powder form, can be introduced upstream in the nozzle (high pressure cold spray) or downstream into the diverging section of the nozzle (low pressure cold spray) and is then propelled by the gas jet against a substrate at high velocities (Fig. 1). At a given impact temperature, each type of spray material requires a minimum level of kinetic energy, above which acceptable bonding to the substrate may occur. The type of gas, gas pressure, and gas temperature determine the amount of kinetic energy available to accelerate the particulate. Many common engineering materials can be successfully cold sprayed at relatively low pressures (less than 300 psi) and gas temperatures (below 600°C), by using nitrogen or air.

Metal powder adheres to the substrate and the deposited material is achieved in the solid state. Therefore, cold spray deposit characteristics are unique, making this technique suitable for depositing well bonded, low porosity, oxide-free coatings using a range of traditional and advanced materials on many types of substrates, especially in nontraditional, temperature-sensitive applications, such as high-value aerospace component repair.

COLD SPRAY IN THE AEROSPACE INDUSTRY

For many years, aluminum and magnesium alloys have been the materials of choice for use on both structural and nonstructural aircraft components including castings for housings of many aircraft components. Well-known performance characteristics, established fabrication methods, and recent technological advances are just a few reasons these alloys are still preferred. An aircraft lifespan often surpasses the commercial availability of standard replacement components. One challenge for the industry is that this obsolescence makes replacement components increasingly expensive or even impossible to obtain. Therefore, the ability to economically and reliably restore damaged components is an important necessity of aircraft maintenance.

Thermal spray processes, such as plasma or arc wire spraying, have traditionally been used to perform limited repairs on damaged aircraft components. However, excessive heat, porosity, distortion, oxide inclusions, and other issues associated with conventional thermal spray have prevented their widespread use in a vast number of aircraft repairs. In addition, the thermal spray plume is usually very wide and requires labor-intensive masking procedures to protect areas around the repair from overspray. Masking often represents a sizeable portion of repair costs.

Over the past decade, pioneering thermal spray shops serving the aerospace industry have developed numerous cold spray repair procedures to bring back to service hundreds of high-value aircraft components. This requires the ability to restore these components to the same quality standards as original OEM components while saving the industry millions of dollars.

REPAIR OF INTEGRATED DRIVE GENERATOR (IDG) HOUSINGS

One excellent attribute of cold spray technology is its ability to create well bonded, low porosity, oxide-free coatings in the solid state and at low temperatures. This is paramount when restoring tight tolerance aircraft castings made of magnesium and/or aluminum, which do not tolerate distortion. Over the past few years, the use of cold spray has seen a significant increase in the repair and restoration of housings for integrated drive generators (IDG), which are used in commercial aircraft such as the Boeing 737NG, 747, 777, and Airbus A320, A330, and A340 (Fig. 2).

An IDG is an in-flight power generation device that converts the variable input rotational speed of an aircraft engine into constant speed, which is used to drive an AC generator unit contained within the device. Ultimately, the IDG supplies constant frequency AC electrical power to the aircraft, greatly simplifying the design of the aircraft's electrical system.

Fig. 1 — Commercial downstream injection cold spray system. Courtesy of CenterLine Windsor Ltd.

Fig. 2 — Boeing 747 integrated drive generator (IDG). Courtesy of L.J. Walch.

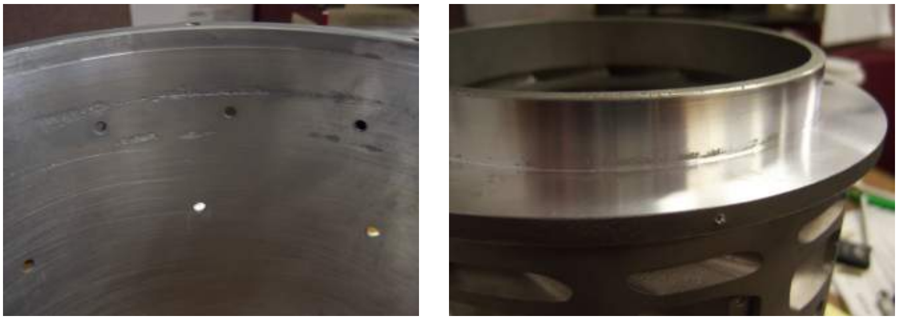

Fig. 3 — Pitting corrosion damage in a Boeing 747 APU generator housing. Courtesy of L.J. Walch.

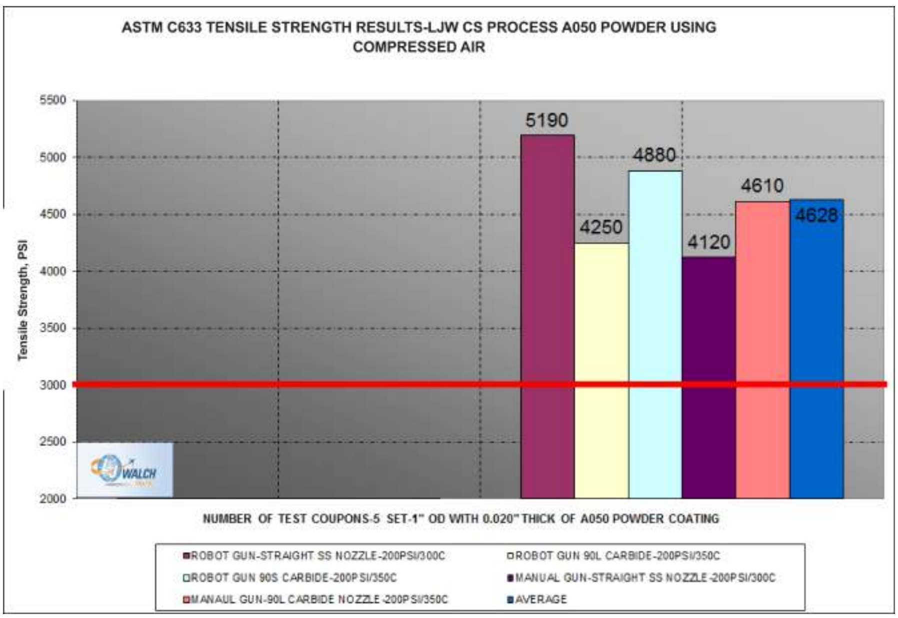

Fig. 4 — ASTM C633 qualification test results. Courtesy of L.J. Walch.

The device's complex casing is often made of magnesium or aluminum alloys. After years of service, the housing becomes worn or damaged beyond normal repair. Many failures are located at tight tolerance, heat-sensitive areas such as stator bores, exciter bores, pilots, mounting pads, and mating faces (Fig. 3). These areas are difficult to dimensionally restore using conventional thermal methods such as plasma flame spray. With the cold spray approach, these repairs are both feasible and economically viable.

PROCESS QUALIFICATION

With regard to IDG repairs, process qualification included selecting optimum cold spray grade powders (in this case, CenterLine SST A050) and process parameters to produce coatings within the required specifications. Validation was successfully obtained by ASTM C633 bond strength tests, metallographic examination, and 90° bend tests per the OEM's repair validation specifications (Hamilton Sundstrand SPR52). Bond strength results indicate that all test samples failed at stress levels well above the minimum level required (Fig. 4). Metallographic examination reveals a microstructure with porosity levels of less than 2%, no cracking, and no lack of bonding. A typical microstructure is shown in Fig. 5. Further, 90° bend tests with the coating in tension bent around a 0.25-in. radius exhibit no spalling or chipping.

REPAIR PROCEDURE AND QUALITY ASSURANCE

The following steps were taken to ensure proper surface preparation, repair, and inspection:

(a) Existing corroded and/or damaged surfaces were removed.

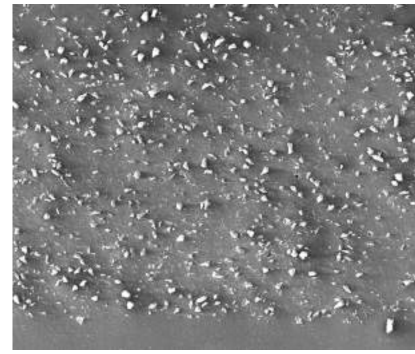

Fig. 5 — Microstructure of SST A050 cold spray composite deposit showing well-dispersed aluminum oxide particles in an aluminum matrix. No lack of bonding with porosity less than 2%. Substrate is aluminum 6061. Courtesy of CenterLine Windsor Ltd.

(b) Spray deposition was facilitated by pre-machining as necessary.

(c) Grit blasting or other methods were used to prepare surfaces and increase surface roughness.

(d) Robotic gun or manual cold spray took place (Fig. 6a).

(e) Repairs were post-machined per OEM engineering specifications (Fig. 6b).

(f) Visual and dimensional inspection occurred.

(g) Nondestructive examination took place.

(h) Painting and/or anodizing was performed as required to improve corrosion performance (Fig. 7).

The main justification for using cold spray in the restoration of these types of components is its ability to extend component lifespan at a fraction of their OEM replacement cost, assuming that the part is commercially available. In many instances, components are no longer available, thus making even stronger economic sense for cold spray restoration. Figure 8 shows examples of the relative cost of replacement of IDGs versus the cost of cold spray restoration to meet required OEM specifications.

CONCLUSION

Cold spray has become an essential tool that complements traditional thermal spray methods for repair and restoration of IDG housings used


(a)


(b)

Fig. 6 — Robotic cold spraying (a) and post-machining (b) operations.

in commercial aircraft. The process enables the aerospace industry to recover high-value and irreplaceable components that otherwise would be scrapped—at a fraction of their replacement cost—thus maximizing profitability. ~AM&P

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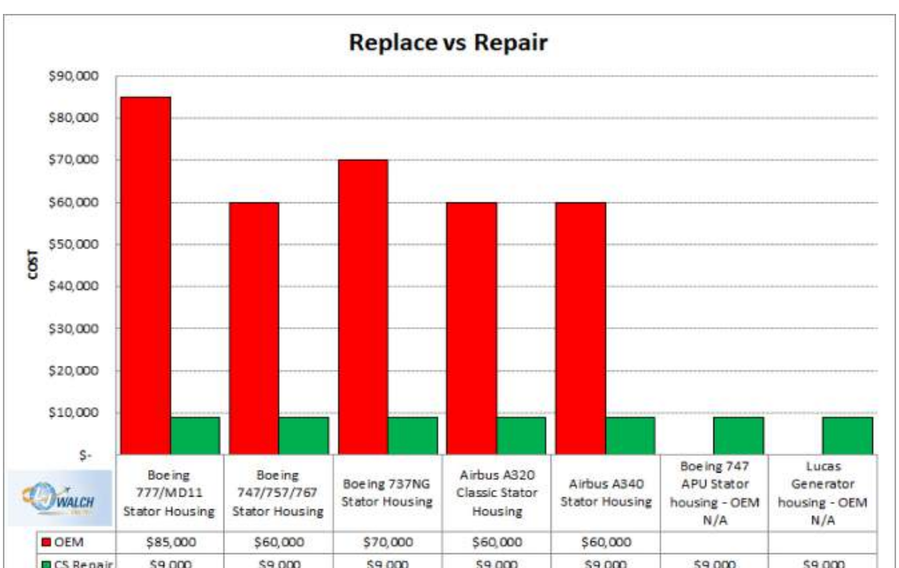

Fig. 8 — Relative cost of cold spray repair versus replacement for IDGs. Courtesy of L.J. Walch.


(a)


(b)


(c)

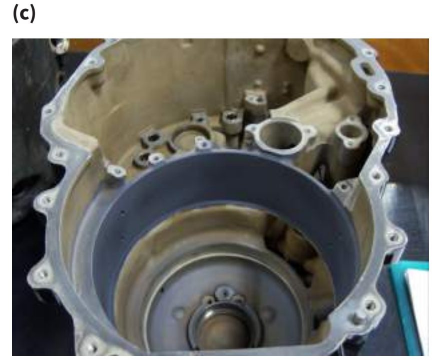
(d)

Fig. 7 — Repaired and finished components: (a) Pilot OD, (b) stator bore ID, (c) housing mating surface, and (d) housing bore. Courtesy of L.J. Walch.