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Cold Spray Technology

Industry Perspectives

**Engine-Driven
Welding Machines**

Historical Aircraft Soars with Cold Spray Technology

This process allows the restoration of vintage engines

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More than 70 years after first entering service, hundreds of vintage Chipmunk airplanes remain airworthy around the world, mainly as trainer aircraft. Repair and maintenance of many of their components remain a challenge due to lack of components as well as process temperature sensitivity. Fortunately, there is cold spray, a solid-state metal consolidation process that can be used to dimensionally restore components made of materials that are highly sensitive to elevated process temperatures.

In this article, a leaky engine casing of a Chipmunk vintage aircraft was successfully restored, for the first time, using cold spray technology. This study shows a step-by-step restoration procedure, which was then certified as a new repair procedure by Transport

Canada (TC), the Canadian organization responsible for safe air transportation policies and programs.

A History of the Chipmunk

The Chipmunk, named after a small Canadian chipmunk squirrel, is a post-war, vintage aircraft originally developed and manufactured in 1946 by De Havilland Aircraft of Canada Ltd. (De Havilland Canada), now part of Bombardier. The De Havilland Canada DHC-1 Chipmunk is a tandem, two-seat, single-engined primary trainer aircraft. During the late 1940s and 1950s, this aircraft was procured in large numbers by military air services, such as the Royal Canadian Air Force,

Royal Air Force, and several other nations' air forces, where it was used as their standard primary trainer aircraft.

Many of the Chipmunks that had been formerly in the military were eventually sold to civilians, either to private owners or to companies, where they were typically used for a variety of purposes, often involving their excellent flying characteristics and capability for aerobatic maneuvers.

However, spare components for these historical aircrafts are either scarce or price prohibitive, and repair technologies are not always available for maintenance of a variety of their components.

Restoration Challenges

Mechanical wear and tear had put a toll on the integrity of the engine casing of a Chipmunk DHC-1 aircraft. During overhaul of the Gipsy DH Major 10MK1-3A engine, following the Canadian Historical Aircraft Association's TC-approved *Maintenance Manual*, unacceptable cracking of a flange area and bolt holes of the lower crankcase and upper cover were discovered by the liquid penetrant nondestructive examination (NDE) method (Ref. 1) — Fig. 1. These cracks put the mechanical integrity of the engine at risk by allowing engine oil to leak out. One of the flaws included a through-thickness crack at the root of the flange, which caused detachment of the flange and thus eradication of one fastening post to the lower crankcase.



A Chipmunk aircraft repaired by cold spray. (Photo courtesy of the Canadian Historical Aircraft Association.)

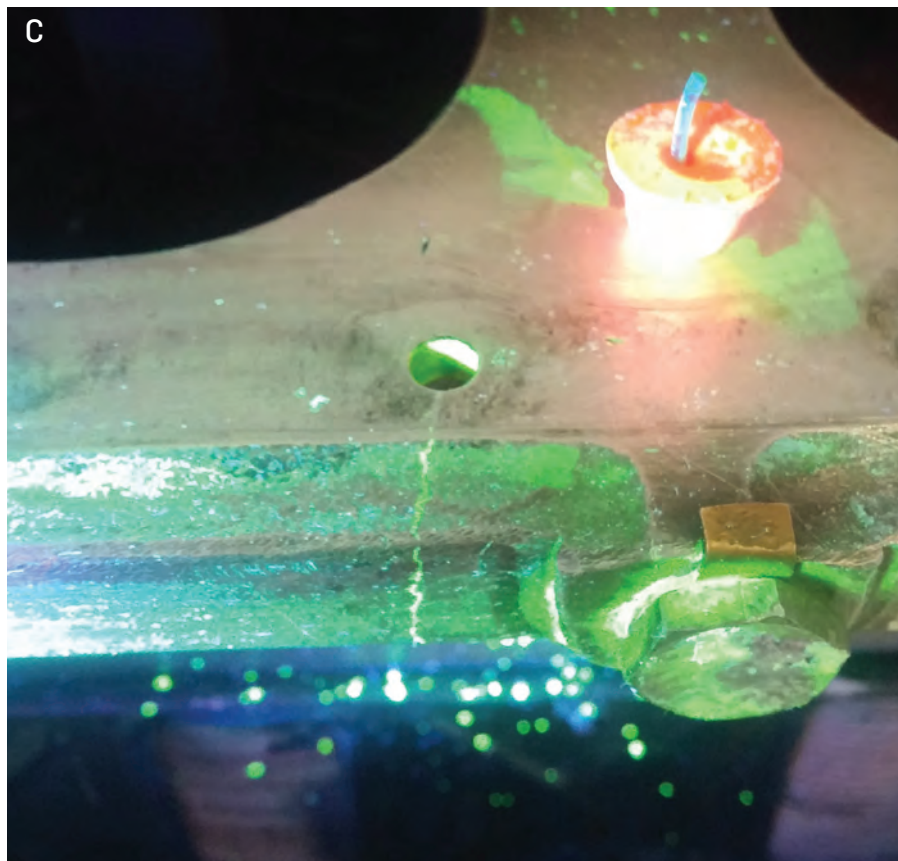
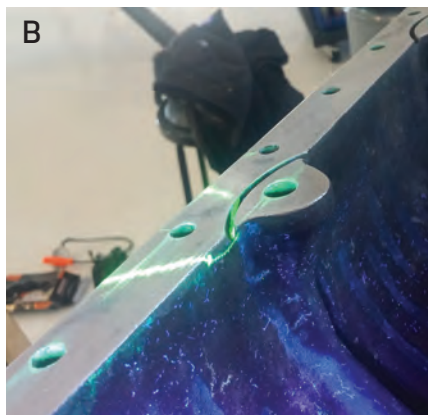


Fig. 1 — A — Gipsy DH Major 10MK1-3A engine overhaul; B — liquid penetrant NDE of the cover; C — liquid penetrant NDE of the lower crankcase.

The materials of the top cover and lower crankcase were magnesium and aluminum cast alloys, respectively, which would not tolerate elevated-temperature repair processes, such as welding.

Cold Spray Technology

Cold spray is a solid-state metal consolidation process that uses a high-speed gas jet to propel metal and other powder particles against a substrate where particles plastically deform and consolidate upon impact. The term cold spray refers to the relatively low temperature involved in the process, which is typically much lower than the melting point of the spray material and substrate. In the Supersonic Spray Technologies (SST™) cold spray equipment, air can be used as a propellant gas and temperatures will be low enough not to thermally disturb the substrate material. After low-temperature dimensional restoration of the area, the new consolidated material can be effectively machined back to tolerance using standard machining techniques. SST cold spray

offers the ability of all-metal consolidation for dimensional restoration in both manual and robotic applications — Fig. 2.

The Repairs Take Off

Both the top cover and the lower crankcase were assessed for restoration by cold spray. Due to the already weakened condition of the material, it was recommended that both the cracked flange at the cover and the cracked region on the lower crankcase be completely removed.

The missing features were rebuilt using the SST cold spray process, following the recommendations of MIL-STD-3021(2), *Department of Defense Manufacturing Process Standard: Materials Deposition, Cold Spray*, for nonstructural repair (Ref. 2). A specific repair procedure was developed in conjunction with TC, which included simulation trials of the free-form rebuild to ensure the viability of the repair — Fig. 3. The pre qualified spray material recommended for this repair was a mixture of 99.5% aluminum par-



Fig. 2 — Commercial SST Series P cold spray system.

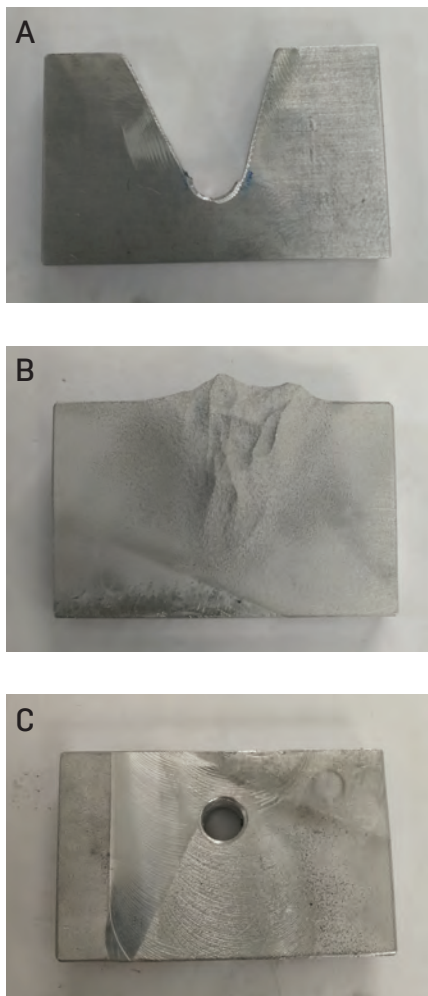


Fig. 3 — Simulation coupons. A — Before spraying; B — as sprayed; C — machined to tolerance.

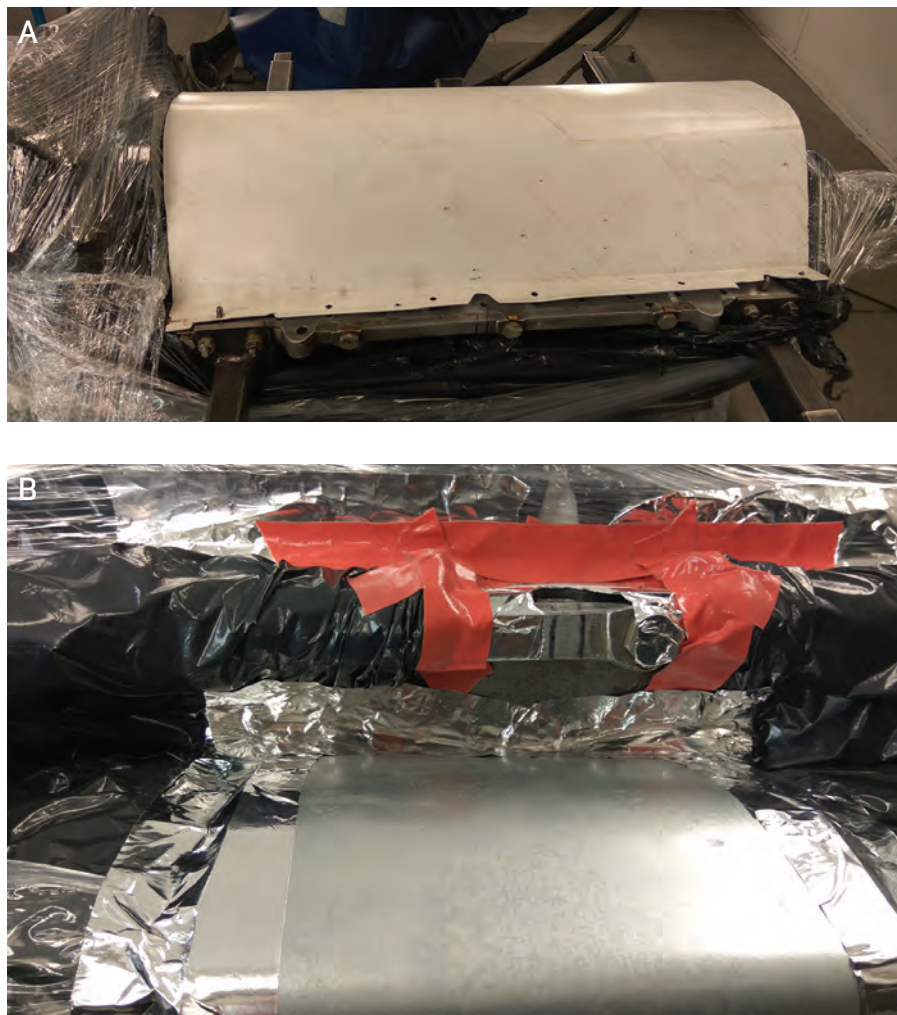


Fig. 4 — Ready the engine lower crankcase prior to the repair procedure. A — A custom-fabricated hard mask; B — a polymeric wrap mask around the work area.

ticles and 99.0% aluminum oxide particles. When sprayed using the parameters in Table 1, the material met the requirements of ASTM C633, *Standard Test Method for Adhesion or Cohesion Strength of Thermal Spray Coatings*, yielding cohesive/adhesive strengths higher than 6000 lb/in.² with densities higher than 99.5% (Ref. 3).

During the actual repair, the lower crankcase needed to be carefully masked to protect engine components during spraying and post-machining as well as avoid any kind of engine tear

down or disassembly. Masking included dual hard mask and polymeric wrapping — Fig. 4.

The final repair procedure was approved under TC Standard 625, *Aircraft Equipment and Maintenance Standard — Canadian Aviation Regulations*, and documented. The new TC repair procedure “specifies the process by which a repair may be performed on the following engine cover flanges. The flanges are used to bolt the engine cover down on a De Hallivand DHC-1 aircraft equipped with a Gypsy Major piston engine.”

The procedure consists of removal of damaged areas, surface preparation with SST-G0002 alumina grit to roughen surfaces (Ref. 4), free-form spraying using the spray parameters depicted in Table 1, conventional machining to dimensional tolerances, dimensional check using coordinate measuring machines, and approval and release. The repair procedure for the top cover and lower crankcase are illustrated in Fig. 5. The engine was finally assembled and readied for delivery — Fig. 6.

Conclusion

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 unique, making the process suitable for producing well-bonded, low-

Table 1 — Spray Parameters

Machine: SST Series P, manual gun, 2.0-mm orifice, UltiLife™ nozzle
Spray Powder: SST A0082 (aluminum – alumina)
Gas: Nitrogen
Surface Preparation: Sections completely removed, grit blasting with SST-G0002
Gas Temperature: 425°C
Gas Pressure: 180 lb/in. ² (12.5 bar)

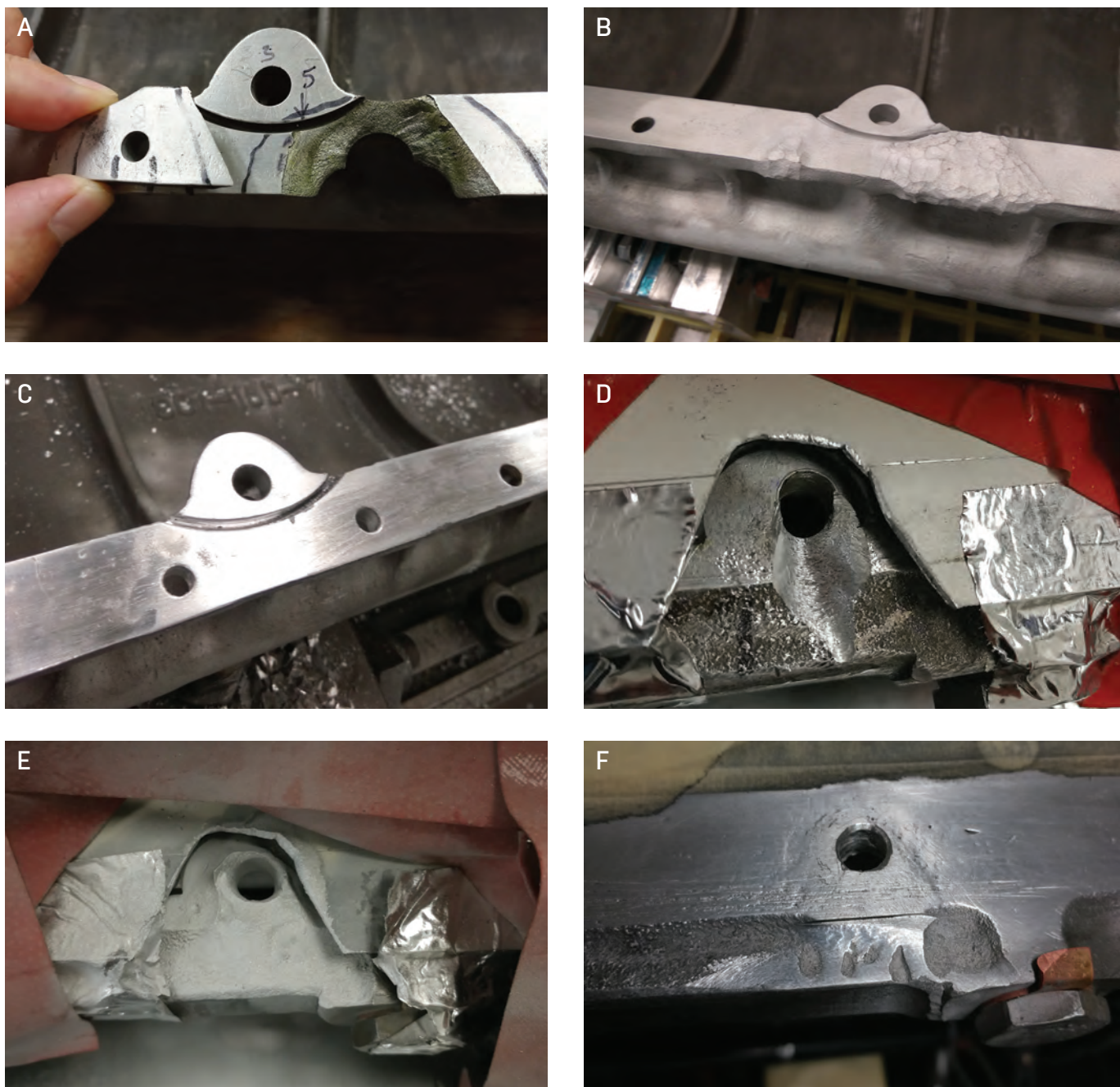


Fig. 5 — Gipsy DH Major 10MK1-3A engine top cover and lower crankcase flange repair by cold spray. A — Cover prior to spray; B — cover as sprayed; C — cover machined to tolerance; D — lower crankcase prior to spray; E — lower crankcase as sprayed; F — lower crankcase machined to tolerance.



Fig. 6 — Gipsy DH Major 10MK1-3A engine assembled and readied for delivery.

porosity, oxide-free deposits. These attributes make cold spray fit for depositing a range of temperature-sensitive materials. [WJ](#)

References

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