SST COLD SPRAY TECHNOLOGY
KEEPING HISTORICAL AIRCRAFT AIRWORTHY - CHIPMUNK ENGINE RESTORATION

CASE STUDY
September 2020

Figure 1. Chipmunk aircraft repaired by Cold Spray (Courtesy of the Canadian Historical Aircraft Association)

REASON TO CONSIDER RESTORATION

The Chipmunk **(Figure 1)**, named after a small Canadian Chipmunk squirrel, is a post-war vintage aircraft originally developed and manufactured in 1946 by Havilland Canada, now part of Bombardier. The 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 (RCAF), Royal Air Force (RAF), 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. More than 70 years after first entered service, hundreds of Chipmunks remain airworthy around the world. Spare components for these historical aircrafts are either scarce, price prohibited, or not enough repair technologies may be available for maintenance of a variety of their components.

Figure 2. (a) Gipsy DH Major 10MK1-3A Engine overhaul

Figure 2. (b) Liquid penetrant inspection of the cover

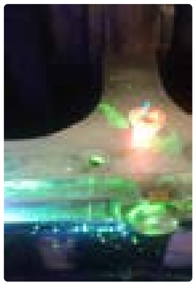


Figure 2. (c) Liquid penetrant inspection of the lower crank case

RESTORATION CHALLENGES

In this case study, mechanical tear and wear 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 Transport Canada-approved Canadian Historical Aircraft Association Maintenance Manual, unacceptable cracking of a flange area and bolt holes of the lower crankcase and upper cover were discovered by the liquid penetrant non-destructive inspection method (Ref 1) **(Figure 2).** These cracks put at risk the mechanical integrity of the engine 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 crank case. The material of the top cover and lower crank case were Magnesium and Aluminum cast alloys respectively, which would not tolerate elevated temperature repair processes, such as welding.

OPTION

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 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 technology offers the ability of all metal consolidation for dimensional restoration both manual or robotic application **(Figure 3).**

Figure 3. Commercial SST SERIES P Cold Spray system

THE SOLUTION

Both the top cover and the lower crank case were assessed for restoration by cold spray. In both cases, due to the already weakened condition of the material, it was recommended that both the cracked flange at the cover as well as the cracked region on the lower crank case be completely removed. The missing features would be rebuilt using the SST cold spray process, following recommendations of MIL-STD-3021 standard (Ref 2) for non-structural repair. A specific repair procedure was developed in conjunction with Transport Canada, which included simulation trials of the free form rebuild to ensure viability of the repair **(Figure 4).** The pre-qualified spray material recommended for this repair was a mixture of 99.5% aluminum particles and 99.0% aluminum oxide particles (Ref 3) which, when sprayed using the parameters in Table 1, yields ASTM C633 cohesive/adhesive strengths higher than 6000 psi with densities higher than 99.5%.

Figure 4. Simulation coupons (a) before spraying; (b) as sprayed; (c) machined to tolerance

During the actual repair, the lower crank case needed to be specially masked to protect engine components during spraying and post-machining and, thus, avoid any kind of engine tear down or disassembly **(Figure 5).**

Figure 5. Engine lower crank case masked prior to cold spray operation

The final repair procedure was approved under Transport Canada (TC) "Aircraft Equipment and Maintenance Standard -Canadian Aviation Regulation" and documented as TC Process Design Repair Doc #1701 Rev 1. Dated 29/11/17 and TC Maintenance Manual Supp #1701M Rev 1. Dated 5/12/17. The new TC repair process "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 DeHallivand DHC-1 aircraft equipped with a Gypsy Major piston engine". The procedure consists of (a) removal of damaged areas, (b) surface preparation with SST-G0002 alumina grit (Ref 4) to roughen surfaces, (c) free form spraying using the spray parameters depicted in Table 1, (d) conventional machining to dimensional tolerances, (e) dimensional check using co-ordinate measuring machines (CMM), and (f) approval & release. The repair procedure for the top cover and lower crank case are illustrated in Figure 6. The engine was finally assembled and readied for delivery **(Figure 7).**

Figure 6. Gipsy DH Major 10MK1-3A engine top cover and lower crank case flange repair by cold spray.

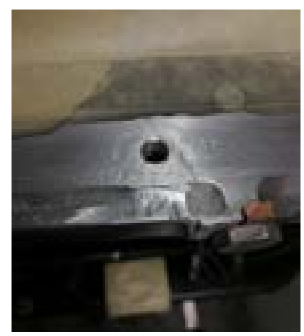
A) Cover: prior to spray

A) Lower crank case: prior to spray

B) Cover: as-sprayed

B)Lower crank case: as-sprayed

C) Cover: machined to tolerance



C) Lower crank case: machined to tolerance

Table 1. Spray Parameters

Machine: SST SERIES P / Manual Gun / 2.0MM Orifice / UltiLife™ nozzle
Spray Powder: SST A0082 (Aluminum – Alumina)
Substrate: Aluminum casting
Gas: Nitrogen
Surface preparation: sections completely removed - grit blasting with SST -G0002
Gas Temperature: 425 C
Gas Pressure: 180 psi (13 bar)

BENEFITS

Since 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 suitable for depositing well bonded, low porosity, oxide-free deposits. These attributes make cold spray uniquely suitable for depositing a range of temperature-sensitive materials.

Figure 7. Gipsy DH Major 10MK1-3A engine assembled and readied for delivery

REFERENCES

1. ASME PT-1. 5200 2015 -Rev 1
2. MIL-STD-3021 (W/ CHANGE-2), DEPARTMENT OF DEFENSE MANUFACTURING PROCESS STANDARD: MATERIALS DEPOSITION, COLD SPRAY (04-MAR-2015)
3. https://www.supersonicspray.com/uploads/documents/SST-TDS-A0082-PR-2_0-0120.pdf
4. https://www.supersonicspray.com/uploads/documents/SST-TDS-G0002-PR-2_0-0120.pdf

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