EVOLUTION OF SHOT PEENING ON THE CF-18 – FROM OEM TO ROBOTIC

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ABSTRACT
In this article, the evolution of the shot peening process on the CF-18 will be discussed. This includes the original peening on the aircraft as performed by the manufacturer, the manual peening performed later as part of a life improvement program and the robotic peening more recently developed to ensure a peening of high quality and repeatability in difficult to access locations. The steps taken over the years to improve manual peening will be described as well as the requirement leading to the development of the in-situ robotic shot peening system. The in-situ robotic shot peening system will be presented along with the software and hardware development performed to obtain a fully functional production system. Finally, current in-situ robotic shot peening applications on the CF-18 will be presented to highlight the challenges in applying this new technology.

SUBJECT INDEX
CF-18 Aircraft, Fatigue Life Improvement, Manual Peening, Robotic Peening

INTRODUCTION
The CF-18 aircraft is a multipurpose, high-performance twin-engine fighter acquired by the Canadian Department of National Defence starting in 1982 to handle air-to-air or ground-attack roles. The CF-18 structure is made of several thick, machined components that are sometimes shot peened to improve the fatigue life. The Original Equipment Manufacturer (OEM) first performed peening on critical components during the production stage of the aircraft. Later, using results from a full scale structural test, several more locations were identified as requiring peening to reach the fatigue life desired by the Canadian Forces. Because major components of the aircraft cannot be readily removed, shot peening has traditionally been performed by hand directly on the aircraft. However, in certain critical, hard to access locations, concerns were raised as to the consistency of the manual peening. A new in-situ robotic shot peening system was therefore developed to address these concerns. In the next sections, the OEM, manual and in-situ robotic peening are discussed to show the evolution of peening on the CF-18 fleet.

ORIGINAL EQUIPMENT MANUFACTURER (OEM) PEENING
During the assembly of the aircraft, a few critical locations on the wing carry-through bulkheads were peened by the OEM to improve the fatigue life of the aircraft. The peening was performed to an intensity of 6-10A with either steel shot or flapper wheels. A second peening, to the same intensity but using glass beads, was also

performed on some of the most critical locations in order to obtain the best possible fatigue life.

A very thorough investigation into the peening practice of the OEM was performed by Sharp (2001) for the Australian Department of Defense. This investigation is also applicable to the CF-18 since the Royal Australian Air Force (RAAF) purchased the same aircraft as the Canadian Forces (CF) at roughly the same time period in the early 1980`s. This investigation revealed that the surface finish of the OEM peening was very poor with lots of embedded glass fragments and some areas showing no indication of peening. The investigation also ascertained that although the OEM claimed a life improvement factor for its peening, the main US customer for the aircraft did not consider this beneficial effect because of the large variability in the process.

These findings, shared by the RAAF and the CF as part of a collaborative structural test program known as the International-Follow-On-Structural Test Program (IFOSTP) lead to the removal of the original peening and re-peening of many critical locations on the aircraft to ensure an optimum fatigue life improvement.

MANUAL PEEENING

This peening was done manually, directly on the aircraft, but this time using ceramic media instead of glass beads. The use of ceramic beads was prompted by OEM test results that showed an increased fatigue life over glass beads. Furthermore, ceramic peening does not require decontamination when used on aluminium components. All peening was performed at an intensity of 8A using 200% coverage to ensure no areas were forgotten. A large and somewhat awkward apparatus was used to ensure a proper stand-off distance between the nozzle and the part. Two trained technicians were required to peen a part on the aircraft. One with a timer and a second to do the actual peening.

As more results from IFOSTP became available, several new locations requiring peening were identified. An improved peening process was implemented to reduce variability (Desautels, 1998). This included tightening of the Almen intensity to 8A+/- 1A, the use of layout ink to help the technician see the peened area, a new slimmer device for the stand-off distance, a tighter tolerance of $90^\circ \pm 10^\circ$ on the impingement angle, peening of the filet radii and inside corners before the flat surfaces and finally, the use of digital Almen gauges instead of analog.

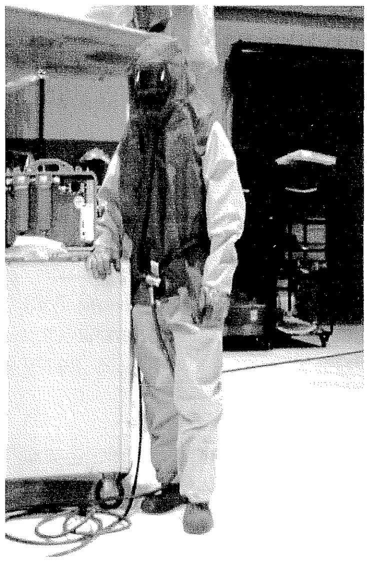

Figure 1 Technician dressed for manual peening

An extensive coupon test program with a very representative coupon geometry and loading showed an average life improvement of 2.9 for the improved manual peening (Martin, 1999) over the baseline crack initiation life. Tests also showed a reduction of 52% in variability over the original manual peening process. Peening performed after cycling the coupon to an equivalent of 40% of the baseline life produced a fatigue life improvement of 3.6.

Although these improvements were very encouraging, concerns still remained with respect to quality and consistency of the peening process in areas that are difficult to access. For health and safety reasons, the technicians are dressed as illustrated in Figure 1 during the manual peening process. In some cases, they then have to crawl inside small fuel tanks to peen critical locations on the face of bulkheads. Although the technicians are well trained, it becomes very difficult to maintain a proper impingement angle, stand-off distance and coverage in these conditions.

As more and more life improvement modifications relied exclusively on shot peening to provide fatigue life extension to the structure, a improved peening method was required for the peening of difficult locations.

IN-SITU ROBOTIC PEENING

Since in-situ robotic peening is more expensive to develop for a specific location than manual peening, three conditions must be met to consider using robotic peening. The first is that the component must be fracture critical, the second is that the access to the location must be difficult and finally, the possibility of future inspection remote.

A study was performed to identify the requirements for a robotic peening system. The requirements are as follows: The system must be fully automated with the control and monitor of all major shot peen parameters such as the trajectory, stand-off and impingement angle, pressure and media flow rate. The system must have a high precision and repeatability and use an optimum coverage of 100% instead of the 200% used in manual peening. The robot must be small enough to fit inside the CF-18 to reach the areas of interest but large enough to be used at several different locations on the aircraft. Finally, the robotic system must be easily transportable from aircraft to aircraft and meet the process specification for computer monitored shot peening (AMS 2432A)

A survey of existing equipment revealed that no integrated off-the-shelf robotic systems were available on the market for in-situ applications. It was therefore decided to design and build a new system that would fulfill the above requirements.

A small robot, the Motoman SV3X, was selected because of its size, payload, precision, and controller architecture that allow to interface with a personal computer. The robot dexterity and its ability to work upside down were also factors in its selection (Perron, 2000).

The peening machine offered another challenge since very few machines on the market could control the flow rate of ceramic media, the standard media used on the CF-18. The Baiker mobile peening unit became available on the market at the right time and was selected since it fulfilled most of our requirements (Leblanc, 2002). This peening machine offers a closed loop type of control on the air pressure and the media flow rate while also offering the possibility to interface with a personal computer.

The third major component of the in-situ robotic shot peening system is the robotic interface (Leblanc, Aug. 2003). This interface is the heart of the system and it was designed and built in-house. The robotic interface performs three main tasks: 1) Interface with the operator through an industrial touch screen, 2) control the robot and the shot peening machine and 3) monitor and record the robot position and shot peening parameters. Figure 2 illustrates the complete in-situ robotic shot peening system used on the CF-18.

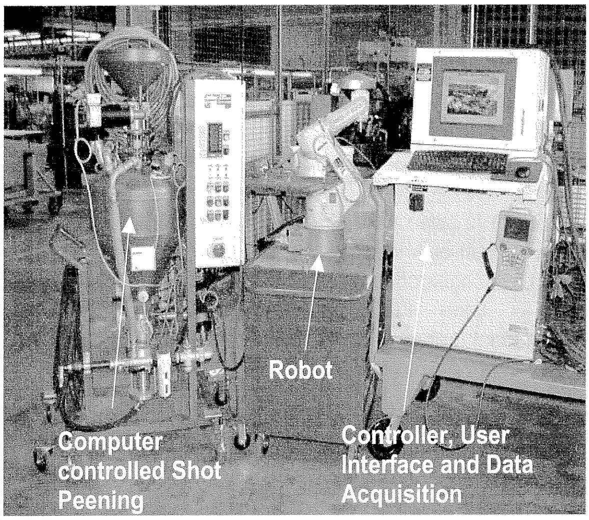

Figure 2 In-Situ Robotic Shot Peening System

A process was developed along with several new tools to support the development of robotic shot peening modifications. The typical steps to develop a new modification are as illustrated in Figure 3.

The first step is to Identify the surfaces on the 3D model and run a machining application called NCMill that produces the normal of the preliminary trajectories to cover the part. In parallel, the surrounding environment and tooling must be imported into the simulator. The preliminary trajectories are verified using an application developed in-house called Robot TG that links with the simulator to allow the correction of the trajectories to avoid obstacles. Robot TG can

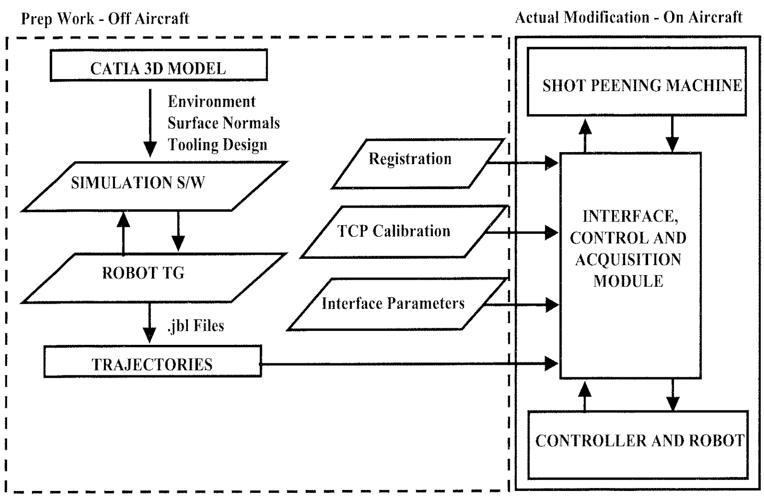

Figure 3 Robotic Shot Peening Modification Development Process

also mirror trajectories when necessary thereby saving considerable time. Once trajectories are completed, they are downloaded into the robotic shot peening system. A registration is then required to properly localize the part with respect to the robot and to ensure that geometry is as expected. This is followed by a tool center point calibration that verifies that the proper nozzle is installed for the job by using an algorithm and a wide beam laser.

Finally, the interface guides the operator through the different steps of the job while controlling the robot and the shot peening machine as well as monitoring and recording all the parameters.

EXAMPLES OF IN-SITU ROBOTIC PEENING ON THE CF-18

The first application on the CF-18 was extremely challenging. The robot was inserted upside down (Figure 4) in the fuel tanks to peen a small area on one of the critical bulkheads (Leblanc, June 2003). Registration was performed with a laser that measures key geometrical features on the bulkhead to adjust the nozzle trajectories.

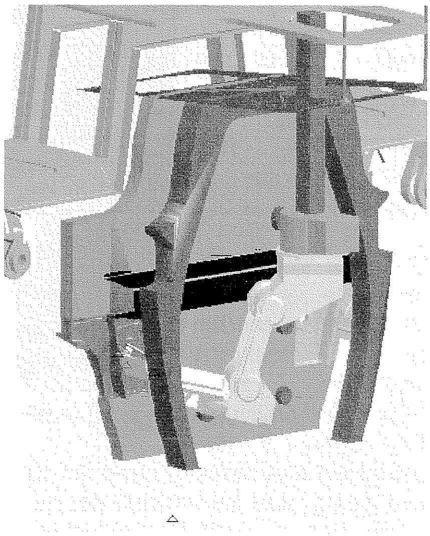

Figure 4 Robot is inserted upside down in CF-18 fuel tank

Since the robot had very little room to move, designing the nozzle was also challenging. The nozzle was designed to maximize the use of the optimum impingement angles while ensuring the proper intensity and coverage.
Fatigue testing of representative coupons for this location have shown a remarkable average fatigue life improvement of 18.9 after shot peening with the in-situ robotic system at 40% of the baseline life (Forgues, 2003). This provides an indication of the life improvement factor possible with the robotic system.

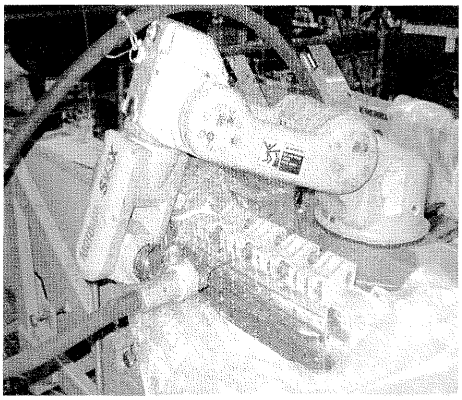

Figure 5 Robotic Peening of the Inboard Leading Edge Flap

Another successful application of the robotic shot peening technology on the CF-18 is at the inboard leading edge flap (ILEF) (Pouliot, 2003). In this case, robotic peening was performed after crack removal between the small lugs attaching the ILEF to the aircraft (Figure 5). With only 5.5mm between the lugs, manual shot peening would be impossible. A small lance type nozzle was used to project the ceramic beads deep inside the lugs at 90 degrees with respect to the nozzle axis. To date, close to 200 ILEFs have been peened with the in-situ robotic peening system and the system has been very reliable. A full-scale test has demonstrated a significant fatigue life improvement at this location despite a stress increase because of material removal and a loading spectrum with many compressive cycles.

ON-GOING RESEARCH PROGRAM

Improvements to the in-situ robotic shot peening system are ensured through a Research and Development (R&D) effort, which has focused recently on adding machining capabilities to the robotic system. This internal R&D effort is complemented by a collaborative research program with the National Research Council/Aerospace Manufacturing Technology Center and the Department of National Defence.

CONCLUSION

In conclusion, the shot peening process on the CF-18 has seen considerable improvements over the years. The manual peening procedure is now much more rigorous which results in a higher level of quality and consistency.

The robotic shot peening system is a new tool to ensure optimum fatigue life improvement on the CF-18 at difficult to access locations, The robotic shot peening system offers a peening of exceptional quality in a process that is controlled, accurate, and repeatable even in confined areas. The robotic shot peening system has successfully been used for the peening of several components on military and commercial aircraft.

The robotic system is undergoing continuous improvements through internal R&D and through collaborative projects with government research agencies and with our main client, the Department of National Defence.

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