



Special Edition
"THE AGING AIRCRAFT FLEET"

impact

Fall, 1991

INTRODUCTION

If you are in the aircraft or airline industries please bear with us for a few lines: among our readers are many who are not intimately familiar with the challenges of maintaining the safety and integrity of our commercial, military, corporate and private aircraft fleets. For that matter, there may well be a few (a very few, we hope) who are asking "What's Shot Peening, anyway?" This introduction is primarily for their benefit, as well as to give credit to some of our people who have furnished first hand information for this Special Edition, "The Aging Aircraft Fleet".

We will answer the question first because from the answer you will understand very quickly how the Shot Peening process relates to the Aging Aircraft situation. Shot Peening is a cold process which uses millions of tiny spheres of steel, glass or ceramic (typically 0.023 inch or just over half a millimeter in diameter). These spheres are propelled at about 200 feet per second (60 m/s) on to the surfaces of metal parts to induce a residual compressive stress which prevents or greatly retards

Shot Peening Plays a Major Role in the Rejuvenation Process

failures from metal fatigue, corrosion fatigue and stress corrosion cracking. In the aircraft industry, Shot Peening is also used to form the aerodynamic curvatures into wing skins; to correct the shape of distorted parts; to permit the use of much harder materials and, particularly applicable to aging aircraft, to identify areas of subsurface corrosion known as exfoliation. If you would like more details, please mark and return the reply card, requesting our engineering manual entitled "Shot Peening Applications". There is no charge for this book.

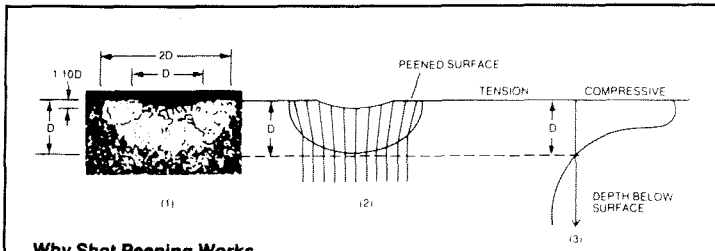
The public was suddenly made aware of the term "Aging Aircraft" on April 28, 1988 when a 19 year old Aloha Airlines B-737 explosively depressurized at 24,000 feet (7300 m) and 18 feet (6m) of the skin ripped from the fuselage. Though one crew member was lost, miraculously the pilot made a safe landing. Subsequent investigation revealed that the cause of the Aloha incident was corrosion and metal fatigue. Lest you immediately vow never to fly again, let us site some statistics that show flying to be unquestionably one of the very safest modes of transportation.

The incidence of structural or skin failures have been so few as to be, statistically at least, almost nonexistent when considered in the context that there are about 3,500 aircraft just in the U. S. airline fleet, accounting for 17,000 flights each day and half a billion passengers per year. Approximately 18 percent of these aircraft are older than 20 years. Ultimately, the safety of the older aircraft depends on the quality of the maintenance performed. On March 6, 1990 the Federal Aviation Authority (FAA) adopted new regulations regarding extensive structural modifications to older aircraft to be completed by 1994 deadlines. These regulations apply to the large commercial airliners with which we are all familiar. However, of the 3,500 aircraft mentioned above, about 1,800 are the so-called "commuters", by definition carrying less than 60 passengers and operating in domestic, regional service. This fleet is made up of 59 different types of airplanes from 17 (mostly foreign) manufactures, and operated by no less than 165 different carriers. The Small Airline Directorate of the FAA has the responsibility for the Aging Commuter Aircraft Program. The above facts are presented only to give some perspective to engineers not associated with the aircraft and airline industries. There are also large numbers of military and private aircraft that are not counted here.

The rest of this Special Edition is devoted to real life examples, some long before the Aloha incident, where Shot Peening has been used to rejuvenate or restore aircraft components. In many cases the Shot Peening work is performed by Metal Improvement Company (MIC) field crews on the aircraft. In others, notably engine, landing gear and brake parts, the components are dismantled at overhaul and sent to one of our 20 plus FAA approved service centers for treatment. The



MIC field crew prepares to peen form B-737 replacement wing panel.



Why Shot Peening Works

1. Impact of a high speed pellet creates a dimple of diameter "D". The depression is about 1/10 D.
2. The surface is stretched by the impact. The depth of the stretching is approximately "D".
3. The "not stretched" core exerts a compressive force in attempting to restore the surface to its original condition.

information for these examples, which are far from exhaustive, was provided by Roger Thompson and Peter O'Hara of MIC Newbury (England), David Axline of MIC Dallas, Jeff Meister of MIC Cincinnati, Bob Kleppe of MIC Los Angeles and Kevin Tower of MIC Hartford. Our thanks to them.

John S. Eckersley,
Editor

AGING AIRCRAFT APPLICATIONS

DC-9 Landing Gear Attach Fittings

As far back as the early 1970s, Stress Corrosion Cracking was found on DC-9 main landing gear attach fittings (aluminum).

McDonnell Douglas required that all DC-9s in service at that time be shot peened on site in the critical areas of the attach fittings. The paint and anodic coating were removed in the critical areas and energy absorbent tape applied to mask off adjacent surfaces. The general area was enclosed in plastic sheeting. The shot was contained by a differential pressure peening nozzle and returned to the pressure generators for conditioning and recirculation. After peening, the anodic coating and paint were reapplied. It would appear that no further evidence of cracking in these areas has been found, after the shot peening was performed.

CONCORDE Power Control Cradles

In a paper entitled "Maintenance of Concorde into the 21st Century," Mr. M. J. Phillips, Senior Engineer, British Airways plc., states the following: "The power flying control unit (PFCU) cradles have caused problems in the past... The rudder PFCU cradles were reshaped using a clamp-on profile jig as a guide, and then the cradle was shot peened in situ, to improve its structural reliability". Since this report, MIC has further shot peened, on all seven Concorde, the much larger area of the wing ailerons to improve the fatigue life of the attachment brackets.

B-737 Tail Fin Attachment Lugs

There is a current and similar Boeing specified retrofit process on all attachment lugs for the B-737-200 tail fin assemblies. The rework calls for reaming the lug bores to an oversize dimension and shot peening of the bores, followed by installing new bushings to fit. Due to the proximity of the lugs, a special tool has been manufactured to allow on-site controlled shot peening of the lugs so that the fittings do not need to be disassembled from the aircraft or the fins. Sophisticated masking tools are used in conjunction with differential air pressure techniques to contain the shot.

B-737 Startstruss Assembly

This large fitting has lugs that protrude through the fuselage skin, to which are attached the vertical and horizontal stabilizers. The overhaul schedule calls for these lugs to be rebored and refaced, followed by controlled shot peening. Again, we have manufactured dedicated tools to access these areas to obtain the specified levels of intensity and coverage at the correct angles of incidence.

B-747 Lower Web, Wing Center Sections

Drawings relating to Boeing 747, "corroded lower web, wing ctr. section, stn. 1000," carry the following "Repair Procedure" (abbreviated):

1. To inspect lower web for corrosion hidden by lower chord, refer to Boeing S.B. 747-53-2064.
2. Blend out corrosion in web...
3. Remove fasteners shown...
4. Shot peen corroded area per BAC 5730 all over blended area. Use 230-280 grade shot, .004"-.008" A-2 intensity see ref. drg. 65B 10276 note 6 and Boeing Overhaul Manual Chapter 20-10-03 for information.
5. Alodine and paint whole of repaired area...
6. Apply sealant...to all faying surfaces.
7. ...replace removed section of chord along with splice plates and fixings."

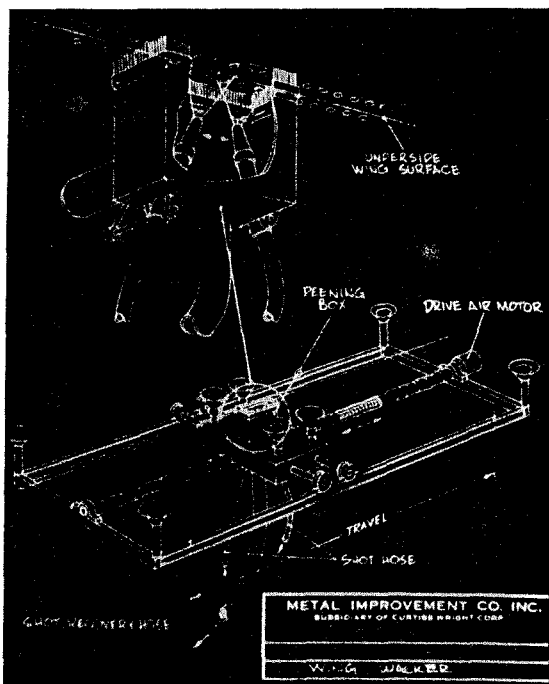
B-747 Landing Gear

Overhaul Manual, 32-10-21, page 410, Feb. 1, 1991, carries the following notation (before chrome plating):

"Shot peen (all over except on threads) (Ref 20-10-03)

- (1) RC55-60 Shot Heat Treat
- (2) 0.016-0.033 Shot Size
- (3) 0.014-0.018 A₂ Intensity
- (4) 2.0 Coverage (use Peenscan to verify coverage)

Material: 4340M Steel (275-300 KSI)."



Design of "Wing Walker" machine for fully automated shot peening along rivet runs.

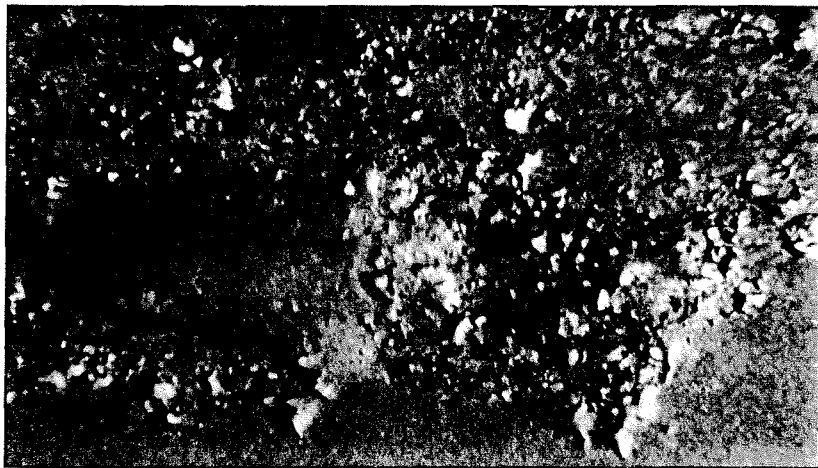
Some explanation might be useful so we have added the numbers in parenthesis, for reference below:

(1) If you look at the last note, on "Material", you will see that this landing gear part is very hard, equivalent to HRC 54-58. To generate the maximum residual compressive stress from shot peening, it is necessary to peen with a shot that is as least as hard as the part being peened: see also MIL-S-13165C "Shot Peening of Metal Parts" and Federal Specification QQ-C-320 "Chrome Plating (Electrodeposited)". (Check Reply Card if you would like a free copy of these specifications).

(2) Item specifies actual diameters of shot that can be used: M1230H shot falls within this range of diameters as well meeting the hardness requirement.

(3) Item is an industry standard for measuring (relatively) the kinetic energy that is transferred from the shot to the part. (Check Reply Card at "Shot Peening Applications - Seventh Edition.")

(4) Coverage is essentially a visual determination of when the part surface is 100% impacted with peening dimples. On very hard parts, this determination is very difficult even with the accepted 10X magnification. Metal Improvement Company uses and licenses the patented PEENSCAN® process, where the part is coated prior to peening with a fluorescent tracer liquid that, when dry, is removed by the direct impingement of the shot. Under ultra-violet light, the highly fluorescent tracer material makes it easy to determine when 100% coverage has been reached. 2.0 signifies that the time required, in the **automatic** peening machine, to reach 100% coverage should be doubled. (Check Reply Card for "SAE Technical Paper #850708, Dyescan Tracers as a Quality Control Tool for Coverage Determination in Controlled Shot Peening.")



Close-up of exfoliation corrosion revealed by MIC's search peening process.

B-747 Lower Wing Skins

The auxiliary fuel pumps are positioned within the wing structure, between the inboard engine and the fuselage. A modification in this area requires shot peening on the inner surface of the lower wing skin. This area can be reached only through the fuel tank access ports. Again, MIC has designed and built dedicated Shot Peening tools for this operation and we use PEENSCAN to verify coverage in an area of very limited accessibility.

DC-8 Surface Corrosion Removal

In addition to on site shot peening, MIC can also undertake on site controlled abrasive blasting. A typical case was a DC-8 freighter with a requirement for corrosion removal on all the exposed steel fastener heads. The original specification called for blast cleaning using glass beads but we demonstrated to the airline's engineers that glass was the wrong media for this application. By the time the glass beads had removed the corrosion from the fasteners, the cladding had been damaged on the surrounding skin. From our experience, we recommend certain parameters of abrasive media, kinetic energy and dwell time that removed the corrosion perfectly off the fasteners with no damage to the skins. Blasting time was also reduced significantly so that the airplane could be returned to service much sooner than originally anticipated.

The above examples are only typical of many applications of highly controlled Shot Peening performed by MIC on aging aircraft to prevent or greatly retard Stress Corrosion Cracking, Corrosion Fatigue and Metal Fatigue. Our process is applicable not only to the aluminum alloys (including aluminum lithium) but also to steels (landing gears, for instance), titanium and the super alloys used in jet engines. Jet engine components, incidentally, are shot peened several times for restoration of compressive stresses at periodic overhauls, usually as a protection against fretting fatigue.

Shot Peening Retards Failures From Metal Fatigue, Stress Corrosion Cracking, Corrosion Fatigue, Fretting and Galling.

EXFOLIATION CORROSION

Exfoliation Corrosion, a more severe form of Intergranular Corrosion, occurs along aluminum grain boundaries which in sheet and plate are oriented parallel to the surface of the material, due to the rolling process. It is characterized by delamination of thin layers of the aluminum, with white corrosion products between the layers. It is often found next to fasteners where the electrically insulating sealant or a sacrificial cadmium plating, for instance, has broken down, permitting a galvanic action between the dissimilar metals. Where fasteners are involved, the corrosion extends outward from the fastener hole, either from the entire circumference of the hole, or in one direction from a segment of the hole. In severe cases, the surface bulges outward, but in less severe cases, there may be no telltale blisters, and the corrosion can only be detected by nondestructive inspection methods that are not always totally effective.



Wing surface showing fastener areas after dressing to remove exfoliation.

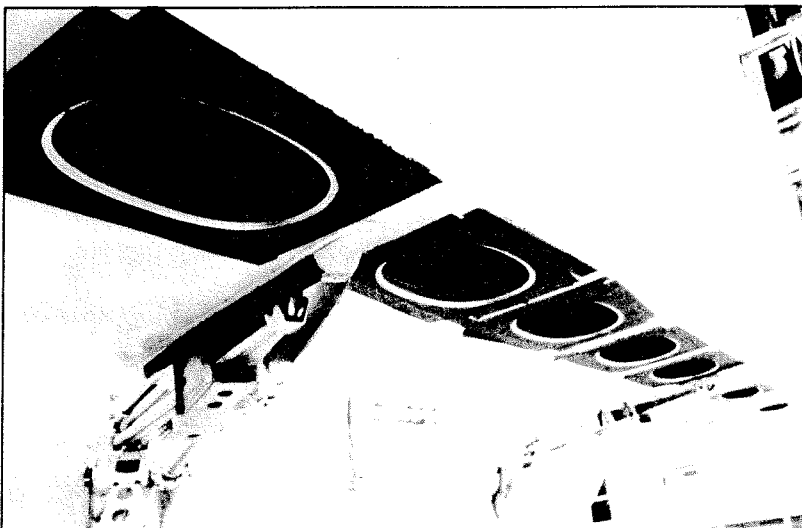
Controlled shot peening is of little value in preventing Exfoliation Corrosion but it can be very effective in the process of both identifying and repairing the damage. Service manuals normally call for the removal of the fasteners and then for the use of rotary discs to sand away the corroded material followed by blending the area and polishing out the tool marks. Aircraft structural engineers have used MIC's controlled peening after polishing to compensate for the lower fatigue strength of the newly reduced cross-section. The action of the peening, however, will cause the surface to blister again where deeper exfoliation is present. The surface can then be redressed and repeened until no further blistering occurs. This process, now called "Search Peening," provides a reliable Non Destructive Testing of the exfoliated material. The action of the peening on the thin exfoliated layer is essentially the same as that employed in the process of Peen Forming, used to generate the aerodynamic curvatures in the wing panels of most commercial airliners. Peening of corroded surfaces can be accomplished using special enclosures to contain the media. It is essential to maintain extreme control on the intensity of the peening so as not to cause distortion of the skin itself, rather than just the blistering of the exfoliated layers. MIC has applied for a patent on our "Wing Walker" machine which is used to undertake automatic and fully controlled Search Peening for exfoliation corrosion along the fastener runs on the wing and tail surfaces.

B-737 MIC have worked on a significant number of older aircraft of this model to remove surface corrosion, to search peen for and dress areas exhibiting subsurface exfoliation corrosion and to subsequently shot peen the affected areas per original equipment manufacturing specifications (BAC 5730) to restore the now even more essential residual compressive stresses. Typical areas include rivet lines along upper and lower wing skins and horizontal and vertical stabilizer surfaces. Also included are landing gear bay structures, the landing gears themselves and a number of internal airframe components where exfoliation and surface corrosion have created obvious damage.

B-747 We first developed the techniques for "Search Peening" when we were contracted to saturation peen (for fatigue) the upper and lower wing planks along the fastener lines after airline maintenance personnel had already dressed out all visible traces of Exfoliation Corrosion (actually, "invisible traces" also, because their usual NDT methods gave no indications of deeper exfoliation). To their surprise, the peening caused numerous areas to blister, revealing deeper layers. Redressing and repeening was done in some areas for as many as ten times, with exfoliation being found to depths of as much as 0.090 inch (2.25 mm). Service experience shows that if hidden exfoliation is left and not removed, it will quickly manifest itself by new surface blistering, once the aircraft re-enters service.

MIC field crews have since carried out the search peening and dressing work on a number of different aircraft. Typically, on B-747s, we have applied our skills to exfoliation not only along the rivet lines as described but also to fuel tank access ports, to the keel beams and on other structural components, particularly in the corrosion prone wet areas of the galleys and toilets.

B-757 Hardly an "old" aircraft but fretting corrosion followed by exfoliation corrosion has been found extensively in the recesses of the fuel access ports, where the cover plates fit. This seems to be more common with the 757s but we have also treated 747s and 737s in the 20-25 access ports under each wing. Special tooling and masking techniques have been developed by MIC that allow us to be very efficient at this job.



Fuel tank access ports masked before shot peening in door recesses.

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3. _____ QQC-320, "Chrome Plating (Electrodeposit)"
4. _____ SAE #850708, "Dyescan Tracers as a Quality Control Tool for Coverage Determination in Controlled Shot Peening."
5. _____ "Shot Peening Stress Profiles," Henry Fuchs, Editor.
6. _____ "Shot Peening Conference," Cincinnati, OH, September 29-30, 1992, I.I.T.T. Sponsor.

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L-1011 We have worked on detection and removal of significant exfoliation in the center torque box and wing box areas, on the "bath tub" fittings. We have also treated structural frames that suffered severe exfoliation, particularly in the cargo hold and, of course, the ubiquitous rivet lines along the upper and lower wing surfaces where exfoliation corrosion has been brought on by the galvanic action between dissimilar metals.

PEEN FORMING

B-737 Boeing Service Bulletin 737-57A1081 covers the repair of the left and right front wing chords. To access the chords, it is necessary to remove a wing skin panel that is approximately 10 inches wide by 120 inches long. The replacement panel is essentially flat and so does not fit the aerodynamic contour of the wing. To restore the contour, after the trailing edge of the panel is riveted securely, the Service Bulletin instructs as follows:

"5. Shot peen designated area per Boeing Standard Overhaul Practices 20.30.03 or operator's comparable procedure... using cut stainless steel wire shot at **coverage**

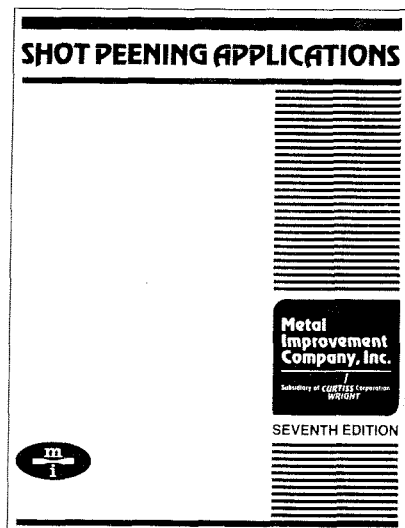
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ENGINEERING MANUAL: Prevention of Metal Failures

Eighty-five pages, much of them new data, makes SHOT PEENING APPLICATIONS the best resource for every engineer and technician responsible for design, stress analysis, metallurgy, product testing, weight reduction, corrosion control, processes, facilities, and production. Mail the REPLY CARD for your copy of this Standard Reference Manual that will introduce you to **Failure Prevention** before you are forced to go to **Failure Analysis!**



and intensity sufficient to bring spring-up value(s) to less than 0.03 inch."

Implied (but not stated) is that these panels must be peened formed on the aircraft, a procedure that requires considerable experience and skill. Any distortion or even over-forming cannot be corrected once it has happened, so that the panel would have to be replaced and the process started over again. MIC crews have developed forming techniques so that the spring-back value is less than 0.01 inch and no shimming is necessary.

COMMENTS

Some general comments are appropriate:

Many of the components that are being peened in the field on aging aircraft were peened during original manufacturing to the stringent specification of the builders of the aircraft. It is essential that the re-peening results in a comparable quality of residual compressive stress.

Flapper wheel peening has intensity control problems related to surface geometry. For instance, it is practically impossible to adequately flapper peen into a fillet radius. A further practical problem is that the processing time on a typical peening repair can take as much as five times longer to flapper peen than to shot peen.

MIC has developed specialized equipment for on-site work that varies from small portable machines that can be used anywhere on the aircraft, to side firing nozzles and lances, used in conjunction with masking tooling, to achieve the required intensities in holes, clevises and other areas of restricted access. Development continues in all these areas with the object of automating more and more as soon as possible.

Wherever practical, masking is carried out with dedicated tooling and differential pressure systems are used to contain the shot in the area requiring peening. The peening media of our choice for on-site work is ceramic (zirconium oxide) shot. This material is capable of achieving all normal steel shot intensities, has a long life before breakdown and it is chemically inert. This has two advantages: should a particle of shot become lodged in the airframe it will not become a source for galvanic corrosion and, during the peening operation, ceramic media do not cause surface ferritic contamination that must be removed before priming and painting of aluminum.

When using rotary sanding disks to remove exfoliated material, we have always been careful to preserve a minimum width to depth ratio of 20:1 with well blended edges. This operation is always followed by a saturation peening to introduce the residual compressive stresses for fatigue and stress corrosion cracking protection.

CONCLUSION

The problem of aging aircraft now has a high profile both within the industry and, as a result of a few highly publicized incidents, amongst the general public. It is an unfortunate fact that all aging aircraft suffer from fatigue and corrosion in all its forms: the only difference between them is one of degree. This will vary with the operating conditions and the operators maintenance program: for example, obvious factors are coastal operation and frequency of re-painting. When the time comes that treatment for these problems is required you need to find experts with experience in this highly specialized field.

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Metal Improvement Company is the acknowledged leader in the Shot Peening industry and we operate over 25 Shot Peening service centers, throughout North America and Europe, which are approved by the FAA or the comparable local regulating authority. From them, highly qualified field crews are regularly deployed to all parts of the world, for both aircraft and industrial applications. Below is a list of those facilities with their phone and fax numbers. You may contact them directly or through our Corporate Offices in Paramus, New Jersey. Please ask for the Technical Services Manager.

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	MASSACHUSETTS	617/599-4165	617/599-3350
	MICHIGAN	313/397-8400	313/397-2650
	MINNESOTA	612/425-2400	612/425-4669
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