THE 7th INTERNATIONAL CONFERENCE ON SHOT PEENING ICSP 7 INSTITUTE OF PRECISION MECHANICS WARSAW, POLAND

EXFOLIATION CORROSION LOCATED BY SEARCH PEENING

W. WÜBBENHORST
Metal Improvement Company, Inc; Haan-Gruiten, Germany

ABSTRACT
Exfoliation Corrosion, a more severe form of Intergranular Corrosion, occurs along aluminium 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 aluminium with white corrosion products between the layers.

Search Peening can be defined as the use of controlled shot peening as a tool to expose subsurface corrosion. The stretching of the surface coupled with the compressive stress induced by the multiple impacts of the shot help to delaminate hidden layers, as is found in exfoliation corrosion.

KEY WORDS
Aging Aircraft, Aerospace Corrosion, Exfoliation Corrosion, Airworthiness, Search Peening

INTRODUCTION

The term Search Peening has been derived directly from practise and experience in the use of Controlled Shot Peening as a corrosion control tool in the aircraft structures repair and overhaul workplace.

Aircraft structures engineering personnel are well aware of the major benefits to be gained by the provision of surface residual compressive stresses at design and new manufacture stages. - Modern design concepts using Controlled Shot Peening will take credit from the benefit obtained as a direct result of the residual compressive stresses that has been induced at the surface. The beneficial effects are to increase resistance to fatigue, corrosion fatigue, stress corrosion cracking, fretting and galling. A principal benefit is the introduction in the surface of a defect tolerant layer of controllable depth by the process, thereby giving damage tolerance to the operational components.

It has been common practise for many years where in the aerospace repair and overhaul business that many rotable aircraft parts will be subject to controlled Shot Peening at regular specified intervals during their life, such as aero engine propeller blades, jet engine turbine and compressor blades along with landing gear. The repair and overhaul mandate in these cases would be the requirement to certify and re-life the components with the requirement for controlled shot peening to be carried out as per the quality and standard as produced and certified at new.

The modern aircraft airframe poses a significantly different problem since it is normally not practical to dismantle at major overhaul. The major concern with the ageing aircraft fleet is the degradation of structural integrity generally caused by uncontrolled corrosion ultimately combining with various forms of damage in particular fatigue, stress corrosion cracking, exfoliation corrosion. (As illustrated at Figure 1)

It should be noted that many of the aircraft designed and manufactured in the 50's and 60's used aluminium alloys , such as 7075-T6, 7079-T6, and 7178-T6, that were more susceptable to corrosion than materials used today.

Continued structural airworthiness is dependent totally on successful maintenance inspections and the subsequent detection and rectification of damage. Aircraft operators now have mandatory corrosion control programmes instituted by International Government Agencies that would not jeopardise the airworthiness of the aircraft providing these directives were correctly applied. - These mandatory corrosion control programmes took a significant step forward after the Aloa Airlines Boeing 737 accident in 1988.

Fatigue enhancement and damage tolerance are key benefit factors obtaines from the use of Controlled Shot Peening. It is also the basis of aircraft design in that the structure is tolerant of damage from any source, fatigue or foreign object damage and further that it will not propagate to a size sufficient to cause catastrophic failure or degrade the stability and control of the aircraft to a dangerous level.

Exfoliation Corrosion

The manufacturing processes such as rolling, extruding and forging used in producing wrought aluminium alloys, elongate the matrix strains and string out the secondary phases in the microstructure. In the subsequent thermal treatments used for aluminium, the grain boundaries do not re-crystallise into an equ-axed shape. The mechanical and many corrosion properties are therefore highly anisitrophic and vary considerably in the three principal directions relating to the direction of working ie longitudinal, long transverse and short transverse ie through the thickness.

Exfoliation corrosion sometimes described as layer of stratified corrosion generally proceeds along multiple narrow paths in the elongated grain boundaries parallel to the metal surface. It is characterised by leafing or alternate layers of thin, relatively uncorroded metal and thicker layers of corrosion products which cause the metal to de-laminate and swell. Rivet and other fastener holes have a high vulnerability to exfoliation because the holes provide a pathway for the electrolyte/precipitation to the most susceptible short traverse endgrain of the alloy.

SEARCH PEENING PROCEDURE

The developement of Search Peening has been driven by the mandatory requirement to remove all corrosion elements from airframe structures followed by the positive requirement for reintroduction of fatigue strength following reductions in section thickness as a result of dressing out surface and subsurface exfoliation.

One of the major areas of concern are the fasteners along the spar skin attachment lines where there are long runs of rivet heads. It is necessary, whilst not by choice, to use dissimilar materials such as steel and aluminium on aircaft structures. Unfortunately fasteners plated to provide insulation, suffer subsequent surface degradation which will allow water to penetrate with the initiation of intergranular and exfoliation corrosion. - Figure 2 illustrates automated micoprocessor controlled equipment for controlled and repeatable processing along such spar skin rivet lines.

Prior to initiating the search peening technique, Figure 3 illustrates the "as received" condition of the aircraft component surface. (Boeing 747/Keel Beam Plate). Figure 4 is the surface finish of the same component after PMB **(Plastic media paint stripping)** carried out by MIC using techniques for intensity control [1, 2]. Clearly exposed are the corroded and damaged areas. If compared directly with Figure 3, it is noted that corrosion on the material surface has taken place but not all was visible under the paint and areas apparently damaged. - The benefit of controlled PMB stripping in this intance is the lack of surface disturbance enabling accurate assessment of the damaged area.

The **search peening technique** is initiated by **aluminium oxide blasting** of the surface to remove any visible oxides from the area concerned, covering all local fastener heads and probably a strip extending 50 mm either side of the fasteners (see Fig. 5). Any further visible surface corrosion will require dressing with normal hand tools, ensuring minimal stress concentration effects.

Following satisfactory **dressing**, controlled search peening is then carried out in linear fashion. The **Search Peening** induces surface compressive stresses that stretch and yield the outer material surface. If visible blistering and flaking at the surface is noted, the existence of exfoliation corrosion, that is selectively attacking the aluminium substrate, has been exposed. (As illustrated in Figure 6)

This is understandable since shot peening causes the surface layers to stretch as clearly illustrated in figures 7 and 8 of [1] and separate along the wakened corrosion paths beneath the surface.

Subsequent inspection after search peening may reveal fresh areas of exfoliation, near fastener holes and may require further dressing.

Another example here is Figure 9, where the original component condition is showing signs of edge exfoliation corrosion.

Figure 10 is the aluminium oxide blast of the surface to clear debris and remove surface oxides for inspection and Figure 11 is a close up of this oxide surface. Figure 12 is the same edge now dressed with a removal of some 0.38 mm (0.015 inches). Figure 13 is the area fully shot peened showing further indications of exfoliation. Figure 14 is a close up of the same exposed edge exfoliation. Further dressing and a further pass with the controlled search peening equipment is required. The inspection and process will be continued until no further blistering occurs.

Finally the full fastener spar skin line will be **controlled shot peened**, where possible, using the appropriate manufacturers controlled shot peening specifications as most wing, tail and fuselage areas are saturation peened for prevention of stress corrosion cracking and fatigue. - Final surface treatments would then be applied as specified by the aircraft manufacturers. Search peening experience to date has shown that the problem of exfoliation corrosion is considerably more widespread than was believed. On certain aircraft where work has been carried out along spar lines on wing skins, the search peening technique has found siginificant subsurface exfoliation requiring repeated processing and dressing. In certain circumstances the amount of dressing required has removed a greater depth of material than is accepted for the fatigue strength and damage tolerance of the skin and has required replacement. However as the structure in these situations had little inherent strength, exposure and remove was critical and necessary.

It should be noted at this time that previous and some existing techniques of removing visibel corrosion and a further percentage of the surface by dressing, would not have been adequate in many instances of exfoliation. This removal of a percentage of material may result in a further drop of fatigue and stress corrosion resistance.

Where the component had specified controlled shot peeing at new, it is essential to re-institute the residual compressive stresses in a controlled manner and in accordance with the manufacturers original specifications [5].

SUMMARY

Again, where peening was not originally specified, it is now a requirement, due to the reduction on section thickness, from dressing out of corrosion.

In the light of increasing aged aircraft experience manufacturers are striving to improve their repair and overhaul practises calling out for tighter control and closer tolerancing of process specifications. Controlled Search Peening is an aid in furthering these objectives.

LITERATURE

[1] Engineering Manual SHOT PEENING APPLICATIONS, 7th Edition.
Metal Improvement Company, Paramus, N.J./USA

[2] AMS-S-13165 Shot Peening of Metal Parts

[3] Impact/Review of Shot Peening Technology
The Aging Aircraft Fleet
John S. Eckersly
Metal Improvement Company, Paramus, N.J./USA

[4] Corrosion Detection and Control
Terry Ford
Aircraft Engineering and Aerospace Technology
Volume 71, Number 3, 1999

[5] Boeing Overhaul Repair Manual 20-10-03

[6] U.S.A..F. Aging Aircraft Program
J.W. Lincoln, W.R. Elliott
Aerospace Engineering, October 1994

[7] Preventive Medicine
A. McGreal, British Airways
World Engineering, September 1994

[8] Exfoliation Corrosion
J.R. Harrison, E.R. Thompson
1994 U.S.A.F Structural Integrity Program Conference

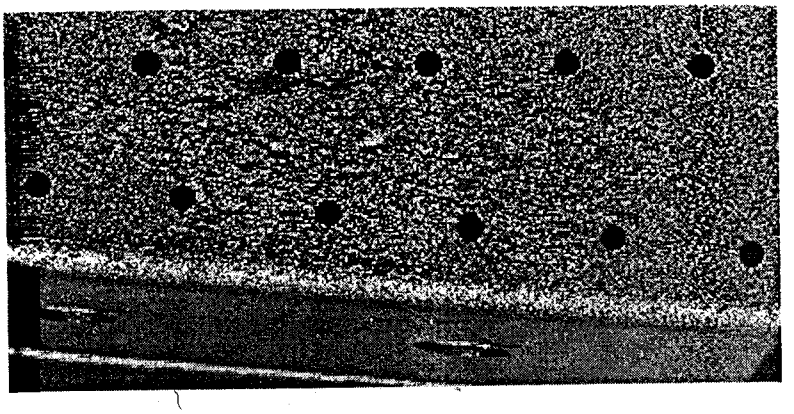

Fig. 1 Exfoliation Corrosion

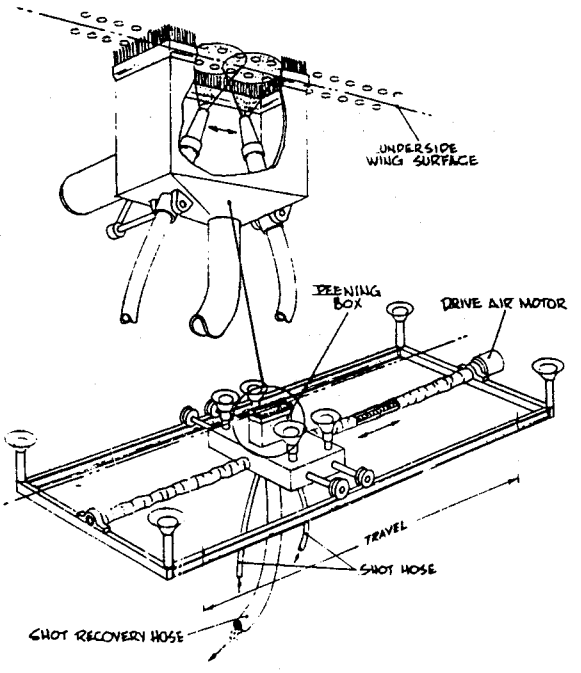

Fig. 2 Design of „Wing Walker" machine for fully automated shot peening along rivet runs

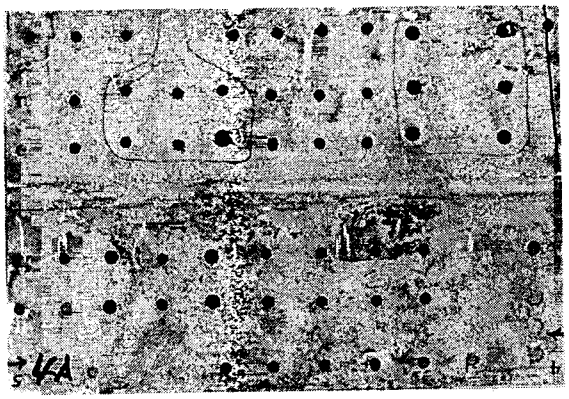

Fig. 3 As „received" condition

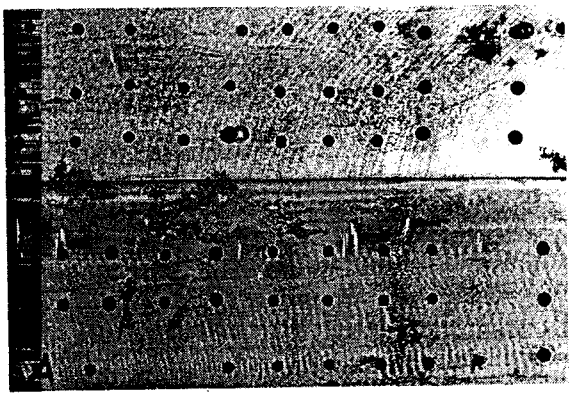

Fig. 4 Plastic Media Paint stripped – Exposing clearly corroded and damaged areas

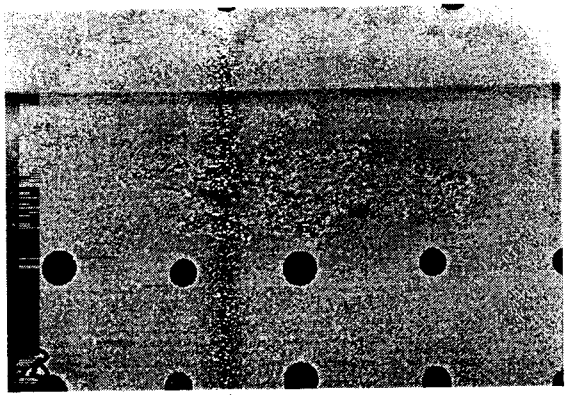

Fig. 5 Close up of Aluminium Oxid blasted areas showing slight exfoliation

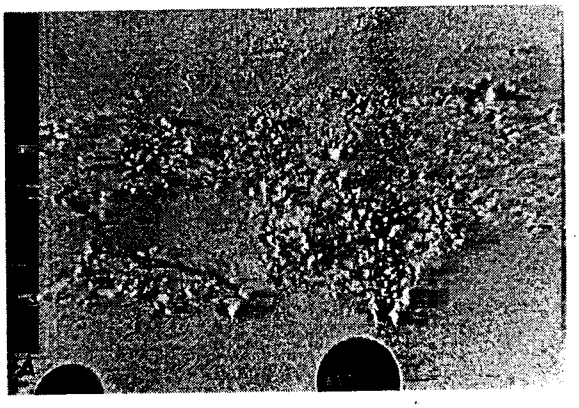

Fig. 6 Closer view after light Shot Peening (MI 110 0,006" A 200%). Exfoliation very evident and typical of first pass of Shot Peening on such areas.

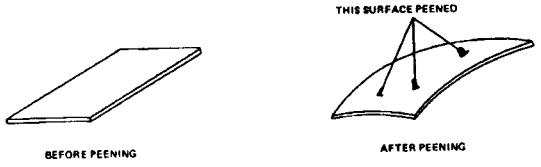

Fig. 7 Compound curvature result of Tri – Axial Forces induced by shot peening

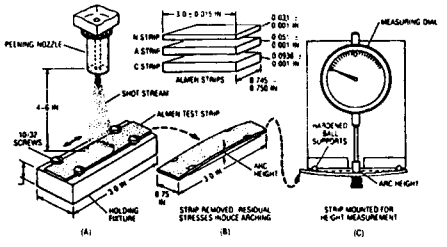

Fig. 8 The Almen Strip System

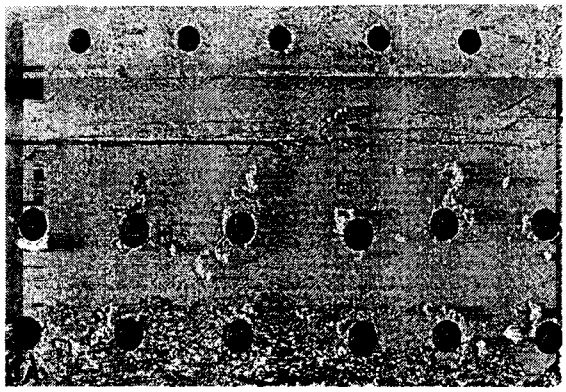

Fig. 9 Plate edge „as received" condition

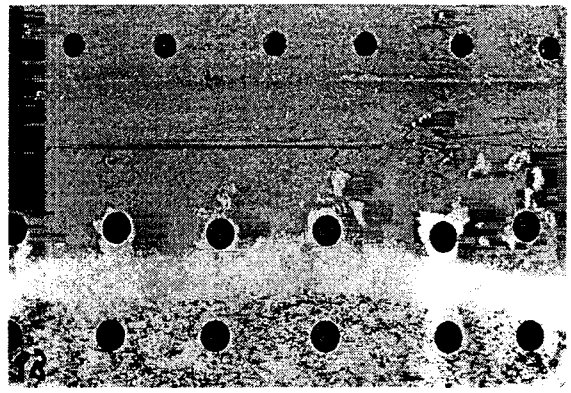

Fig. 10 Aluminium Oxide blasted to remove surface oxides

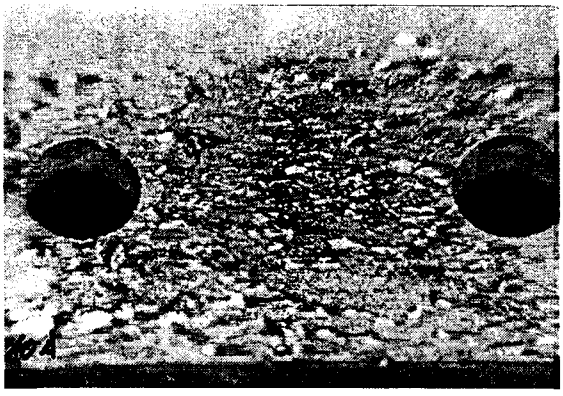

Fig. 11 Close up of Aluminium Oxide blasted area exhibiting exfoliation corrosion already

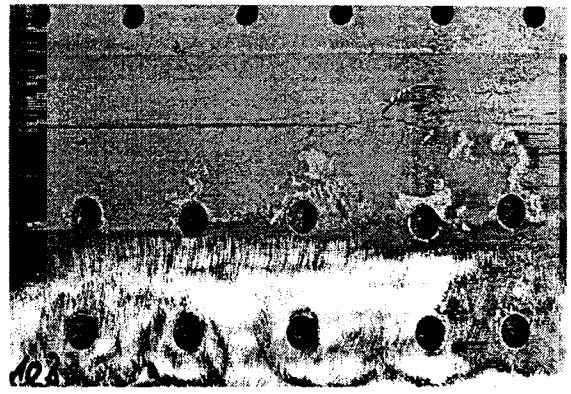

Fig. 12 0.015 ins. (0.038 mm) material removed by dressing

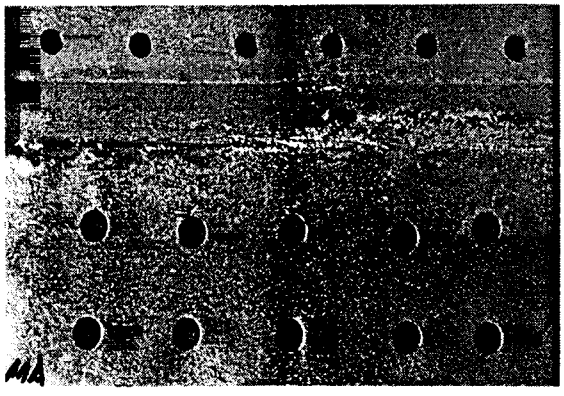

Fig. 13 Controlled Shot Peening (MI 230 / 0.008" A / 200%). Exfoliation still evident in two small areas.

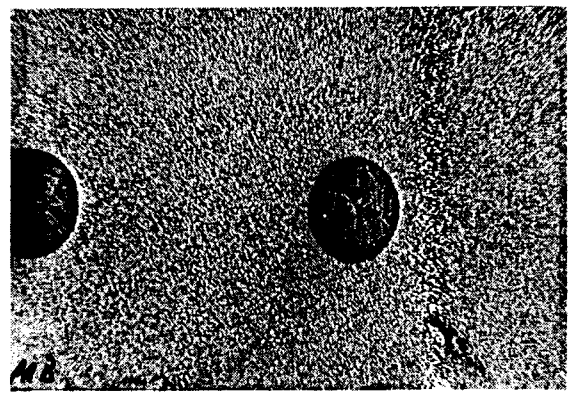

Fig. 14 Close up showing exfoliation more clearly. Further 0.010 ins. (0.254 mm) had to be removed by dressing.