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"SHOT PEENING CAN REDUCE EFFECTS OF AGING ON AIRFRAME AND ENGINES"

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ABSTRACT

Metal Fatigue, Corrosion Fatigue and Stress Corrosion Cracking are the catastrophic modes of metal failure that can be significantly controled or even avoided by the use of Controlled Shot Peening. This processes is often applied to new airframe, engine and landing gear components but it is being increasingly used at overhaul to restore compression to metal surfaces that have been subjected to high cycles and/or stresses, corrosion, wear, fretting, etc.

There are some cautions to be observed relating to ensuring correct intensity, coverage and choice of media, particularly when parts are to be peening on previously fatigued specimens. Computer Monitored Shot Peening, on site and off, will also be discussed.

DISCUSSION

Shot peening is a well-recognized method of preventing or greatly retarding metal failures from fatigue, stress corrosion cracking and corrosion fatigue (Fig. 1).[1,2] Most aircraft structural parts are shot peened during manufacture to offset the life-debitting effects of machining, grinding, welding, anodizing, etc. (Figs. 2&3) Shot peening introduces known, high magnitude residual compressive stresses.[3,4] As long as these compressive stresses remain in the surface of the part, there is little danger of crack initiation. Over time, though, there are factors that can dissipate the protective effect of the shot peening. The subject of this paper is to outline some applications where peening has been used as a rejuvenation process but it is useful, first, to consider the dissipation factors.

* Heat, of course, will relieve the compressive stress. Structural components are not usually subject to high heat (more than 250°F for aluminum and 800°F for titanium) in service. However grinding or welding a shot peened surface will not only relieve the beneficial compressive stresses, but will replace them by detrimental tensile stresses.

* Service stresses, particularly peak load stresses, will eventually cause localized yielding of the peened surface, after many, many cycles. Peening the surface again, before cracks appear, will restore the compressive stresses to the original value of at least 50% of the ultimate tensile strength of the material. (Fig. 4)

* Physical removal of the surface layers, by general or pitting corrosion or exfoliation can cause eventual penetration of the compressive layer. In this category falls also the mechanical dressing of the surface to remove the corroded layers, which will also remove the shot peened layer. To further weaken the component, the dressing of the surface will reduce the effective cross section and in many cases, the dressing can introduce tensile stresses.[5] Under these circumstances, repeening of the dressed surface is mandatory.

SHOT PEENING FOR REJUVENATION

The same parameters and specifications should be adhered to when peening an aged component as were employed during manufacturing.[6] The one recommended change is to use ceramic shot rather than cast steel. Cast steel will leave an iron deposit on the surface of aluminum. During manufacturing, the iron is removed prior to the application of the anodic coating but it is better to avoid it altogether when peening a structural component that is attached to the aircraft.[7]

Maintaining Almen intensities is critical, particularly in thin areas (Fig. 5). Coverage is especially critical when the problem is associated with stress corrosion and the use of a fluorescent tracer is recommended (Fig. 6).[8,9] Where peening on the original part might have been desirable, now repeening of a reworked part becomes essential since even with the repeening, the aged part is not as resistant to fatigue and SSC as when it was new. For this reason, automatic or even computer controlled shot peening is to be preferred and available.[10,11] Peening using hand-held nozzles or flapper wheels is not recommended and shuld be avoided (Fig. 7).

With a clearer understanding of the process, applications can be described where shot peening has been used to increase or restore the resistance to SCC & CF on aging aircraft.

a) As far back as the early 1970's, SCC was found on DC9 main landing gear attach fittings (aluminum). McDonnell Douglas required that all DC9s 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 sheet. The shot was contained by the differential pressure peening nozzle and returned to the pressure generators for 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.

b) In an 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" (Fig 11).[12]

c) 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."

d) There is a current 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, 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 peening of the lugs so that the fittings do not need to be disassembled from the aircraft or the fins. Sophisticated mask tooling is required to contain the shot.

The above examples are only typical of many applications of shot peening used on aging aircraft to prevent or greatly retard SCC, CF and metal fatigue. The 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 overhaul, usually as a protection against fretting fatigue (Fig. 8).[13]

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 aluminum, with white corrosion products between the layers. It is often found next to fasteners where the electrically insulating sealant or a 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 upward, but in less severe cases, there may be no telltale bulging, and the corrosion can only be detected by nondestructive inspection methods (Fig. 9&10).[14] Controlled shot peening is of little value in preventing exfoliation corrosion but it can be very effective in the process of repairing the damage. Service manuals normally call for the removal of the fasteners and then for the use of rotary files to grind away the corroded material followed by blending the area and polishing out the tool marks. Aircraft engineers have used controlled peening after the polishing to increase the fatigue strength of the newly reduced cross-section. The action of the peening can cause the surface to bulge out again where deeper exfoliation has taken place. The surface can then be reground and repeened until no further bulging occurs. The shot peening provides excellent NDT 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 (Fig. 11).[15,16] Peening of corroded surfaces can be accomplished using special enclosures to contain the media (Fig. 12). It is essential to maintain extreme control on the intensity of the peening not to cause bulging of the skin itself, rather than just the exfoliated layer, which would scrap out the entire panel.

PREP OF CORRODED SURFACES

Chronologically, this section should have preceded the other but it is necessary to understand the principles of controlled shot peening to properly appreciate how these principles can be applied to effective blasting for removal of paint and the products of corrosion.

Plastic Media Blasting for paint removal showed great initial promise but has fallen down in some important areas. Airframe manufactures, for instance, have limited, by specification, paint removal by PMB to one time only because of the danger of damage to the surface of aircraft skins.[17] Most aircraft will require several paintings during their useful life so a better method is still to be found. Also, dust and disposal of paint contaminated PMB has become a major problem -- not on the magnitude of the disposal of paint solvent chemicals, but a problem nonetheless. The current application techniques for PMB have largely been developed by the manufactures of plastic media in conjunction with the manufactures of paint.

There is a process development under way to apply the controls of shot peening to the technique of paint removal which, together with non-toxic water soluble blasting media, shows considerable promise in reducing substrate damage, dust and disposal of paint chips. Blasting to remove the products of corrosion from aircraft surfaces is very cost effective but it requires great expertise. The most common products of corrosion on aircraft are iron oxides on fastener heads and aluminum oxides on the skins and structural members. These oxides are very hard and removal is difficult unless a media of equal or greater hardness is used. Glass beads, for instance, may be too soft. Fine aluminum oxide grit works very well and has been used successfully on a DC8 to clean along the rivet lines of the wings and fuselage prior to repainting. The expertise comes in determining the energy level (intensity) and dwell time for a given area bearing in mind that it is quite easy to blast a hole right through the skin if the correct parameters are not observed. Of necessity, the DC8 was blast cleaned manually but automatic equipment is now being developed for this purpose.

There exists also a requirement for blast cleaning the corrosion, followed by shot peening, between the skins in the overlap joints. After the fasteners are removed, the skins can be separated sufficiently to allow insertion of specially designed, automated, differential pressure nozzles that will contain the media in addition to doing the blasting.

CONCLUSION

Well established techniques of controlled shot peening, as used on aircraft components at the manufacturing stage, are being applied to aging aircraft in the field to prevent or retard failures from fatigue, stress corrosion cracking, corrosion fatigue, fretting, etc., by the introduction of high magnitude compressive stresses. Peening is also being used to identify and combat the effects of exfoliation corrosion. Similarly, the controls of shot peening are being applied to blasting for the removal of paint and the products of general corrosion.

REFERENCES:

1. W. P. Koster, et al, "Surface Integrity of Machined Structural Components"; Technical Report AFML-TR-70-11, March 1970.
2. J. H. Milo, "Shot Peening Prevents Stress Corrosion Cracking in Aircraft Equipment"; Materials Protection (NACE), September 1968.
3. W. J. Harris, "Metallic Fatigue"; Pergamon Press, p.61.
4. H. O. Fuchs, "Shot Peening Stress Profiles"; available from Metal Improvement Company.
5. H. W. Zoeller and B. Cohen, "Shot Peening for Resistance to Stress Corrosion Cracking", AMS Technical Report No. D5-20.1.
6. B. W. Lifka and D. O. Sprowls, "Shot Peening - A Stress Corrosion Cracking Preventive for High Strength Aluminum Alloys"; Paper 86, NACE 26th Annual Conference Proceedings.
7. J. E. Campbell, "Shot Peening for Improved Fatigue Properties and Stress Corrosion Resistance"; Metals and Ceramics Information Center, Report No. MCIC-71-02.
8. MIL-S-13165C, "Shot Peening of Metal Parts", U.S. Military Specification, June 1989.
9. P. O'Hara, "DYESCAN Tracers as a Quality Control Tool for Coverage Determination in Controlled Shot Peening"; SAE Technical Paper Series 850708, February 1985.
10. J. J. Daly and D. E. Johnson, "Computer-Enhanced Shot Peening"; Advanced Materials and Processes, May, 1990.
11. "Shot Peening Applications - Seventh Edition"; available from Metal Improvement Company.
12. M. J. Phillips, "Maintenance of Concorde into 21st Century"; British Airways plc.
13. S. S. Manson, "Metal Fatigue Damage -- Mechanism, Detection, Avoidance and Repair with Special Reference to Gas Turbine Components"; ASTM STP-495, 1971.
14. D. J. Hagemeier, "Exfoliation Corrosion"; Materials and Process Engineering, Douglas Service, Volume XXXVII, September/October 1980.
15. D. Finch, "Aging Aircraft"; Engineering, September 1989.
16. C. F. Barrett, "Peen Forming"; Tool and Manufacturing Engineers Handbook 1984, Special Forming Methods.
17. "Plastic Media Abrasive Striping of Organic Finishes"; Boeing Document DC-54705.

CAPTIONS FOR FIGURES 1-10

Figure 2- Residual stress in 4340 Steel (HRC 50) after surface grinding.

Figure 1- Photomicrograph of crack found in a 7079-T6 forging, 500X.

Figure 3- The influence of hard anodizing and shot peening on the failure strength of Duralumin (LI).

Figure 4- Example of Residual stress profile created by shot peening.

Figure 5- The Almen Intensity determination system.

Figure 6- The Peenscan[R] System. (A) Coated, unpeened. (B) Peened 15 seconds, partial coverage. (C) Peened 60 seconds, improper nozzle angle in cavity (arrow).

Figure 7- Schematic of residual compressive stress created by a single shot peen dimple.

Figure 8- Schematic of computer controlled shot peening equipment used inside of containment at nuclear power stations. Insert: SCC failure location at roll transition zone, approximately 600mm (24 inches) inside 20mm (3/4 inch) diameter steam generator tubes.

Figure 7- Shot peening of holes using deflector lance nozzle.

Figure 8- Suppression of fatigue damage of Inconel 713C turbine blades by shot peening.

Figure 9- Exfoliation corrosion, which shows as bulges around rivet heads, can propagate into fatigue cracks.

Figure 11- Compound curvature resulting from tri-axial forces induced by shot peening.

Figure 12- Schematic of computer controlled system for on-site shot peening of aging aircraft structures.

Figure 10- Section through typical exfoliation blister or protrusion.