Fatigue justification for straightening parts with Flap Peening

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Abstract

Flap peening is a form of shot peening that is very useful for rework of small areas. The Flap is also called self contained peening since the shot is bonded to the flap which enables use on assembled structures as the shot does not fly off in all directions. Shot peening is used for forming parts such as wing panels, and though the intensities are limited with the flap they are still high enough to enable straightening under certain circumstances. The fatigue improvement of the shot peening process is well documented but not so for flap peening. Recently a certain OEM questioned the flap straightening process inferring that the process will decrease part life. The common accepted view is that it will not degrade the material or part properties but the contrary is true it enhances fatigue life. The fatigue tests confirmed the accepted view. The paper will show results of fatigue testing of flap straightened aluminium sheets samples. In addition several interesting field applications will be shown of straightened parts that are flying

Keywords flap peening, straightening, fatigue

Introduction

When going over the development of the technique sheet for the forming of our business jet wings I noted that the intensities of the outboard areas were within the capabilities of Flap peening. Extrapolating this knowledge I started to experiment with straightening of sheet as well as machined parts. The method was surprisingly effective and so it was incorporated in our flap peening and straightening process specifications. It was decided that though it is common knowledge that peening enhances fatigue life we should test it on straightened specimens to prove the method is a viable, cost effective method without degrading effects on the parts

Experimental Methods

Aluminum Al 7075 T6 sheets were chosen, as it was readily available and corresponds to high strength alloys commonly used in aircraft today. Most fuselage skins are clad aluminium sheet so clad Al 7075 T6 with a thickness of 1.6mm was chosen. The clad sheet was chemically milled to remove the cladding as this is the common practice when peening, not to peen the cladding. Bare Al 7075 T6 sheets 3.2 mm sheet was also used to represent machined sections. The sheets were rolled to give a calculated radius. It was verified that the radius was such that on clamping down (pre-stress) we stayed within the elastic range, most forming specifications limit the pre-stress to 75% max of the elastic limit.

The verification that the stress required to straighten the specimen of 3.2 mm thickness is in the elastic region was calculated by using the standard equations from Roark &Young.

The design yield stress of Al 7075 T6 is 476 MPa min. and the calculated stress for straightening the sheet 279 MPa. Therefore, the value of the maximum bending stress is in the elastic region.

The peening conditions for the more severe 3.2 mm specimens at R=485 mm were:

5500 RPM yielding a corrected intensity of 0.015" A Almen using a 11/4"X9/16" flap

The thinner 1.6 mm specimens were 400mm long and 59.5 mm wide with an 11 mm hole in the middle see fig 1, the 3.2 mm sheet were 300mm long width and hole the same.

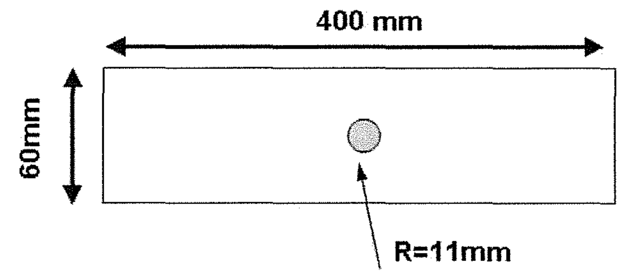

Fig 1 The 1.6 mm fatigue specimen

After the rolling the specimens were straightened by pre-stressing see fig 2

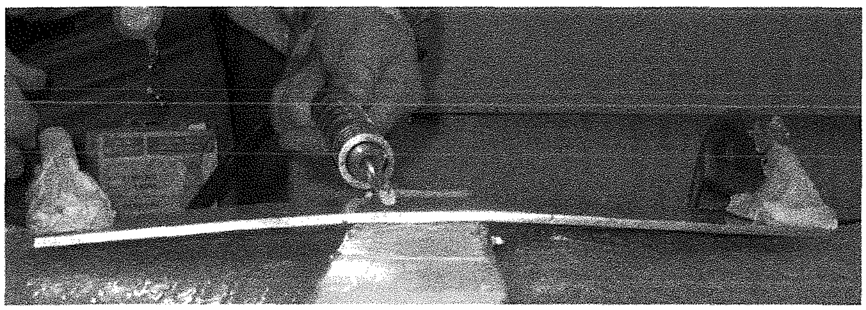

Fig 2- The 3.2 mm specimen with pre-stress being straightened

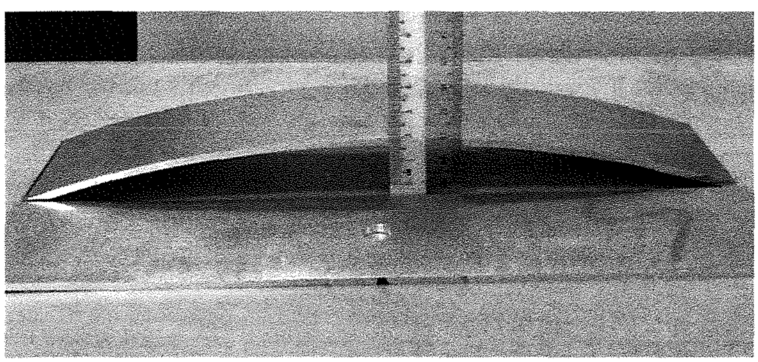

Fig 3- The 3.2 mm specimens after rolling and after straightening

Strain gages were placed to note the strains that develop on closing the grips and at a load of 1134 Kgs (2500lbs) this gave us an indication of the symmetry of loading on the samples also crack propagation indicators were placed on either side of the hole see fig 4.and fatigue tested Fig 5

Each value is an average from 3 to 5 readings

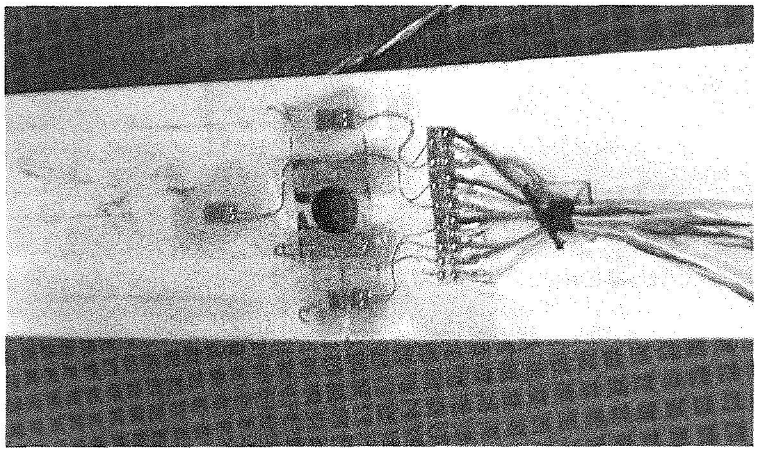

Fig 4 gauged specimen

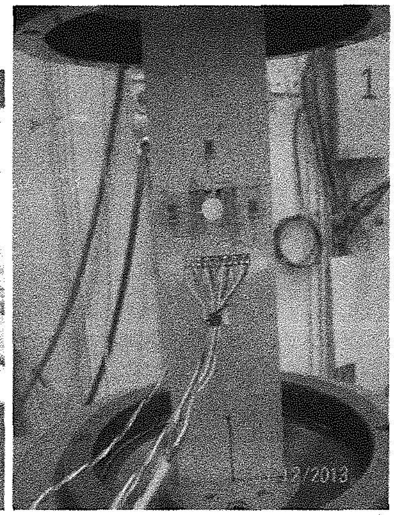

Fig 5 fatigue testing

Table 1shows the fatigue testing loading sequence

Test stress MPa. (KSI)			Cycles	Notes
Max	Min	R		
122 (17.73)	6.1 (0.89)	0.05	490	
146 (21.16)	7.3 (1.06)	0.05	5	Load marker

Experimental Results

Table 2 average life of 3.2 mm Flap Straightening R= 485 mm and R= 1526 mm

Specimen	Average cycles to fracture	Ratio peened to un-peened
control	**29339**	1
R=1526	38739	1.32
R=485	33845	1.15
All peened	35680	1.22

The crack initiation averaged 0.851 of life i.e. 85% of fatigue was crack initiation and 15% crack growth to failure

Table 3 average life of 1.6 mm Flap Straightening R= 600 mm

Specimen	**Average cycles to fracture**	**Ratio peened to un-peened**
control	**39735**	1
Hole after straightening	49942	1.26
Hole before straightening	60358	1.52
All peened	55150	1.39

The following Fig 6 and fig7 are stereomicroscope pictures of the fracture surfaces
The marker loads are very clear as is the crack initiation area of 1.6 mm specimen

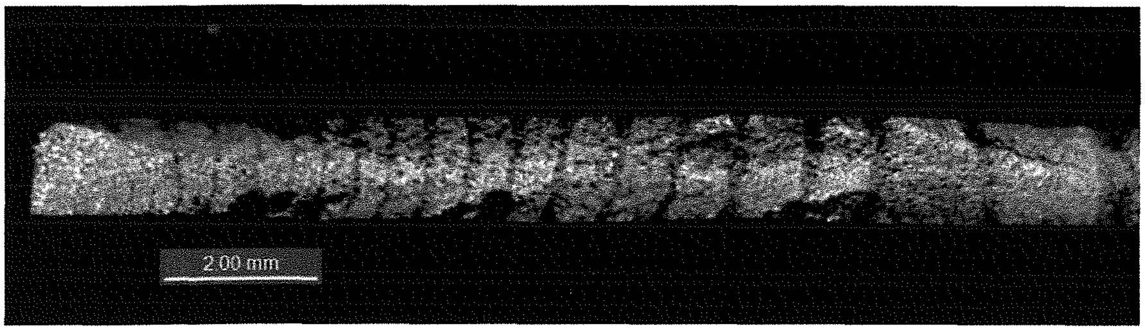

Fig 6 crack origin and load lines of 1.6 mm specimen

The 3.2 mm specimen's crack origin was planer parallel to the paper surface after some growth the crack continued in a 45° angle to the initiation plane. See fig 7

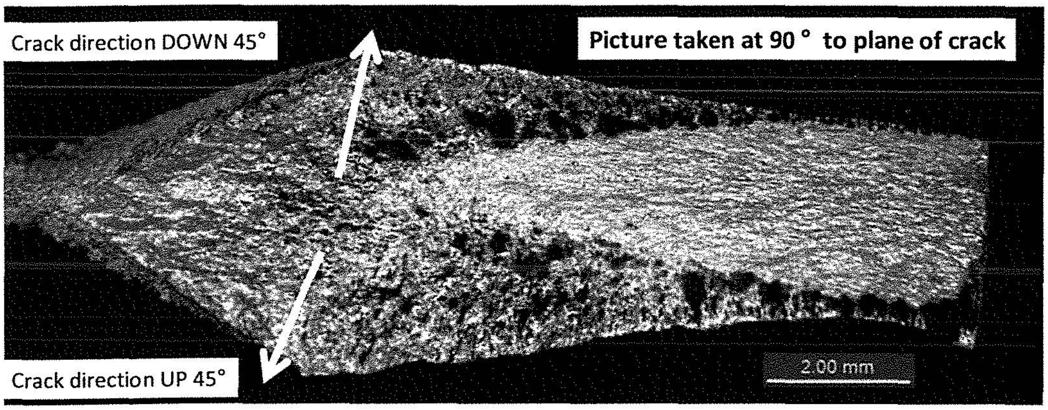

Fig 7 vertical photo of the crack plane for the 3.2 mm samples

Discussion and Conclusions

Our goal was to verify that the parts do not degrade as a result of peen straightening.
The parts were fatigued at stresses that are on the high end of stresses common for aircraft design especially as we tested with an open hole
Each straightening operation is a new challenge as we have to work out where to apply the pre-stress and how much deflection is within the elastic limit and will enable to move the part sufficiently to bring it to within the drawing tolerances. See examples below
The tests did support many of the "rules of thumb" associated with shot peening and flap peening. We were able to get XRD measurements of the surface stresses and:

- Surface stress' were compressive and conform to approximately 2/3 of the yield stress of the material being peened. Measured 325 and 335 MPa Vs. 476 MPa min. yield stress of 7075 T6
- The fatigue crack initiation was at about 85% of total life.
- Even with heavy forming we achieved better than 15% increase in fatigue life in a high strength Aluminum 7075 T6 specimens. In lighter forming conditions we achieved improvements of up to 50%
- We were able to conform to the drawing surface roughness (3.2) as formed or after a light abrading action

More work should be done to continue to generate a more comprehensive S-N curve the following are some flying parts

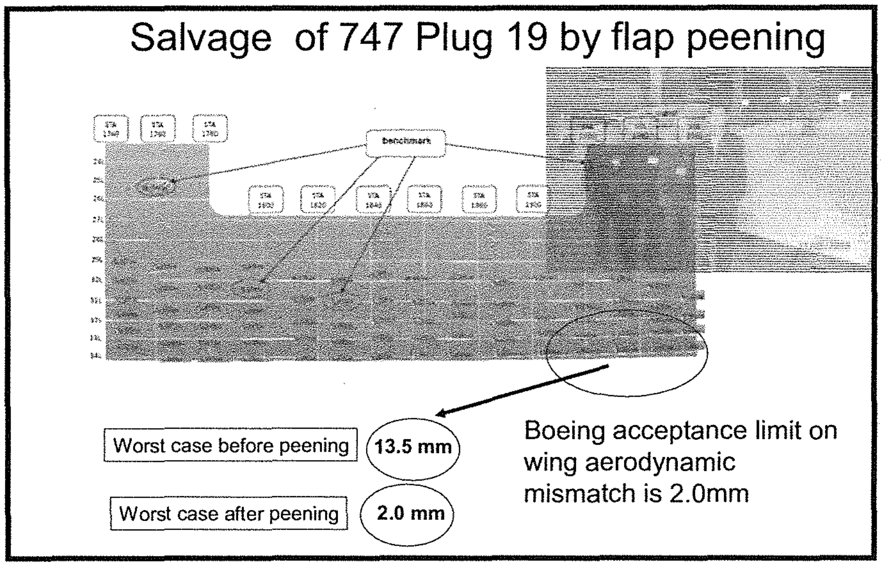

Fig 8 Cargo door surround other stations were less than 1 mm

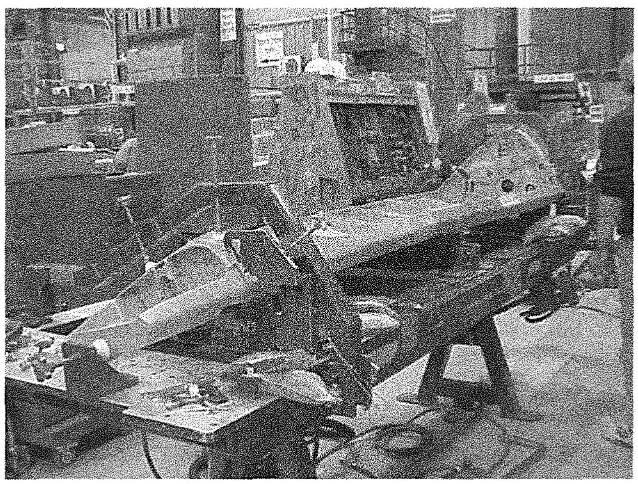

Fig 9 F-16 CFT Lower skin flap peen corrected raising 4 mm in the center station

Fig 10 Greek air force F-16 with CFT over the wing

References

[1] R.J. Roark and W.C. Young, *Formulas for Stress and Strain*, McGraw Hill international book Company

Appendix 1

The deflection in the middle of a uniformly loaded hinged beam equals

$$\delta_c = \frac{5ql^4}{384EI}.$$

For $R = 485_{mm}$ and $l = 300_{mm}$ and $t = 3.2_{mm}$, the deflection equals $\delta_c = 23_{mm}$.

In addition, $E = 7.24 \times 10^3 \left[\frac{kg}{mm^2}\right]$ and $I = \frac{bh^3}{12} = 163.84_{mm^4}$.

For these values, $q = 0.26\left[\frac{kg}{mm}\right]$

The bending moment equals

$M_b = \frac{ql^2}{8} = 2911.6[kg \cdot mm]$. The stress applied at the specimen is calculated according to

$\sigma_b = \frac{M_b y}{I} = 28.43\left[\frac{kg}{mm^2}\right] = 278.9[MPa]$.