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Crack Resistance of AA6156 Welded Stringer Panels

Aleksandar Sedmak[a*], Blagoj Petrovski[b], Aleksandar Grbović[a], Simon Sedmak[b], Nenad Milosević[a]

[a]*Faculty of Mechanical Engineering, University of Belgrade, Serbia*
[b]*Innovation center of the Faculty of Mechanical Engineering, Belgrade, Serbia*

Abstract

Experimental and numerical analysis of crack growth in integral skin-stringer panels, produced by Laser Beam Welding (LBW), was performed in the scope of WELDAIR project and later on. Experiment was performed on full-scale components (four stringers, three welded clips), made of AA 6156 T6. Digital Image Correlation (DIC) was used to measure strains and construct CTOD or J crack resistance curves. It was shown that J vs. Δa can have unusual shape, indicating real component crack resistance instead of critical J value commonly obtained by comparing J—R curves with calculated Crack Driving Forces (CDFs). The applied technique is simple, practical and has no limitation in respect to material and geometry.

Keywords: AA6156; stringer panels; laser beam welding; digital image correlation

1. Introduction

Resistance to crack growth is always a concern in aeronautical components, especially in so-called differential structures, made by riveting, Fig. 1, being ideal location for crack initiation. Therefore, so-called integral structures have been introduced, Fig. 1, based on Friction Stir Welding (FSW) or Laser Beam Welding (LBW) processes, as explained in [1-4]. The National Aeronautics and Space Administration (NASA) carried out several studies in order to acquire experience toward validating the feasibility of using "integrally stiffened" construction for commercial transport aircraft fuselage structure [5], achieving a significant reduction in manufacturing cost [6]. In research presented in [7], LBW has been applied with AA6013 and AA6056 as part of the skin and AA6110 and AA6056 for the stringer of aircraft fuselage. Constant research and improvement of welding processes and procedures enabled further reduction of weight and production costs [8-11], including LBW.

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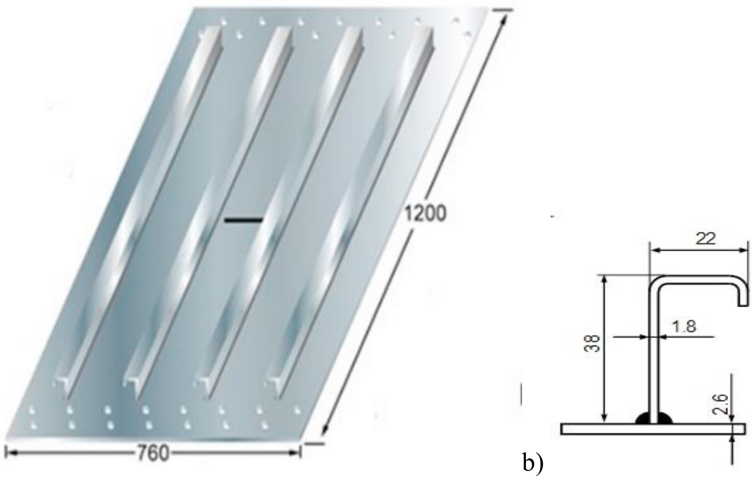
Nevertheless, during repairs following the Qantas Flight 32 engine failure incident, cracks were discovered in wing fittings. As a result, the European Aviation Safety Agency issued an Airworthiness Directive in January 2012 which affected 20 A380 aircraft that had accumulated over 1,300 flights. Fittings with detected cracks were replaced. On 8 February 2012, the checks were extended to cover all 68 A380 aircraft in operation, [12]. The problem is considered to be minor and is not expected to affect operations. Anyhow, further research was performed in addition to previously made analysis of FCG in integral stringers, [13,14]. Digital Image Correlation (DIC) was used to measure strains and construct CTOD or J crack resistance curves, as a simple and practical technique, without limitation in respect to material and geometry. Similar approach was adopted in other research, conducted on welded stiffened panel, as shown in [15-19].



a) b)

Figure 1. a) Stringer panel, b) details of welded joint

2. Experimental research

In the scope of extensive investigation of AA6156 T6 welded panels crack resistance under static and dynamic loading, J-R curve was evaluated using Δa measured by Digital Image Correlation (DIC), as shown in Fig. 2.

Two different welded panels configurations were tested, one with 4 stringers and the other one with additional 3 clips, shown in Fig. 3. As an illustration, strains measured by DIC are shown in Fig. 4.

Figure 2. Testing performed by the second author

Figure 3. Panel with 4S+3C

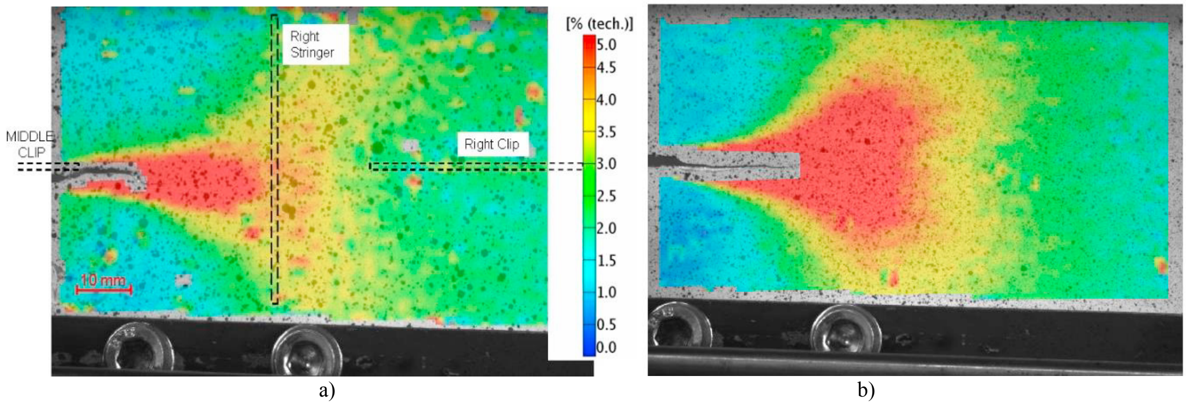
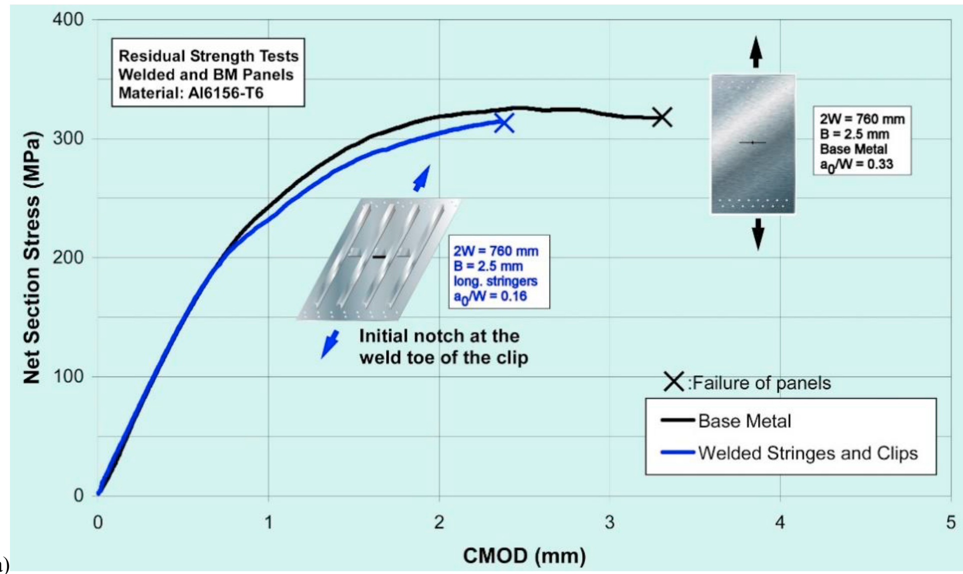
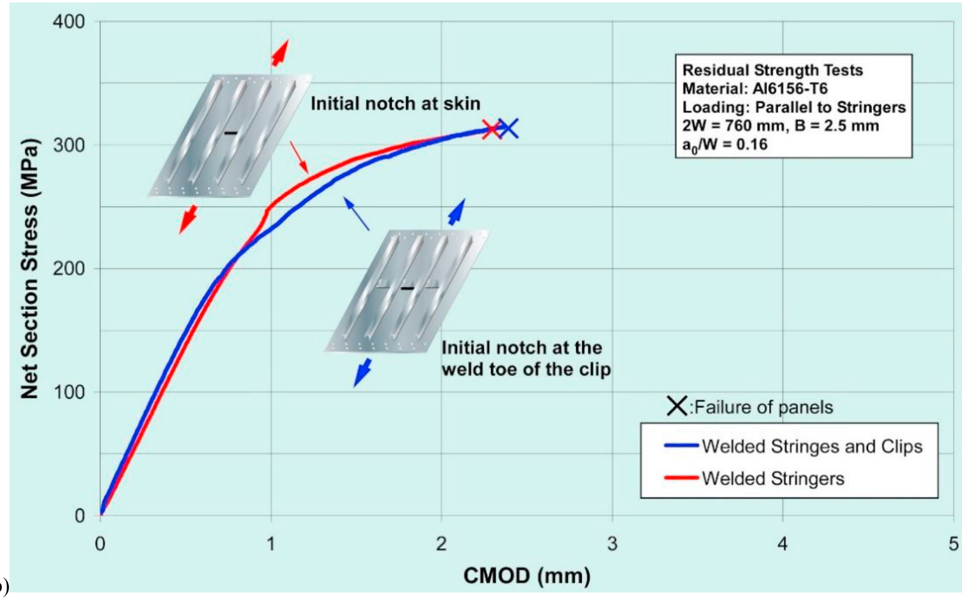


Fig. 4 a) strains measure by DIC, net stress 293.5 MPa, b) strain measruement at the last stage

Residual strength testing was performed for BM, panel+4S and Panel+4S+3C. Results in the form of Net Section Stress vs. CMOD are shown in Fig. 5. One can see somewhat different behaviour of base metal and welded panels with stringers with or without clips under tensile load.



a)



b)

Figure 5. Comparison of Net Section Strees vs. CMOD curves, a) BM and Panel+4S+3C, b) Panel+4S and Panel+4S+3C

Finally, dependence of J integral on propagating crack length are recorded and presented in Fig. 6, indicating unusual shape, more likely for crack driving forces (CDF) than for J-R curves. This can be explained by the fact that experimental points were obtained on the full-scale component rather than on standard specimens, so that obtained values of J integral do not represent material property. On the other side, they also do not represent CDFs since crack was propagating duting testing. These values are simply the real J integral measured for real crack propagation in real component. Once the component fails, corresponding value of J integral becomes the critical one, instead of the value obtained by testing the specimens and comparing J-R curves with calculated CDFs.

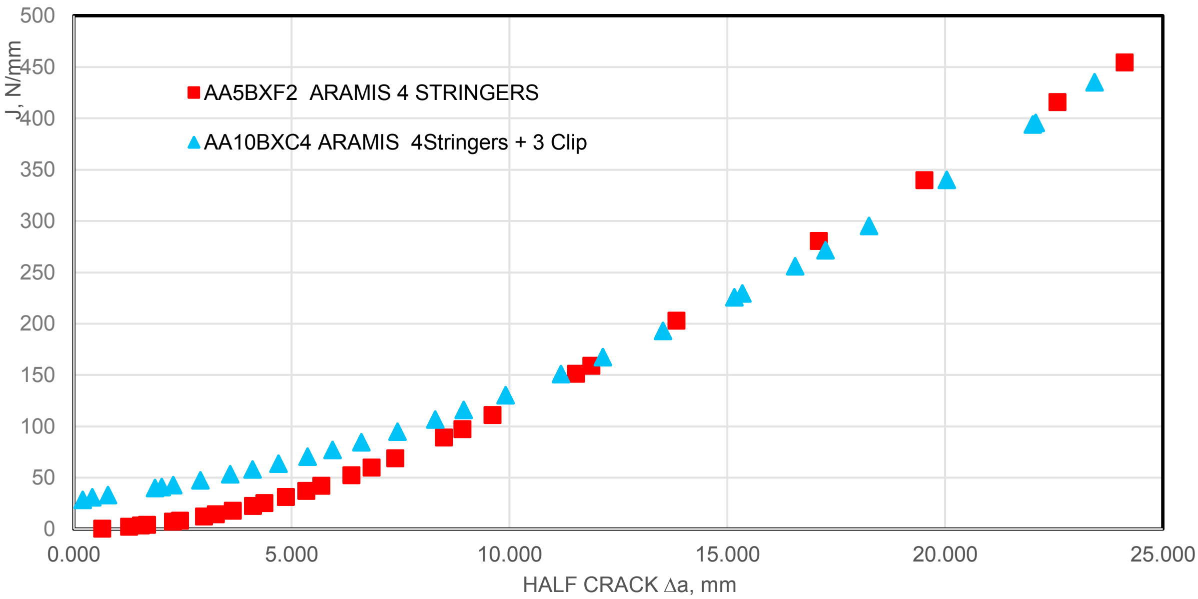


Fig. 6. J integral vs. crack length increment

Conclusions

Based on the results presented here, one can conclude that J vs. Δa curve can have unusual shape, indicating real component crack resistance instead of critical J value commonly obtained by comparing J—R curves with calculated Crack Driving Forces (CDFs). Another important conclusion is that the applied technique is simple, practical and has no limitation in respect to material and geometry.

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