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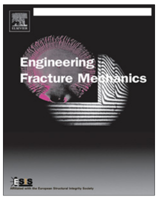

On the potential of supersonic particle deposition to repair simulated corrosion damage

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ABSTRACT

Previous constant amplitude laboratory tests have shown that supersonic particle deposition (SPD) can be used, as an alternative to mechanically fastened doublers, to enhance the structural integrity of aircraft structures. This paper compliments these findings via a numerical study into the potential for SPD scarf repairs to repair simulated corrosion in thin aircraft structural components. The results of this study, when taken in concert with the results of prior applications to full scale fatigue tests and laboratory tests, suggest that a SPD scarf repair to simulated corrosion damage subjected to load spectra representative of helicopters, fighter, maritime, and transport aircraft has the potential to give lives that are compare favourably with either the original design objectives or the stated operational life of the aircraft.

1. Introduction

The Aloha accident [1] was one of the first incidents to highlight the potential problem of multiple mechanically fastened repairs to corrosion damage, see Fig. 1 which reveals that despite the presence of MSD in the fuselage lap joint a section of the failure ran from corrosion repair to corrosion repair. One common approach to corrosion damage in operational aircraft is to blend out the corrosion and rivet a mechanical doubler over the region, see Fig. 1. Unfortunately, if the aircraft is operated in an aggressive environment corrosion can occur over a (relatively) broad area and this can lead to a number of mechanical repairs that lie in relatively close proximity, see Fig. 1. This repair process involves drilling holes that act as stress concentrators in the base structure and, unless the operational environment changes, these holes now provide additional sites at which corrosion can develop and subsequently lead to additional cracking. As a consequence a repair methodology is needed whereby the structure is not further damaged and new sites at which corrosion and subsequent cracking can occur are not created.

In this context it has been shown that, the Rosebank Engineering patented supersonic particle deposition (SPD) process[1], which uses aluminium alloy 7075 metal powder[2] with particles sizes in the range of 30–50 μm, has the potential to address a range of problems associated with aircraft structural integrity [3–5]. Indeed, [5] presented the results of a full scale fatigue test

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[1] Also known as cold spray.

[2] The SPD coating is formed by exposing the structure/component to high velocity (typically between 300 and 1200 m/s) solid-phase particles, which have been accelerated by a supersonic gas flow, in this instance nitrogen, at a temperature that can range between 500 and 900 °C.

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Nomenclature

a	crack length
A	a constant in the Hartman–Schijve equation
da/dN	rate of crack growth per cycle
N	number of fatigue cycles
R	R ratio = $K_{\min}/K_{\max}$
β, D	constants in the Hartman–Schijve variant of the Nasgro crack-growth equation
K	stress-intensity factor
$K_{\max}$	maximum value of the applied stress-intensity factor in the fatigue cycle
$K_{\min}$	minimum value of the applied stress-intensity factor in the fatigue cycle
ΔK	range of the applied stress-intensity factor in the fatigue cycle, as defined below
ΔK_{eff}	effective stress intensity factor
ΔK_{thr}	effective fatigue threshold range value (for the applied stress-intensity factor)
$\Delta F_{\text{eff, thr}}$	effective fatigue threshold range value (for the effective stress-intensity factor)
K_{op}	value of K at which the crack first opens
ΔK_{op}	difference between the opening and the minimum stress intensity factor
ΔK_{opl}	the long crack asymptote of ΔK_{op}
λ	a constant in the McEvily equation governing the decay of crack closure with crack length

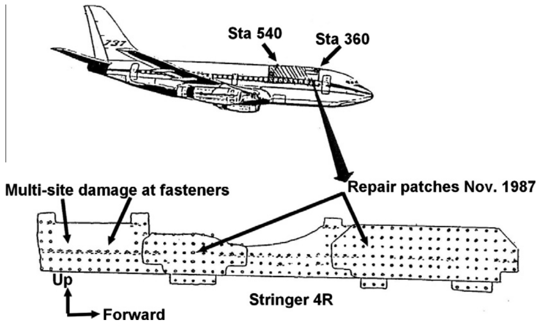

Fig. 1. The linking from multiple repairs in the Aloha, from [2].

on an F/A-18 centre barrell[3], which had twelve SPD doublers, see Figs. 2 and 3, applied to a range of features, which was subjected to a measured operational RAAF spectrum. These doublers were found to experience peak stresses in the spectrum of up to 250 MPa without, at 8500 simulated flight hours, any evidence of cracking or delamination, see [5] for more details. As such this test when taken in conjunction with laboratory test results also presented in [5] highlighted the fact that SPD can withstand representative load spectra with peak stresses greater than 200 MPa without failure.

Subsequent constant amplitude tests [5] revealed the potential of SPD scarf repairs to repair simulated corrosion damage without the need to install a mechanical doubler. The tests reported in [5] involved SPD scarf repairs[4,5] to simulated corrosion damage in 2 mm thick, 400 mm long and 42 mm wide 7075-T6 aluminium alloy specimens, see Figs. 4 and 5. The length of the scarf used in [5] was 50 mm and its depth was 0.3 mm, see Figs. 4 and 5. In [5] the depth of the scarf was taken to correspond to the depth of the simulated corrosion. To simulate small corrosion pitting/damage that was not removed by the scarfing process a 0.2 mm deep notch was machined across the full width of the test specimens [5]. Specimens that also had the material in the "scarfed" section removed but did not have a SPD doubler were also tested. These later specimens will be termed "unrepaired" specimens [5]. The "unrepaired" specimens were subjected to constant amplitude cycling at a peak stress of 140 MPa and R (=$\sigma_{\min}/\sigma_{\max}$) = 0.1 at a test frequency of 5 Hz, whilst the SPD scarf repaired specimens were tested at both 140 MPa, which is slightly below the endurance limit (of ~150 MPa) of the SPD as determined from uniaxial S–N tests on the SPD material alone, and 160 MPa at a test frequency of 5 Hz, at R = 0.1. The tests were performed at room temperature in laboratory conditions. The

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[3] The F/A-18 Hornet aircraft's centre section (or centre barrel (CB)), shown in Fig. 2, carries wing loads into the fuselage through its three main structural elements, the Y453, Y470.5 and Y488 bulkheads.

[4] This approach to some extent mirrors that used for scarf repairs to damaged composite structures.

[5] The purpose of the scarf was to ensure a smooth flow of the load from the base structure into the SPD repair.