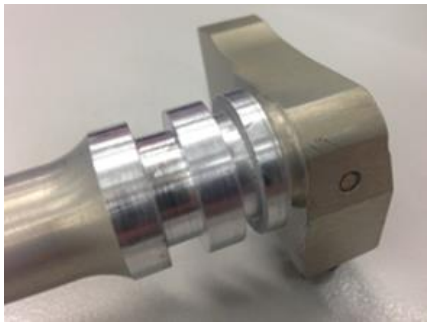



CSAT June 2015
COLD SPRAY - AN AUSTRALIAN UPDATE



Neil Matthews
Vice President Research and Technology
RUAG Australia
23 June 2015

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Introduction

- Introduction
- Background
- Application Status on Platforms
- Structural Integrity (SI) Activity and Focus
  - Summary from CAST 2014
  - SPD Impact on Intergrannular Corrosion
  - SPD Impact on Stress Corrosion Cracking
- Discussions/Questions

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Introduction

- Additive manufacture is increasingly being referred to as the third industrial revolution in that complex shapes can be built up in layers.
- Whilst significant attention is being directed towards creating new shapes there is a genuine need to restore worn/damaged profiles to their original shape whilst also restoring any lost performance integrity.
- Additive technologies provide a number of exciting and cost benefit outcomes particularly in the corrosion protection and restoration of corroded/damaged metallic components/structure to an acceptable level of structural integrity and functionality.
- To this end the presentation outlines the presents a number of deposition technologies but focuses on Powder Reconstitution Technology of Cold Spray

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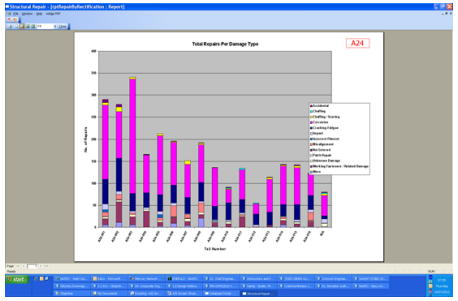
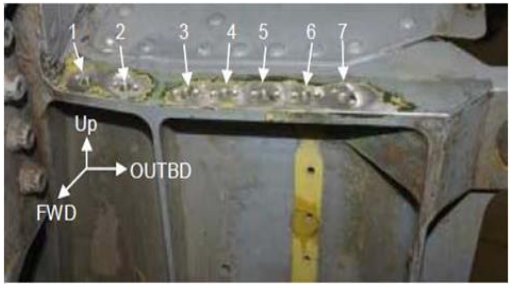
Background

- The susceptibility of damaged to legacy aircraft is well documented and occurs through many different mechanism such as corrosion, wear, impact and fatigue.
  - US DOD 2009 Report on the Annual Cost of Corrosion estimated cost of corrosion was between $10 to 20 $Billon annually with Air Force costs being up to 31% of the total maintenance cost.
  - BAE SYSTEMS Cost of Australian Defence Force Aircraft Corrosion Report (MT-0174A002-R 2014) estimated cost of corrosion for Yr. 2103 @ A$228M





  - In many instances environmental degradation of structural components including wing and fuselage panels has resulted in both aviation accidents and significant costs

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Innovation Sustainment for Ageing Aircraft

- Furthermore the need to operate aircraft longer results in a Beyond Physical Repair disposition or the implementation of repair technologies which invariably require material removal and in many cases external mechanically fastened patches/straps.
- There is no reason that modern and future aircraft will not suffer similar damage. (wear, corrosion, impact and fatigue)
- For new generation aircraft, design tools and manufacturing processes have eliminated “excess” material resulting in limited or no material removal options.

“I am looking forward to the day when the SPD repair is a common repair on the ROMEO”

Hence there is a need to implement additive metal technologies

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AMT – The Challenge & The Technologies

To develop and certify Repair technologies utilising Additive Metal technologies for current and next generation aircraft so that applications on components /structures can be returned to service in a safe, timely and cost effective manner.

Application Material	Corrosion Protection	Wear Resistant	Substrate Geometry Restoration	Structural Restoration	Structural Enhancement
Magnesium Alloy	SPD	SPD,	SPD	SPD	SPD
2024 Al Alloy	SPD, (LAD)	SPD, (LAD),	SPD, (LAD)	SPD, (LAD)	SPD, (LAD)
7075 Al Alloy	SPD, (LAD)	SPD, (LAD)	SPD, (LAD)	SPD,LAD	SPD,LAD
High Strength steels >260ksi	SPD, (LAD)	LAD, (SPD)	LAD, (SPD)	LAD	LAD
Stainless Steels	SPD, LAD	LAD, (SPD)	LAD, (SPD)	LAD, (SPD)	LAD, (SPD)
Titanium Alloys	SPD, LAD	SPD, LAD	LAD, (SPD)	LAD ,(SPD)	LAD, (SPD)
Inconel Alloys	N/R	SPD, LAD	LAD	LAD (SPD)	LAD, (SPD)

SPD – Supersonic Particle Deposition (Cold Spray)
LAD – Lases Additive Deposition (LAD)

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Application Summary

Application Meter	
No of Accepted Applications	**First Applied**
***40**	**2009**
Aircraft Types	**Accrued Flight Hours**
2 (rotary, fixed)	****7700+**

**** More applications in work (2 for another aircraft Type)***
*****Does not include 12 applications which have each accrued 8000+ hours in a full scale fatigue test of a F/A-18 Centre barrel***

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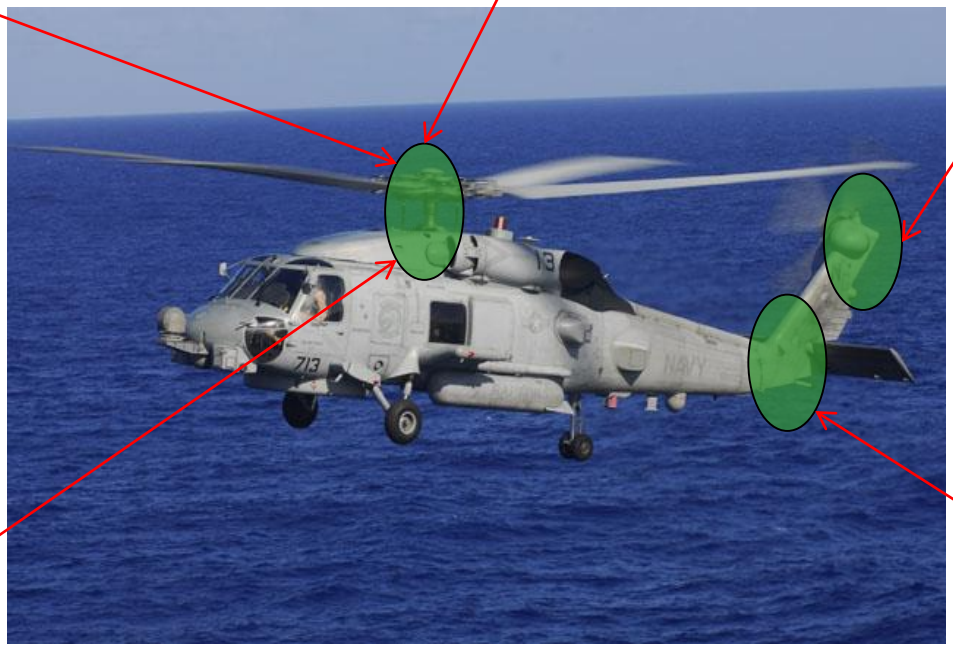
Cold Spray(CS) Successful Applications

RUAG has applied CS to Input module webs and mounting faces **(6)**

RUAG has applied CSD to main module sump and Flight control pad **(5)**



RUAG has a applied CS to TRGB feet **(6)**

RUAG has applied CS to Accessory Module mounting faces for corrosion protection and geometry restoration **(8)**

RUAG has applied CS to IGB feet for corrosion protection and geometry restoration **(5)**

TOTAL 30

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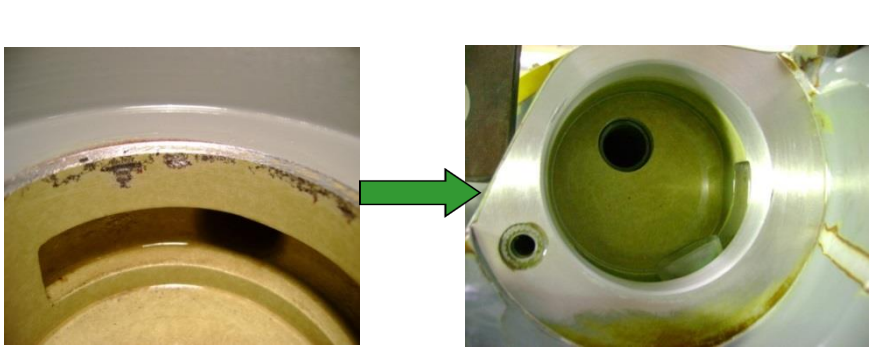
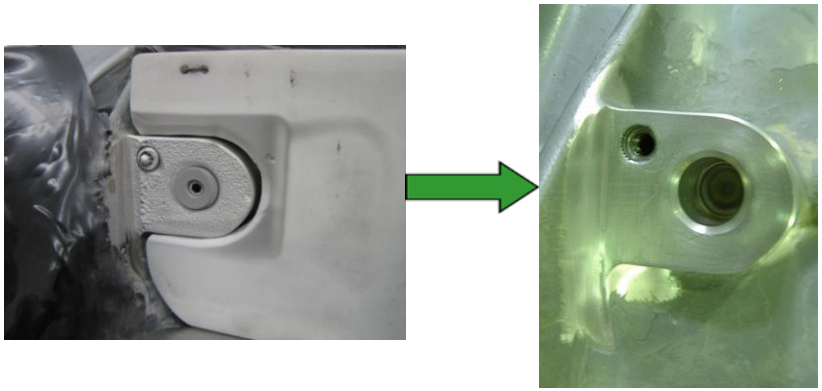
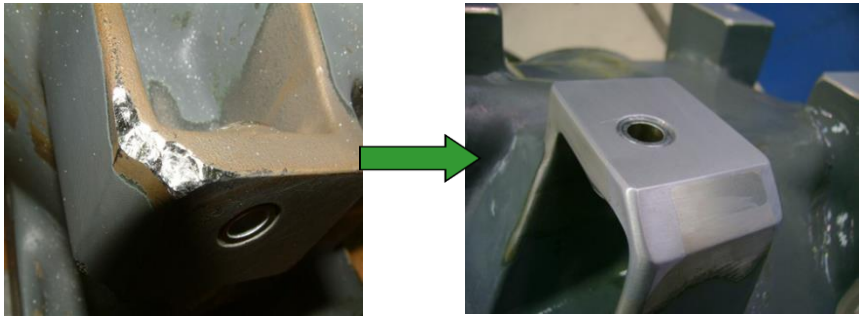
Additive CS Success Applications

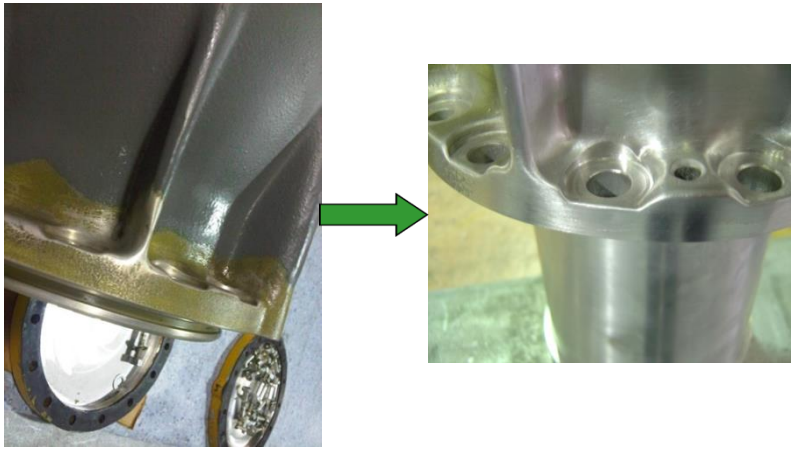




Main Module (now for prevention as well)**



Intermediate Gearbox



Input Module

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Seahawk Intermediate Gearbox

Before

Corrosion Damage

During

Robotic Deposition

After

Reworked Foot Profile

IGB S/N A005-03167 was installed new in May 2008 → Removed for corrosion Apr 09 with 188 AFHRs → CS repaired using FPSPDU → re-installed Oct 12 Current 892 AFHRs

Report from Ship HMAS Toowoomba “no corrosion”

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SPD Successful Applications

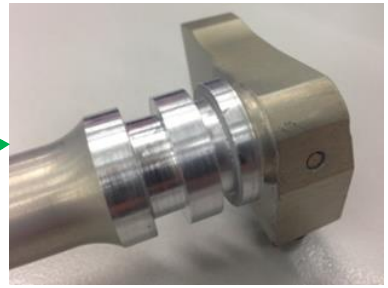
RUAG has applied CS to Centre Barrel which has undergone full scale fatigue test as part of SI BOE

RBE has applied SPD to Brake Carrier for geometry restoration

RUAG has a applied CS to Drag Brace Outer Tube

RUAG has applied CS to Wheel Brake Swivel Assembly Housing

RUAG has applied CS to MLG Axle Hydraulic Swivel Joint



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Further CS Geometric Target Repairs

Brake Carrier

Arresting Pivot Hook

Wheel Hub, Nose

Swivel Joint

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System Specifications/Endorsements

- SPD Technology is an approved is a Military Standard, (MIL- STD 3021_ Materials Deposition, issued AUG 08)

- The Director General of Technical Airworthiness (DGTA) has accepted SPD applications for geometry restoration and considers that sufficient evidence exists to support Technology Transition for SPD within the aerospace community (Jul 2010).

- DGTA has established a Technology Transition Working Group (TTWG) to transition the technology for all users for geometry applications and expand the SPD application for structural restoration/enhancement

- The portfolio of OEMs and significant users who are either positively engaged or supporters of AMT continues to grow. The portfolio includes Boeing, Sikorsky, Bombardier, Messier Bugatti Dowty, AIRBUS Group

- US Army and Navy have approved SPD (Cold Spray) repairs

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Technology to Target

- RUAG (previously Rosebank) awarded CTD program in Jul 2008 to the design and build Field Portable SPD Unit FPSDU with the same capability as the large “fixed plant” SPD capability. Successful field demonstration held at HMAS Albatross on the 2 and 3 August 2010

- Recently trialled on full scale fixed wing Mock Up at RAAF Base Richmond

Video

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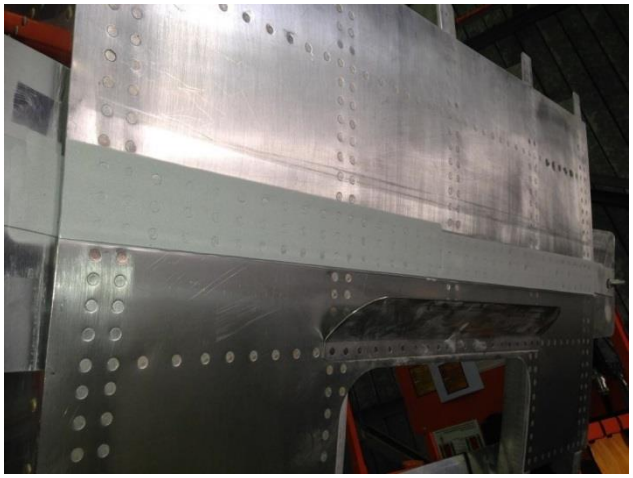
Technology to Target

- Mock Up at RAAF Base Richmond Outcomes



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Other Activities

- Working with RUAG Space for CS Additive Applications
- Working with Monash University on New materials
- Agreement with Moog
- Working with ARL
- Working with USN/DSTO
- Innovative commercial aerospace applications

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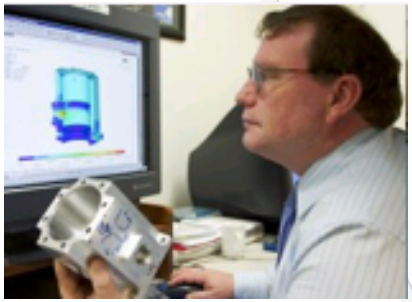
Structural Integrity Restoration/Enhancement



International Conf. on Airworthiness & Fatigue - 7th ICSAELS Series Conf. 25-27 March, 2013 Beijing, China

Application of Supersonic Particle Deposition To Enhance The Structural Integrity Of Aircraft Structures

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[b]Second affiliation, Address, City and Postcode, Country Centre of Expertise in Structural Mechanics, [b]Department of Mechanical and Aeronautical Engineering, Monash University, Wellington Rd, Clayton, Vic 3800, Australia., rhys.jones@monash.edu
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Abstract

This test report summaries the results of an experimen SPD, also known as cold spray, to extend the limit of validity (LOV) of aircraft st structural integrity of corroded panels. In this study we evaluate the potential for d joints and for this seal to remain intact even in the presence of multi-site damage in ignificantly retard, possibly even eliminate, the onset of corrosion d end the LOV of mechanically fastened joints. We also show that SPD ca badly corroded wing skins.

Keywords: Cold spray; fuselage joints; corrosion; LOV

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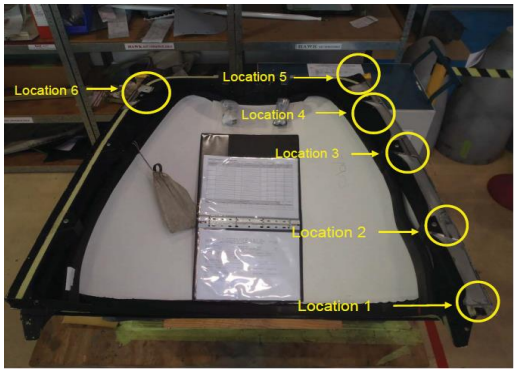
Structural Integrity Enhancement/Restoration_WHY

Corrosion around windscreen frame



Multiple corrosion repairs on a RAAF P3C aircraft wing

Numerous areas of corrosion, damage and

coating degradation

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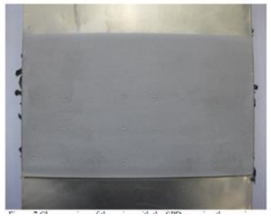
Summary SI - CSAT 2014

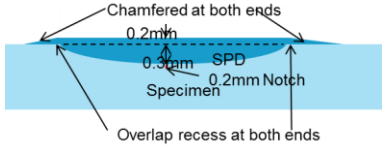
- Considerable research, experimentation and analytical modelling has been undertaken to assess the potential of SPD as a technology for structural restoration and enhancement and also in the development of predictability modelling. Experimentation and analysis has demonstrated the following:

  - SPD (cold spray) can be used on lap joints to effectively seal the joint and significantly retard, and possibly even eliminate the onset of corrosion and subsequent damage in the joint.



  - SPD can replace conventional patch/strap repairs and negate structural issues of introducing new holes and the need to parasitically stiffen (i.e. locally over stiffen) the structure.

  - SPD can be used to repair corrosion damage and that the resultant repaired structure has a dramatically increased fatigue life.



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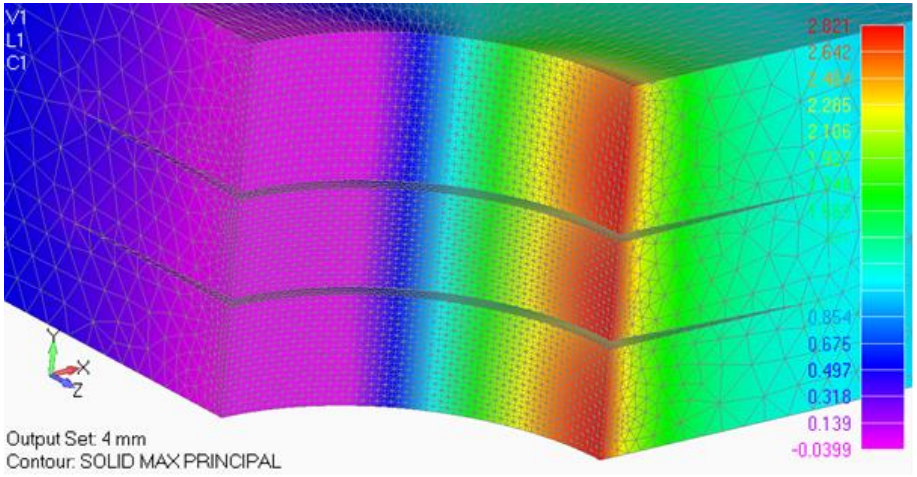
Application of CS to alleviate intergranular cracking

- Analysis was conducted on the ability of CS to restore the structural integrity of panels that contain both intergranular cracks and cracks that grow from small naturally occurring material discontinuities at a fastener hole.
- The geometries that were used are representative of areas in RAAF AP3C aircraft.
- The particular problem analyzed involves multi-layer intergranular corrosion, which arises at fastener holes due to ingress of the environment down the fastener holes in the wing structure, with two intergranular cracks that (in the vicinity of the fastener hole) divide the plate thickness into thirds, interacting with cracks that emanate from the bore of the fastener hole in a 7075-T6 aluminium plate.



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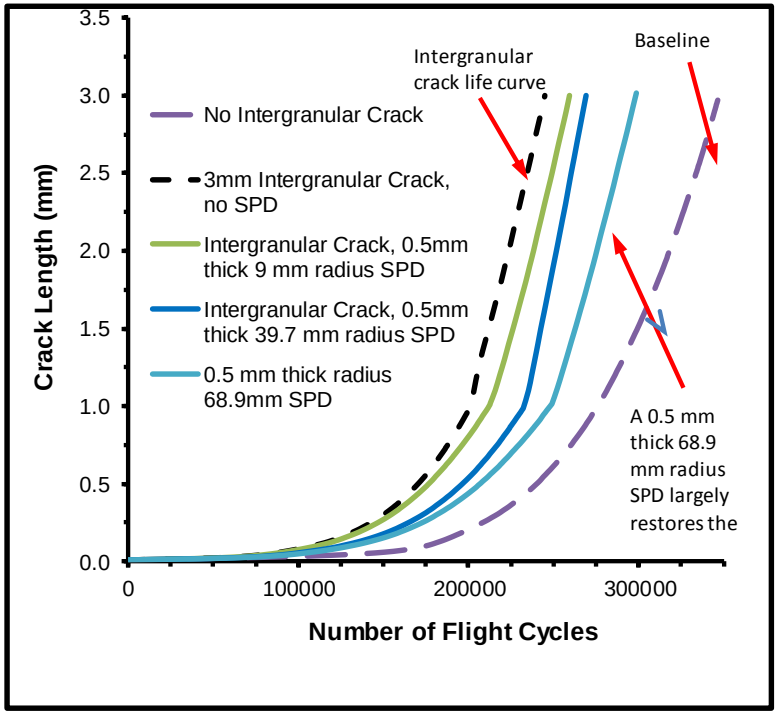
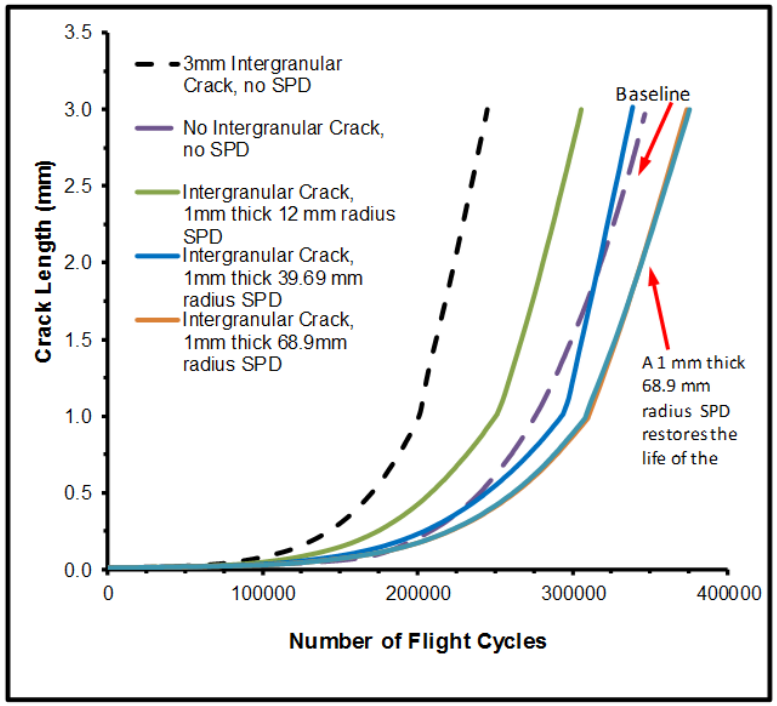
Application of CS to alleviate intergranular cracking



Effect of a 0.5 mm thick SPD on the fatigue life.



Effect of a 1.0 mm thick SPD on the fatigue life.

- The research has shown that CS has the potential to reduce the crack growth rate of a hole containing intergranular corrosion to a level of a of a hole without intergranular cracks.

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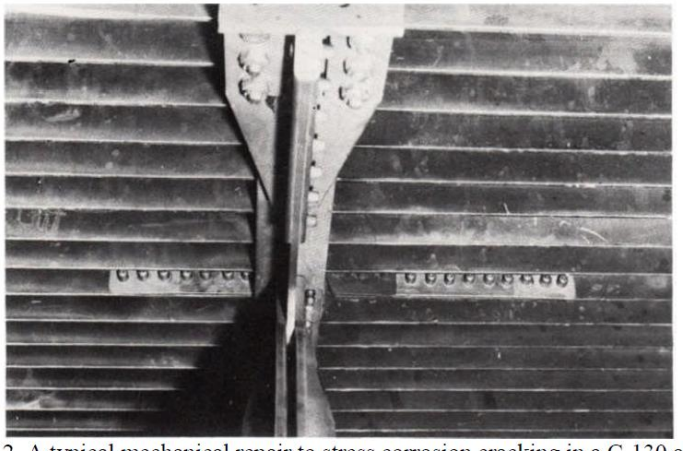
Application of CS To Alleviate Stress Corrosion Cracking (SCC)



- The occurrence of stress corrosion cracking (SCC) in rib stiffened wing planks is common to both transport and maritime reconnaissance aircraft. On compression surface of the wing the allowable size of the SCC is set by the length that will cause local buckling of the wing. In the 1970's this failure mechanism led to an in-flight failure of a US C-130. The presence of SCC in many of our platforms continue to be a problem.

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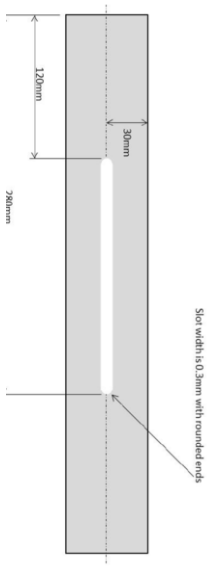
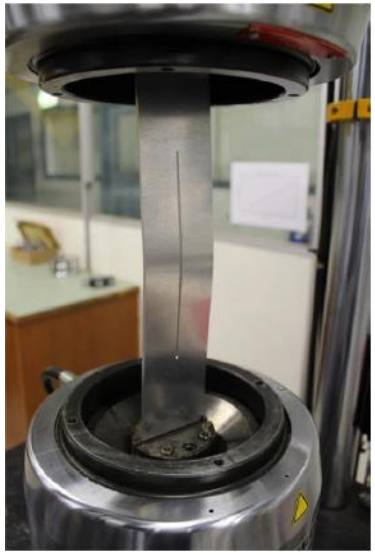
Application of CS To Alleviate SCC

Initial Study

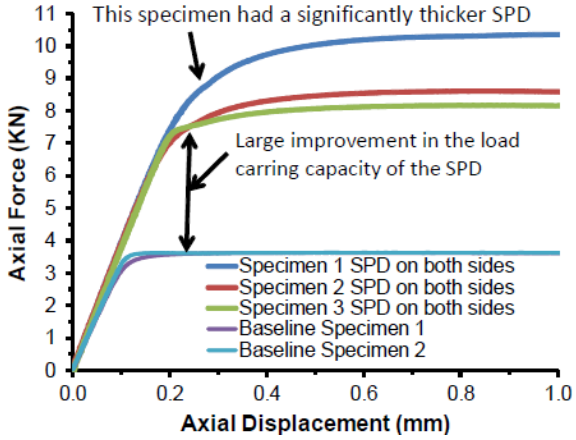


Baseline Specimen



SCC Specimen

CS Specimen



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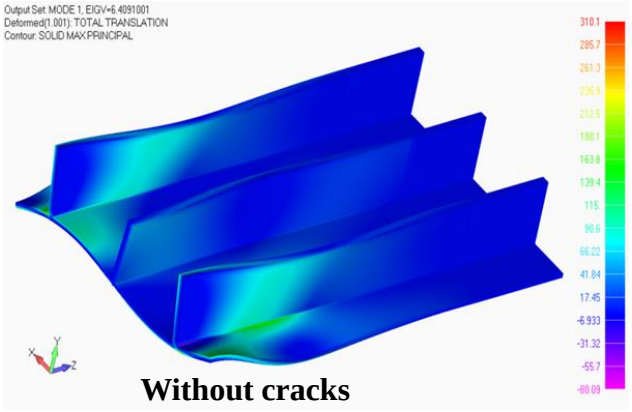
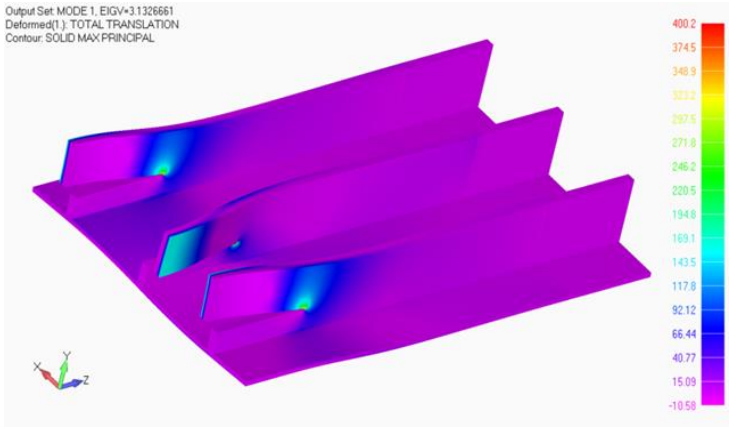
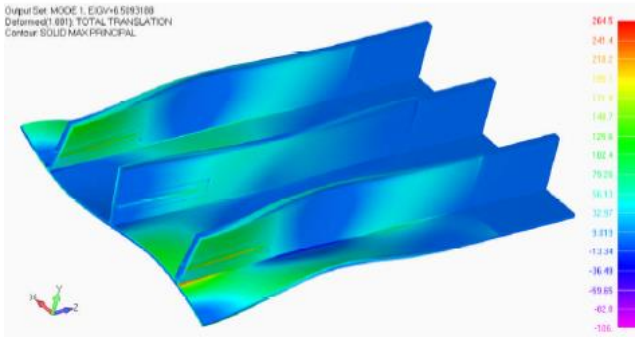
Application of CS To Alleviate SCC
FE Modelling



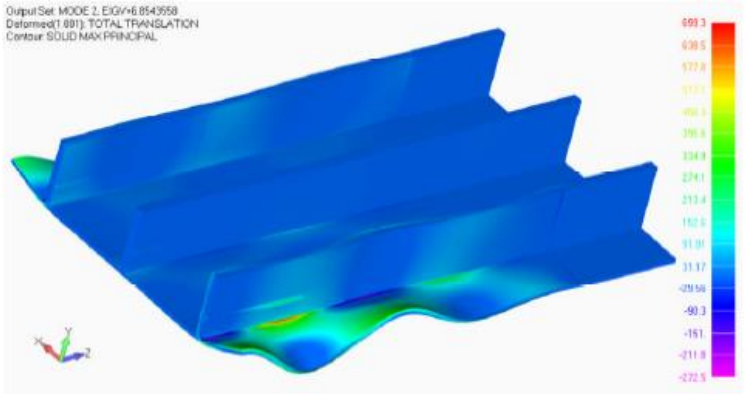
Without cracks



With cracks



With cracks & CS



With cracks & Thick CS

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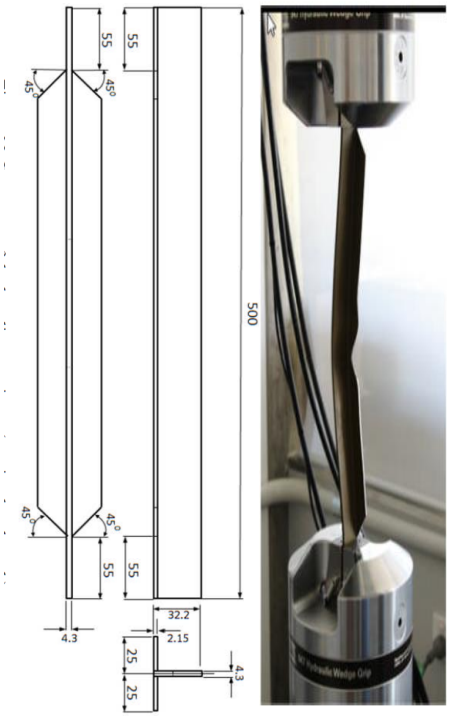
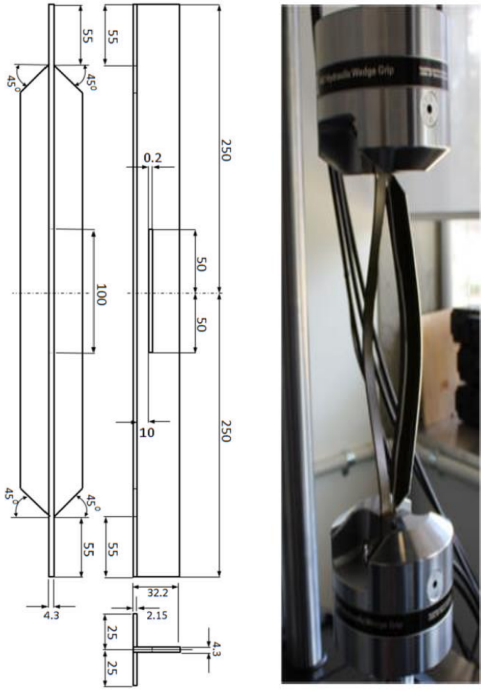
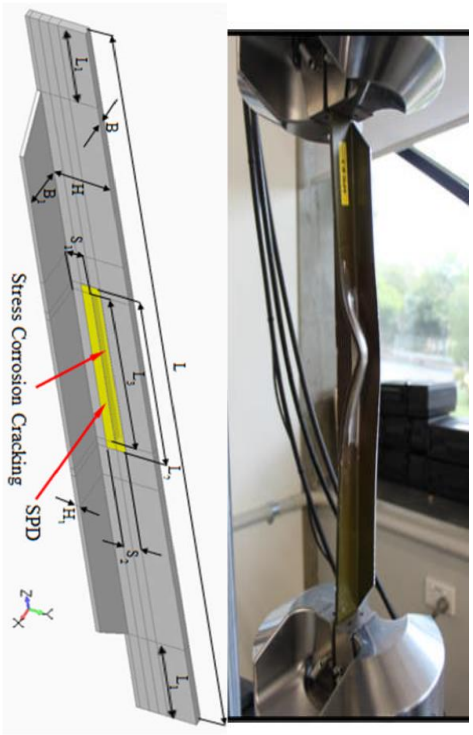
Application of CS To Alleviate SCC



Baseline Specimen



SCC Specimen



SPD Specimen

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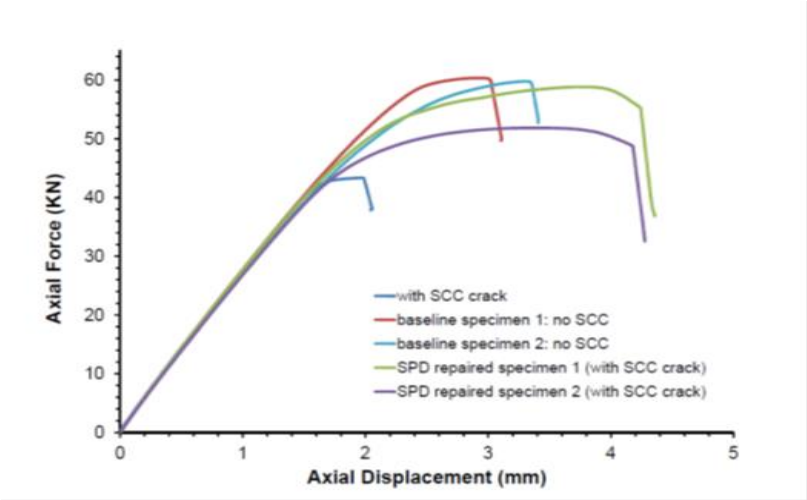
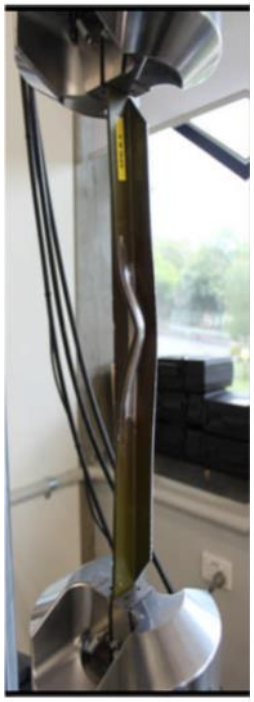
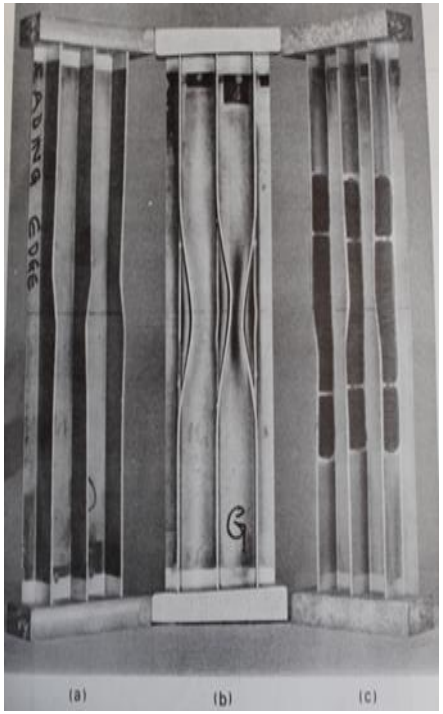
Application of CS To Alleviate SCC

Specimen Type	No	Buckling Load		
		Experimental [Remote mean stress in MPa] (kN)	FEM (kN)	% difference
Baseline specimen	1	60.2 [252]	60	0.3
	2	59.8 [250]	60	0.3
With SCC	1	41.3 [173]	42.8	3.5
SPD repaired	1	58.8 [246]	60.1	2.2
	2	51.9 [217]	54.1	4.3





SPD Specimen



Boron Specimen

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Application of SPD To Alleviate SCC

Conclusion

- ❖ This Research has shown:
- ✓ That SCC can dramatically reduce the buckling loads in rib stiffened wing planks.
- ✓ That SCC can result in local buckling with Mode I, II and III contributions to the stress intensity factors at the tip of the SCC.
- ✓ That SCC can cause failure due to mixed mode cracking that runs the length of the structure.
- ✓ Prior to buckling SCC has little effect on the load versus deflection curve and hence on the load path.
- ✓ The potential for SPD repairs to be designed to essentially restore the load carrying capacity of the structure to its design requirement.
- ✓ The importance of ensuring that the thickness of the SPD is such that the SPD does not fail prematurely or change the failure mode
- ✓ In comparison to composite and riveted metallic repairs SPD has several advantages, viz:
    - ➢ It is significantly faster and can be implemented in under an hour;
    - ➢ It seals the component so that the environment can't reach the crack and thereby stops further corrosion;
    - ➢ It does not introduce a dissimilar material. •

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QUESTIONS ?????

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