Singapore Aerospace Technology & Engineering Conference
10 February 2014 in conjunction with Singapore Airshow 2014
Suntec Singapore International Convention and Exhibition Centre1
Organisers: The Singapore Institute of Aerospace Engineers (SIAE) and the Air Engineering & Logistics Department, Republic of Singapore Air Force (AELD, RSAF)

Paper Title:

Self-healing Technology for Aircraft Composite Structure Repair

Dr Hamid Saeedipour

Senior Academic Staff
School of Engineering, Republic Polytechnic,
9 Woodlands Ave. 9, Singapore 738964
Email: *hamid_saeedipour@rp.edu.sg*

Keywords: Aircraft Structure Repair, Self-healing Technology, and Carbon-fibre Composite Repair

Intensive Abstract

There is a considerable interest towards the achievement of self-healing properties in composite materials. Traditionally, once damage has been detected within a composite structure, the approach has been to undertake cosmetic temporary structural repairs, ranging from simplistic external patches to complex intrusive tapered or stepped scarf repairs with the aim of restoring some of the material stiffness and strength. However, engineers have started to design structures that have some form of damage tolerance, which is ability for the structure to sustain representative weakening defects under representative loading and environment without suffering reduction in residual strength for a period of aircraft service.

Fibre-reinforced composite materials are widely used, especially in the aerospace industry. The concept of repair by bleeding of enclosed functional agents serves as the biomimetic inspiration of synthetic self-repair approaches which are mainly depending on advancement in polymeric materials. In general, this process is the inspiration for the application of self-healing fibres within the composite materials.

One of the common techniques for aircraft repair involves removal of the damaged area with extensive machining operations, followed by replacement, usually with wet prepreg laminate and bagging. Such repair technique can be effective and may last long on an aircraft skin, but it is less efficient and time-consuming to carry out and not very environmentally-friendly due to the nature of composite material, resin and adhesives in disposal. Some successful self-healing systems have been tested in the past which are usually based on a media contained within the structure and bleeding into the structure plies as a result of damage. The healing medium may be stored within the structure by incorporating into either individual particles or capsules or into a Microvascular system.

By comparing the size of the healing agent containers, capsule-based healing method is most suitable for composite skin of aircraft. Nano capsules can be placed into the material layers and no need to use large sized capillary tubes for vascular-healing method which may affect the material strength and structure weight.

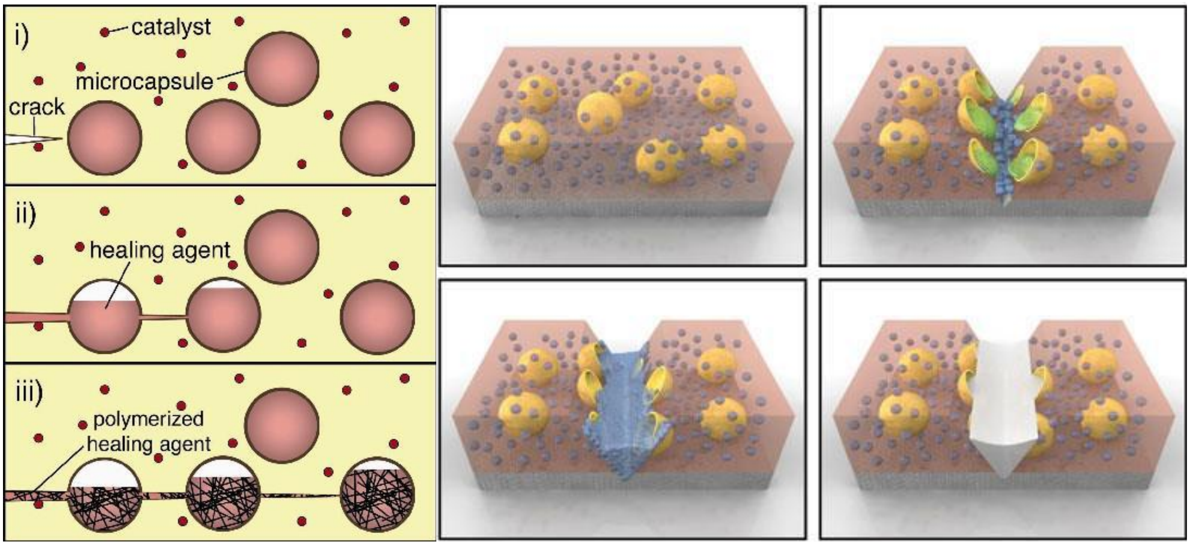

Figure 1: Capsule-based self-healing concept for composite repair.

This research project has been conducted to test the changes in self-healing properties of composite materials and ultimately, to apply it for the carbon-fiber structure repair of an aircraft. This research project is mainly focusing on the aerospace application of self-healing technology for an environmentally-friendly aircraft composite structure repair. The integrity loss due to matrix damage in composite materials can be restored using a technique that distribute a healing medium into the damage region and provide a thermally activated crack removal mechanism.

This research idea has been driven by concerns in connection with the effects of damage due to impacts on aircraft structures. This is in particular concern since it can affect strength and safety of the aircraft without the user being fully aware. The damages that are of greatest concern in aviation are those that involve both matrix cracking and delamination between plies/layers.

In this self-healing methodology, the healing agent is Dicyclopentadiene (DCPD). The healing agent encapsulated by micro-sized bubbles is made of polyurea. In order to polymerise, the healing agent came into contact with a catalyst known as Grubbs. It is important that the catalyst and the healing agent remain separated until they are needed to seal a crack. The ratio of catalyst and microcapsules is 2.5 wt% Grubbs catalyst and 5 wt% microcapsules in a unit of composite material.

Figure 2 shows only three types of wet-layup carbon-fibre samples (out of four) tested in this project. Each test sample is in the size of 20mm by 100mm and deliberately has only one defect in an arbitrary direction of 90^o, 45^o and 0^o. The following four samples have been tested in this research project:

a) sample with no defect,
b) sample with 0^o defect,
c) sample with 45^o defect, and
d) sample with 90^o defect.

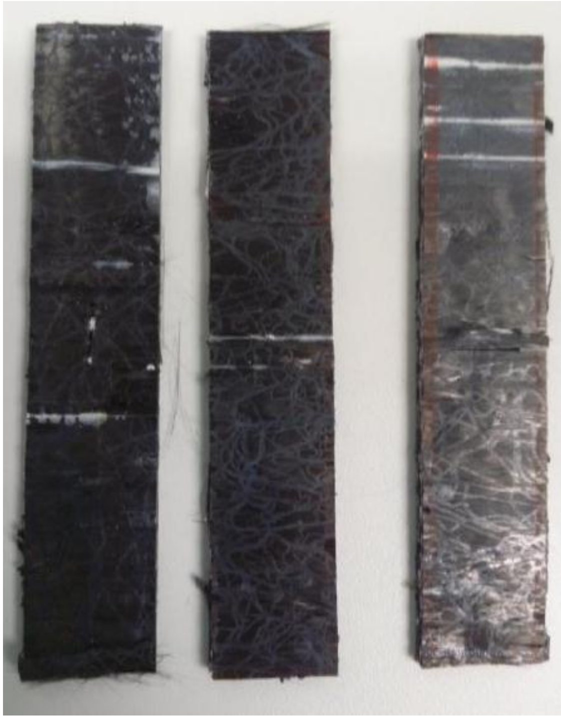

Figure 2: Three types of wet-layup carbon-fibre samples in the size of 20mm by 100mm with three defects in 90^o, 45^o and 0^o directions, respectively.

Several torsional and bending tests have been conducted in this research project. Only the results of bending tests on four samples are shown in Figure 5. These results indicate that the composite sample with 0o defect has least bending strength compare to other three samples as the displacement at the center of this sample was the highest when the same magnitude load applied to all four samples.

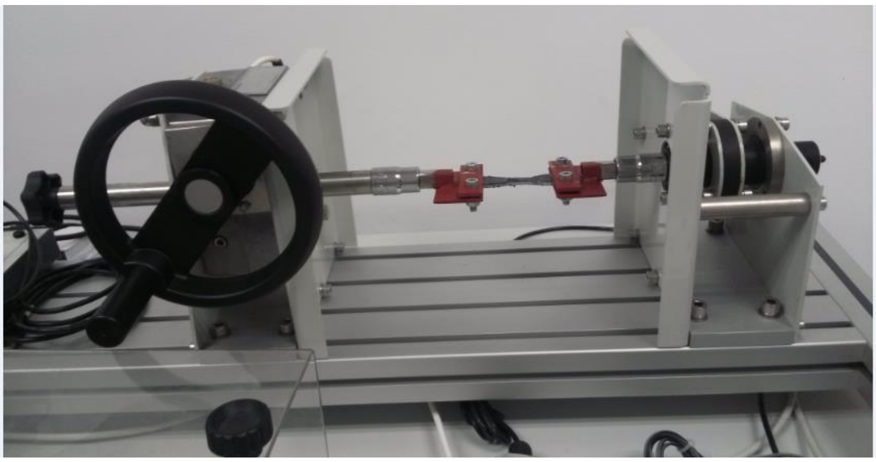

Figure 3 : The torsion test machine with a clamped composite sample.

Figure 4 : The bending test machine with a loaded composite sample

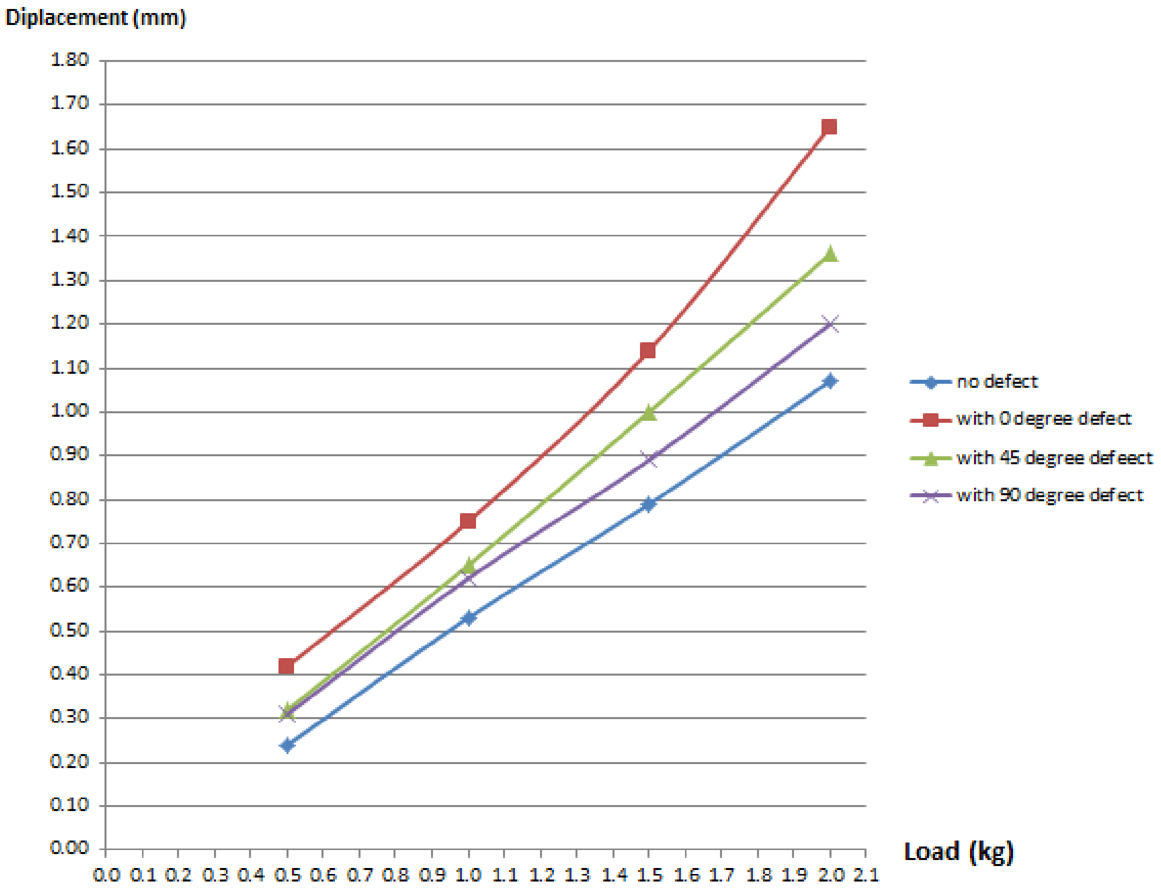

Figure 5: The results of bending tests on four different samples; with no defect, with 0^o defect, with 45^o defect and with 90^o defect.

CAREER PROFILE

(Updated on 12 November 2013)

Dr Hamid Saeedipour

(PhD, MSc, MBS, BEng, IT)

Mobile : (+65) 90125250

Email : hamid_saeedipour@rp.edu.sg

Having an educational background spanning various countries, Hamid received his PhD and MSc degrees in Aerospace Eng. from University of Manchester, two MBS Postgraduate Certificates in International Business and Banking & Finance from Manchester Business School, a 1st-class BEng in Mechanical Eng. from Tehran University and few more diplomas and certificates from France, UK and Iran. He got full scholarship for all of this education at different countries.

Hamid was working in UK, Iran, UAE, Malaysia and Singapore as an aircraft design engineer, lecturer, technical manager and consultant over the past 20 years. He has been teaching at UK's University of Manchester, Iran's Amirkabir University of Technology, University of Science Malaysia (USM), Taylors University/College in Kuala Lumpur and Republic Polytechnic in Singapore. He has been selected as one of the favorite academic staff by students at four different engineering schools. He has been a technical consultant to Avcen Limited UK, Chabok Aviation in Dubai and Civil Aircraft Design Bureau of Iran Aircraft Manufacturing Industries.

After residing in the UK for long time, Hamid arrived in Malaysia in October 2003 on the invitation of USM School of Aerospace Eng. as a lecturer for 3 years. Simultaneously, he took on the role of Aircraft Design Team Specialist for Avcen Limited UK in London for a year before he was appointed to his full-time position as Deputy Director in Aircraft Design for both Avcen Limited UK and Malaysia on May 2006 for four years. Hamid was Associate Dean of American Degree Transfer Program at Taylor's University /College in Kuala Lumpur before joining Republic Polytechnic in Singapore as Senior Academic Staff for the School of Engineering since Feb 2011 and Associate Lecturer for the Continuing Education and Training since Aug 2013. At the same time, Hamid is a Visiting Lecturer for UK's Newcastle University International Singapore (NUIS) and an adjunct-staff for Singapore Institute of Technology (SIT) since Oct. 2012.

Hamid has been working on several R&D projects related to civil aircraft design and manufacturing, thrust-vectoring technology and experimental aerodynamics. He got a large research fund from Avcen Limited UK to work on a VSTOL twin jet transport aircraft in 2006. He had an 18-month joint research with UK's Cambridge University and Imperial College in London on "Advanced Materials in Extreme and Hostile Conditions" funded by UK's Department of Trade and Industry during 2006-08. He had quarterly research finding exchange with Cambridge's Department of Materials Science and Metallurgy on jet-engine noise reduction using new exhaust briquettes in 2007. He had research collaboration with Imperial College's Department of Aeronautics on Composite Wing Joint Design, Quasi Static Test Programme, Thermal Insulation and Bonding Strategies, and Manufacturing Trial during 2007-08. He was a member of research team at University of Science Malaysia working on wind-tunnel testing of a composite remotely-piloted aircraft sponsored by System Consultancy Services and Dian Kreatif companies in 2004-05. He is currently doing practical projects related to Jet Biofuel, Unmanned Aerial Vehicles and Self-healing Repair Technology for Damaged Composite Aerostructures at Republic Polytechnic.

Hamid has a total of 42 papers and technical reports in Engineering and Technology related fields and 27 in Management and Education related fields.