PROJECT OVERVIEW

ENCOMB provided advanced non-destructive testing (NDT) methods for pre- and post-bond inspection of CFRP aircraft structural components in order to establish a reliable quality assurance concept for adhesive bonding. State-of-the-art NDT techniques were screened and the most suitable ones were further developed and adapted to important application scenarios with regard to aircraft manufacturing and in-service repair.

IDENTIFICATION OF FACTORS INFLUENCING ADHESIVE BOND QUALITY

Five application scenarios were identified to be of primary importance for the aircraft manufacturers along with the requirements for extended NDT technologies applying to each scenario.

QUALITY ASSESSMENT OF ADHEREND SURFACES

- Detection of **hydraulic fluid / water** contamination — HF
- Detection of **release agent** contamination — RA
- Detection of **moisture** contamination — MO
- Detection of **thermal damage** of CFRP — TD

QUALITY ASSESSMENT OF ADHESIVE BONDS

- Detection of weak bonds due to **release agent** contamination — RA
- Detection of weak bonds due to **moisture** contamination — MO
- Detection of weak bonds due to **poorly cured** adhesive — PC

COORDINATION

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WHO WE ARE

- Fraunhofer IFAM
- Fraunhofer IZFP
- AIRBUS
- AIRBUS DEFENCE & SPACE
- University of Patras, Laboratory of Technology & Strength of Materials
- University of BRISTOL
- RECENDT – RESEARCH CENTER NON DESTRUCTIVE TESTING
- ENEA – AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE
- NATIONAL ACADEMY OF SCIENCES OF UKRAINE, Usikov INSTITUTE OF RADIOPHYSICS AND ELECTRONICS
- EPFL – ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
- Agilent Technologies
- IMP PAN GDAŃSK
- cnrs
- easn Technology Innovation Services

The project was endorsed by the European Aeronautics Science Network - EASN

EXTENDED NON-DESTRUCTIVE TESTING OF COMPOSITE BONDS

Optimum bonding solutions for
light-weight aircraft structures

ENCOMB

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QUALITY ASSESSMENT OF ADHEREND SURFACES & ADHESIVE BONDS

Pre- and post-bond quality assessment was based on the physico-chemical characterisation of adherend surfaces and adhesive bonds. To this aim reference samples were manufactured for the development of methods. Strict requirements in terms of raw materials, geometry, manufacturing process, adherend surface treatment and bonding process were followed throughout the manufacturing process to ensure minimal deviation in terms of quality of the produced samples and enhance the reliability of the tests.

Adherend surfaces were characterised with conventional laboratory analysis methods (spectroscopic and optical techniques, contact angle measurements) to analyse their physico-chemical properties resulting from sample preparation.

Adhesively bonded samples were characterised with conventional NDT techniques (ultrasonic and x-ray inspection, µ-CT) to analyse their structural integrity resulting from sample preparation.

Mechanical tests were performed on the adhesively bonded samples in order to determine the influence of sample treatment on their mechanical performance. These tests comprised interlaminar fracture toughness and double-lap shear tests.

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SCREENING, ADAPTATION & VALIDATION OF ADVANCED NDT TECHNIQUES

Advanced NDT technologies for the detection of selected physico-chemical properties of CFRP adherend surfaces and the quality of the adhesive bonds were identified, verified, developed, adapted, and validated for their potential to comply with the application scenarios and requirements.

NDT method development was carried out in two steps. The first comprised a simple comparison of treated samples with a clean reference for all scenarios as a rough screening for principal suitability of the NDT technologies. The second step was dedicated to optimising those technologies with demonstrated suitability by means of samples with different contamination levels down to threshold levels of insignificant impact on bond strength.

Adherend surface quality

METHOD	PARTNER	Step 1 Scenarios				Step 2 Potential for detection of				VALIDATION
		RA	MO	HF	TD	RA	MO	HF	TD	
X-ray fluorescence spectroscopy	IFAM	-	-	√	-	used as reference methods				
Infrared spectroscopy	IFAM	-	√	√	√					
Reflectometry / Ellipsometry	IFAM	-	-	-	-					
Laser scanning vibrometry*	IMP PAN	√	√	√	√	○	●	○	○	Fail
Optically stimulated electron emission	IFAM	√	-	√	√	●●	●	●●	●	Pass
Infrared spectroscopy	RECENDT	√	√	√	√	●	●●	●●	●●	Pass
Aerosol wetting test	IFAM	√	-	√	√	●●	○	●	●	Fail
Portable Handheld FTIR spectroscopy	AGILENT	√	√	√	√	●●	●●	●●	●●	Pass
Laser induced breakdown spectroscopy	IFAM	√	-	√	-	●●	○	●●	○	Pass
THz/GHz reflectometry	IRE NASU	√	√	√	-	●	●	●	○	Pass
Optical fibre sensors*	EPFL	-	√	√	-	N/T	●●	●●	N/T	N/T
Electrochemical impedance spectroscopy*	IFAM	-	√	√	-	N/T	●	N/T	N/T	N/T
Electronic nose technology	ENEA	-	-	√	-	●	●	●●	N/T	Fail
Dual-band active thermography	IZFP	-	-	-	-	○	●	●	●	Fail
Laser induced fluorescence	IMP PAN	-	-	-	√	○	○	●●	●●	Fail
THz technology	RECENDT	-	-	-	-					
Optical coherence tomography	RECENDT	-	-	-	-					

Adhesive bond quality

TECHNIQUE	PARTNER	Step 1 Scenarios			Step 2 Potential to detect weak bonds caused by			VALIDATION
		RA	MO	PC	RA	MO	PC	
Active thermography using ultrasonic excitation	EADS -D	-	-	-				
Terahertz technology	IRE NASU	-	-	-	○	○	○	N/T
Linear Ultrasound	UnivBris	√	-	-	●●	N/T	○	Uncertain
Nonlinear ultrasound	UnivBris	√	-	-	●	N/T	○	Pass
LASAT technique	CNRS	√	-	-	●●	●	●	Pass
Laser ultrasound	RECENDT	-	-	-	○	○	○	Fail
Active thermography using optical excitation	IZFP	√	√	-	●	●	N/T	Uncertain
Laser scanning vibrometry*	IMP PAN	-	√	-	○	●	●●	Fail
Electromechanical impedance*	IMP PAN	√	√	√	●●	●	●●	Fail
Ultrasonic frequency analysis	EADS-D	-	√	-	●	●●	○	Pass
Laser ultrasound	EADS IW F	-	-	-	○	●	●	Fail
Active thermography (for T_g analysis)	IFAM	-	-	-				

√ : Clear detection of contaminant, differentiable from reference surface state.
– : No differentiation from reference state.
●● : High
● : Low
○ : No
N/T : Not Tested
* : With structure Integrated Sensor

DEVELOPMENT OF A QUALITY ASSURANCE CONCEPT

IN-LINE AND IN-SERVICE QUALITY CONTROL