QIRT'2022
10.21611/qirt.2022.2007
16th Quantitative InfraRed Thermography Conference

Industrial inspection of composites acoustic panels for aircraft components using infrared thermography

by S. Maillard*, B. Bazin*, A. Baillard**, N. Serre**, N. Leconte***, J. Richez****

* Safran Composites, 33 avenue de la gare, 91760 Itteville, France, samuel.maillard@safrangroup.com
** Safran Nacelles, 4039 Port du Havre, 76700 Gonfreville l'OrcherFrance, andre.baillard@safrangroup.com
*** Safran Additive Manufacturing Campus, 33185 Le Haillan, France, nicolas.leconte@safrangroup.com
**** Safran Engineering Services, Rond Point René Ravaud, 77550 Réau, France, jerome.richez@safrangroup.com

Abstract

In the frame of R&D activities about composites inspection, Safran investigated alternative methods to waterjet through transmission ultrasonic testing for an industrial application on nacelles components.

For aerospace applications, such developments are usually performed according to the Technology Readiness Level (TRL) assessment. This study led to the selection of infrared thermography and the industrial validation of IRIS, InfraRed Inspection System, in Burnley (UK) at Safran Nacelles' factory.

This paper explains the different steps of the project and how the equipment works.

1. Initial inspection and criteria

A nacelle is the equipment around the aircraft engine integrating several functions such exhausts, thrust reverser and noise reduction. Composites materials represents about 60% of the material in current nacelles.

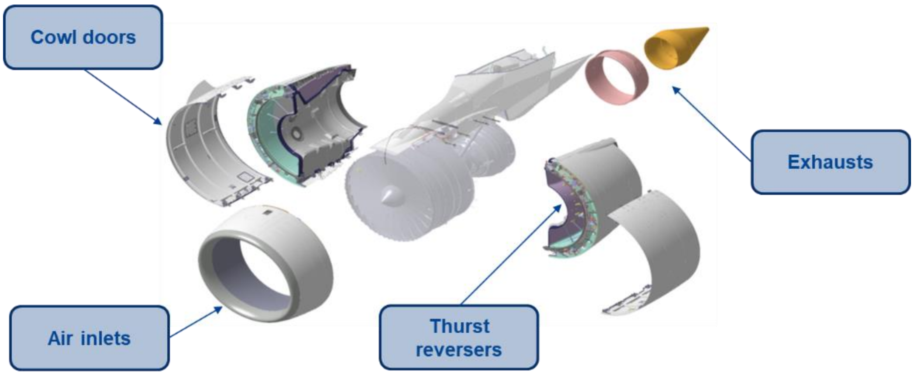


Fig. 1. *The different components of an aircraft engine nacelles*

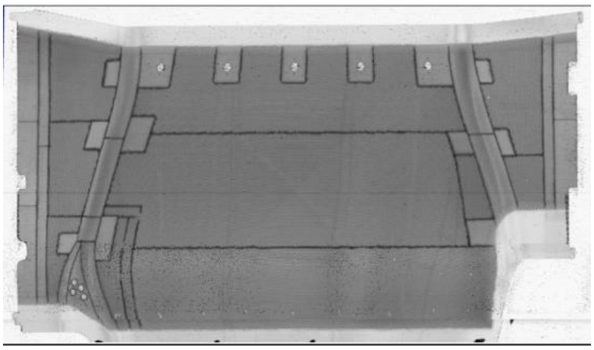
These composites panels are usually aluminium or Nomex honeycomb structures with CFRP skins and their design requires skin thickness and honeycomb density variations. They are manufactured according to the process described in the Figure 2.

Fig. 2. *Acoustics composite panel manufacturing process*

Common defects are:
- Foreign objects,
- Porosities,
- Delaminations (during curing or handling),
- Disbonds (skin/skin or skin/core)
- Other (waviness, foldings,…).

Their maximum acceptable size is about 10 to 30mm according to their location on the part.

Such aerospace sandwich components are commonly inspected using waterjet through transmission ultrasonic testing (TTU). Inspector looks for potential defects by analysing the ultrasonic amplitude going through the part displayed on a C-Scan cartography.

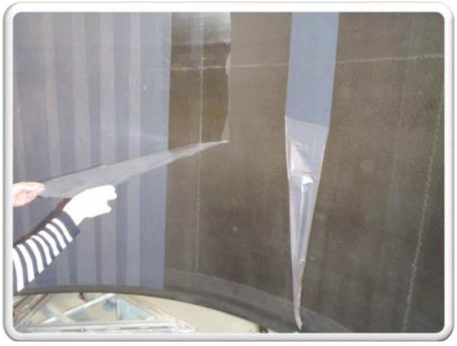


(a) Equipment used *(b) Cartography*

Fig. 3. *Through Transmission Ultrasonic Testing commonly used on acoustic composites panels*

However, TTU only gives an attenuation information but no information about the nature or the depth of the defect. A complementary inspection is then required to confirm what the indication is.

In addition, parts like nacelles components often offer acoustic zones to significantly reduce the noise of the engine. Thus, small acoustic holes drilled in front of honeycomb cells need to be covered by a plastic tape to avoid water ingress during ultrasonic inspection. At the end of the acquisition, parts need to be dried for several hours in the oven.



(a) Acoustic holes *(b) Plastic tape lay-up*

Fig. 4. *Example of acoustic zone on composite panels and plastic tape lay-up for TTU*

The increasing demand of composites components, especially with the success of the LEAP engine, lead to a higher number of parts to be manufactured and inspected. Thus, Safran decided to investigate alternative methods with equivalent detection performances, reduced Hour Per Unit and compliant with HSE and digital thread requirement.

2. Flash thermography, key parameters and key functions for an industrial inspection

During this development, alternative methods such as air coupled ultrasonic, laser ultrasonic and infrared thermography have been investigated. Infrared thermography has been assessed to be the more promising one for this application and the Technology Readiness Level (TRL) process in place at Safran has been followed to industrialise the inspection process on A320neo IFS.

To define an industrial equipment, all the components and all the steps of the process with their associated key parameters have to be considered.

Several excitation sources and cameras have been evaluated on samples with representative material stack (skin/honeycomb) and known defects. This lead to the selection of:

- flash thermography in reflexion on each side: TWI EchoTherm device (covering about a A4 paper sheet for each measurement) appeared to be the best equipment regarding Safran's needs,
- a cooled InSb camera with a 13mm optic allowing to cover the heated area.

Acquisition parameters were studied to take into account all the different skin thickness (varying from ~1mm and ~4mm) and aluminium honeycomb characteristics (density from 68kg/m^3 to 354kg/m^3) encountered in the part. Generic rules have been defined in order to be able to extend to other parts.

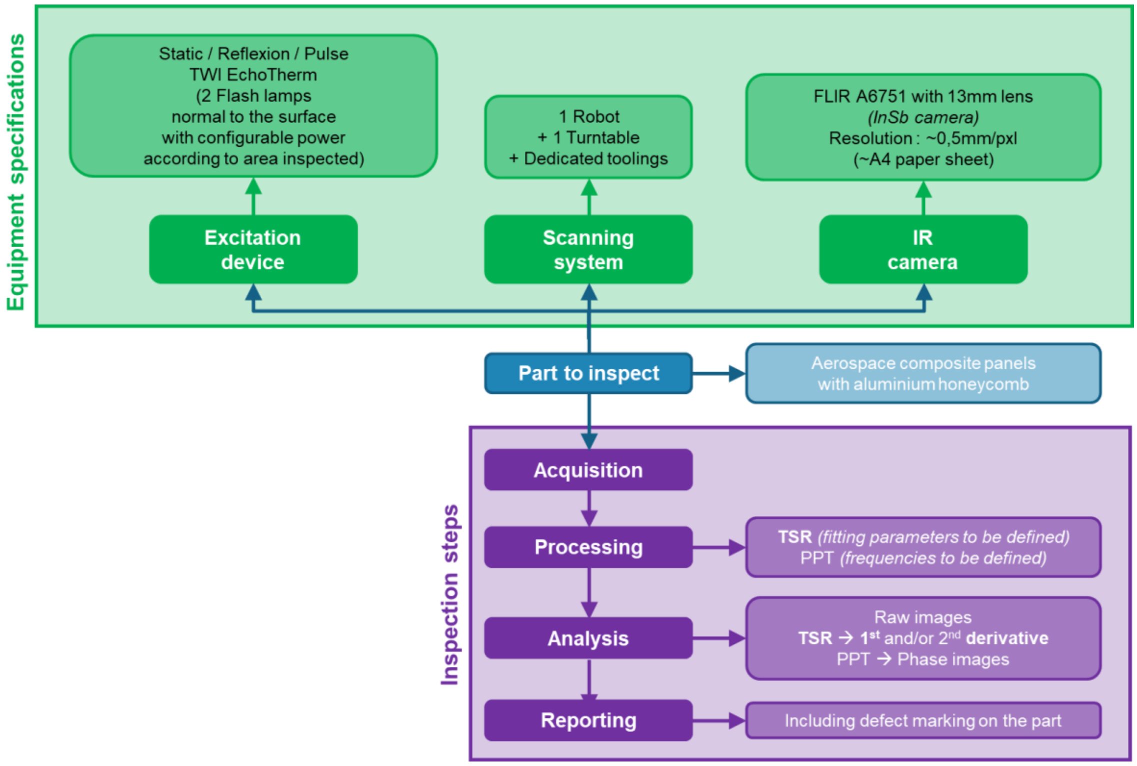


Fig. 5. *IRT equipment specifications and inspection steps according to the part to inspect*

Data processing algorithms such as PPT and TSR have been evaluated to improve data visualisation. Thanks to its early detection allowing a shorter acquisition duration, TSR implemented in Thermal Wave Imaging softwares has been selected and First Derivative data have been assessed to be the most relevant to present to the inspector. TSR fitting parameters have been optimised regarding the different signals expected on a part and a reduced number of images has been selected to optimise the amount of data to be analysed by the inspector.

Considering these NDT key parameters, it was then decided to build a prototype robotic cell called ACTIN (ACtive Thermography INspection) located at Safran Composites (Itteville) to support R&D development around IRT and specify an industrial machine.

3. Product/Process" performance substantiation

For aerospace applications, it is required to demonstrate Product / Process performances. In this case, the demonstration was based on the comparison between the reference method, TTU at 1MHz, and flash infrared thermography.

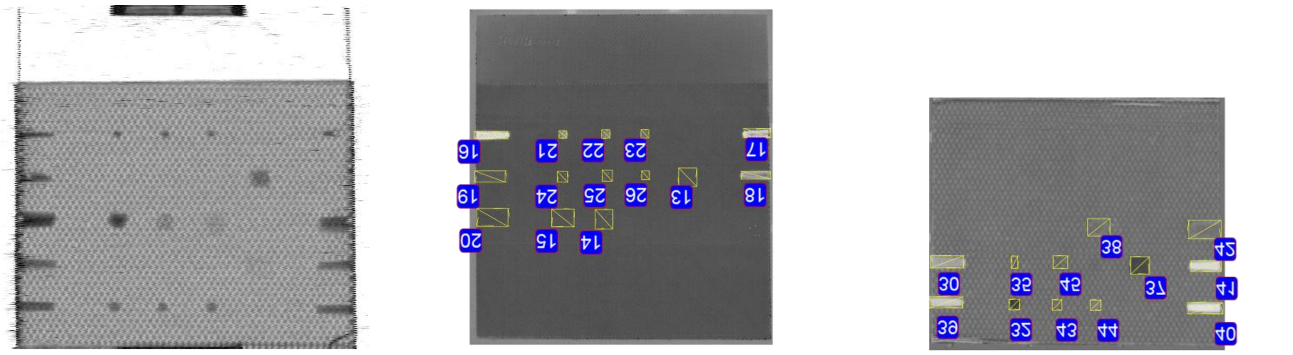
For every part to inspect, the different configurations encountered (material type / thickness / honeycomb density) are listed and extreme configurations are identified.

For these configurations, NDT reference panels have been manufactured with 27 known defects representing what can be found in such parts:

- Delamination in both skins at different depth (2 plies from the external surface, 2 plies from the surface close to honeycomb, at middle of the thickness)
- Foreign object (teflon tape & backing sheet) at different depths (2 plies from the external surface, 2 plies from the surface close to honeycomb, at middle of the thickness, at the interface with the adhesive)
- Disbond at skin / core interface.

A part with 70 known defects located at critical places has been manufactured.

For A320neo IFS application, 11 NDT reference panels and the part have been scanned (IRT then UT) and analysed by inspectors certified Level 2 according to EN4179 in UT and IRT.



(a) Trough transmission ultrasonic

(b) Flash Thermography on precured skin First Derivative Image @ 0,2s after flash

(c) Flash Thermography on cocured skin First Derivative Image @ 0,2s after flash

Fig. 6. *Dual inspection (UT and Flash IRT) on a NDT reference panels with known defects*

Every indication has been reported by inspector and detection between the methods were individually compared. This resulted in 4 scenarios:

- Scenario 1: Reference method → OK / IRT → OK
- Scenario 2: Reference method → OK / IRT → NOK
- Scenario 3: Reference method → NOK / IRT → OK
- Scenario 4: Reference method → NOK / IRT → NOK

Cn Detection		UT (green)	UT (red)
IRT	green	19	0
	red	0	0

(a) Delamination

La Detection		UT (green)	UT (red)
IRT	green	9	0
	red	0	0

(b) Disbond

Sc detection		UT (green)	UT (red)
IRT	green	39	1
	red	18	2

(c) Teflon Tape

Fig. 7. *Example of Dual inspection (UT and Flash IRT) cross results on NDT reference panels with known defects*

Scenario 1 was observed on most of the defects, especially for disbond and delamination. But when facing scenario 2 to 4, additional investigation were performed and discussed with IRT Level 3 and NDT, material or process experts to evaluate relevance of the known defects, statistical analysis justification, possible criteria modification or manufacturing process evolution.

After validating these performances of detection on known defects plates and parts, 15 production parts were submitted to Dual Inspection (UT + IRT) and analysis performed by inspectors certified Level 2 according to EN4179 in UT and IRT was proven to be equivalent.

Thanks to these substantiations, Safran Nacelles was able to fulfil the Qualification Document and Industrial Validation Document that allow to start using IRT for production purpose.

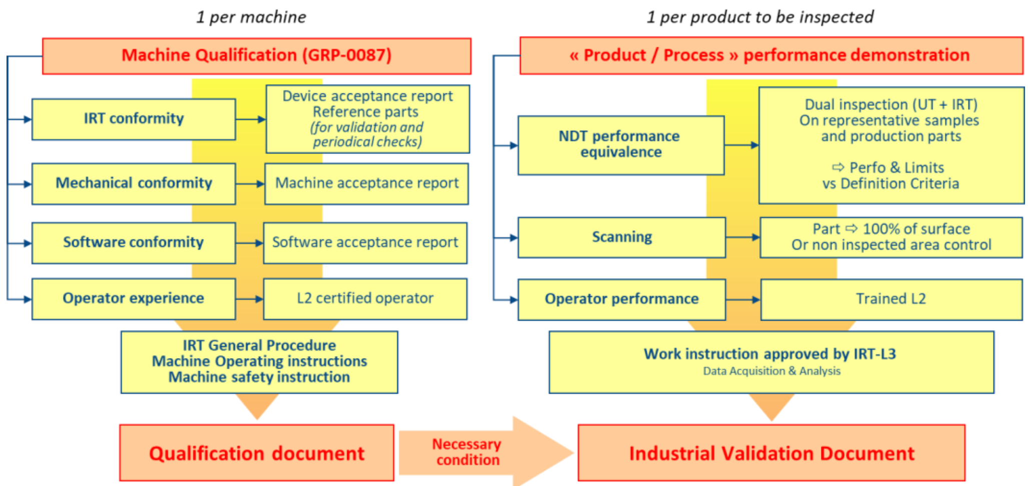


Fig. 8. *Flash Infrared Thermography developed for acoustic composites panels in Safran Nacelles (Burnley-UK)*

4. IRIS, InfraRed Inspection System

After validating TRL6, Safran Nacelles decided to invest an IRT machine called IRIS (InfraRed Inspection System) for Burnley site (UK).

Fig. 9. *Flash Infrared Thermography developed for acoustic composites panels in Safran Nacelles (Burnley-UK)*

This industrial robotic cell is able to inspect parts up to A380 dimensions and is made of:

- TWI EchoTherm equipment with FLIR A6751sc IR camera,
- A robot, a turntable, a PLC to synchronize all the elements,
- Tooling to cover 100% surface of the parts and avoid thermal artefacts due to interface between part and the frame,
- Dedicated software, from machine supervision to data analysis and reporting.

In parallel to this industrialization, several topics were taken into account:

- Robustness of the equipment through the time, including periodical checks to follow the behavior of each component and prevent any drift,
- Transfer of the knowledge from R&D team in Safran Composites to the inspectors, including training prior and post EN4179 IRT certification.

5. Conclusions and perspectives

IRIS is currently used in Burnley (UK) on A320neo and A330neo nacelles components but also on R&D parts. 2 more cells are in preparation (Le Havre-France and Casablanca-Morocco). Safran Nacelles has validated the following benefits:

- Cycle time reduced by 3 due to:
    - Removal of several operations
    - Simplification of complementary inspection tasks
- Recurrent cost divided by 2 due to:
    - Hour Per Unit
    - Consumables
- Digital thread
    - Any indication on any images can be located in the part axis for concession management
    - Paperless process
- Ergonomics & HSE improvement.

Fig. 10. *Thanks to digital thread, indications identified with Flash Thermography are located on the part with augmented reality device*

IRIS is the result of a strong collaboration with equipment suppliers (TWI for IRT device, Axiome for robotic cell) and several companies within Safran Group (Safran Nacelles, Safran Tech, Safran Engineering Services, Safran Electronic and Defense) requiring many skills (NDT, robotics, image processing, software, material,…).

Fig. 11. *IRIS development and operational team*