

# Condition Monitoring of Aircraft Composite Structure Using Infrared Thermography

Muhammad Haziq Mohd Razal<sup>1</sup>, Maznan Ismon<sup>2\*</sup>

1 Department of Mechanical Engineering, Faculty of Mechanical and Manufacturing, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, Malaysia

2 Centre of NDT Training & Calibration (CeNDTeC), Faculty of Mechanical and Manufacturing, Universiti Tun Hussein Onn Malaysia (UTHM), 86400 Parit Raja, Batu Pahat, Johor, Malaysia

\*Corresponding Author: [maznan@uthm.edu.my](mailto:maznan@uthm.edu.my)

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## Abstract

This thesis deals with composite aircraft structure condition monitoring based on infrared thermography and FLIR technologies. The primary objectives are to identify irregularities in airplane structure and secondly, by closely analyzing the time-delayed infrared images captured during FLIR tests for a maximum inspection period. The scope of the study comprises applying a model for an aircraft belonging to University Tun Hussein Onn Malaysia (UTHM) recommended in a hangar that forms an appropriate case study. This research attempts to assess the effectiveness of infrared thermography for monitoring composite structure conditions based on certain distinctive features derived from UTHM aircraft. The study utilizes advanced equipment like the FLIR T640 and Flir tools for accuracy. These instruments are used for high-resolution infrared images, which further analysis helps determine the structural health of composite components. Time comparison will help determine the best time for inspections, revealing the advantages and disadvantages of active and passive inspection methods throughout 24 hours. The ability to enlighten the efficacy of infrared thermography in this context will contribute significantly towards helping boost improvements for aircraft maintenance strategies, thus upholding the safety and reliability of modern aviation systems.

## 1. Introduction

The aviation industry's increasing reliance on advanced composite materials in aircraft structures, owing to their lightweight and robust properties, underscores the critical need for a comprehensive system to ensure the structural integrity of these components. Traditional inspection methods have proven inadequate in terms of speed, cost-effectiveness, and coverage, prompting a search for innovative alternatives. In this context, infrared thermography emerges as a promising non-destructive testing technique, leveraging the detection of infrared radiation emitted by objects to analyze thermal patterns on the surface. This approach holds great potential for identifying defects like delaminations and voids that could compromise flight safety and operational efficiency.

This project is driven by two primary objectives: first, to pinpoint abnormalities in aircraft structures using infrared thermography and analyze captured images through Flir tools, and second, to determine the optimal inspection timing via specific time comparisons. The study's scope extends to evaluating the effectiveness of infrared thermography for condition monitoring, utilizing the UTHM aircraft model in the hangar as a case study. Implementation involves the use of Flir T640 and Flir tools for capturing and analyzing infrared images, with a focus on refining defect detection algorithms and optimizing inspection methodologies in composite aircraft structures. Ultimately, the project aims to establish a robust system that enhances safety, lowers maintenance costs, and extends the service life of aviation components constructed from advanced composites.

## 2. Aircraft Structure

An aircraft's structure comprises circular frames, linear stringers, and machined or formed sheet metal skin panels, intricately [1] assembled to ensure the safety and functionality of the modern aircraft. The key components include the fuselage, wings, empennage, landing gear, and powerplant [2], working collaboratively to provide the necessary strength and stability against external forces. The fuselage serves as the central housing for the crew, passengers, and cargo, connecting the wing and tail assemblies. Wings generate propulsion, the empennage encompasses the tail section, and the landing gear supports the aircraft during takeoff and landing. The powerplant, comprising engines, propels the aircraft forward. The smallest components include the fuselage, electrical system, flying controls, and brakes. Over time, aircraft architecture has evolved from early timber truss structures to modern semi-monocock shell constructions, ensuring the aircraft's ability to withstand various stresses. Wings, varying in shape and size, may be internally supported by an aircraft skin or externally by supporting blades and tubes. However, despite careful control of the operations used in processing aerospace materials, it is difficult to ensure that every structure is completely free from defects [3].

## 3. Methodology

Figure 1 shows the overall procedures of this research. It starts with identifying the problem to be studied and the title of the study. The image was captured and transferred to the software to analyse the data. When the data has been analyzed, evaluate the decision from the image that has been analyzed.

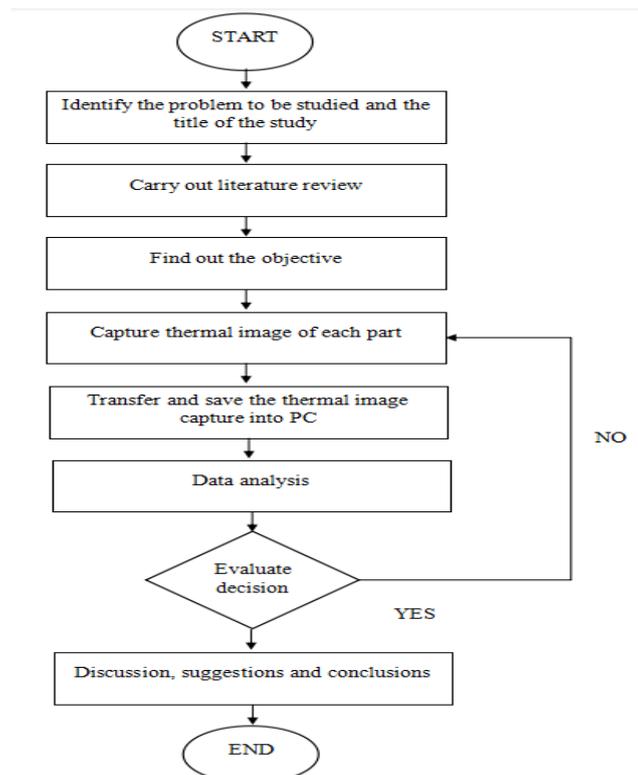


Figure 1 Flow chart of study

### 3.1 Tool and Equipment for Infrared Inspection

Infrared inspection relies on specialized tools and equipment to effectively analyze thermal patterns and identify potential defects in various materials, including aircraft composite structures. One essential tool is the infrared thermal imaging camera, such as the Flir T640, which captures and records temperature variations on the surface of structures. These cameras allow for non-contact and real-time monitoring, enabling swift detection of anomalies like delaminations, disbonds, or voids without causing damage to the material. The Flir tools complement these cameras, providing software for analyzing and interpreting captured infrared images. This combination of advanced tools facilitates precise condition monitoring, aiding in optimizing inspection methodologies and improving defect detection algorithms in aircraft composite structures. However, infrared thermography still has its personal weaknesses too in phrases of cost, accuracy and capabilities to address the defect area [4].



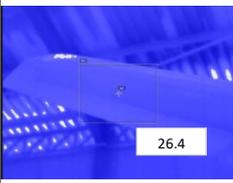
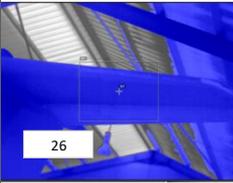
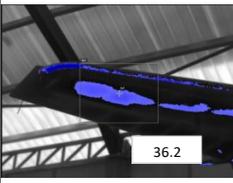
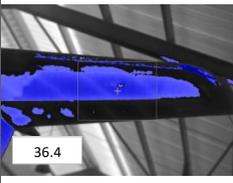
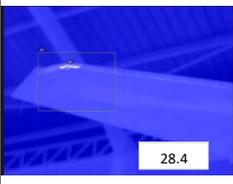
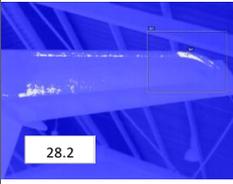
Figure 2 Camera Flir T640

## 4. Result

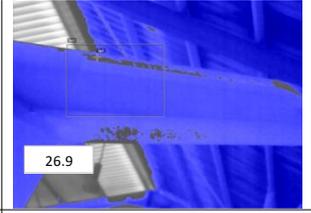
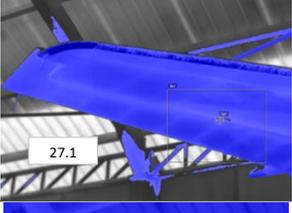
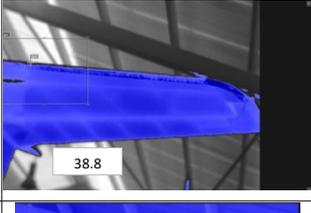
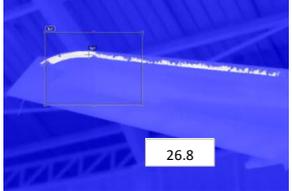
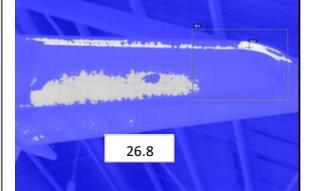
This study reveals the effectiveness of using FLIR tools alongside infrared imaging to spot subtle irregularities in aircraft structures. The discussion will delve into the findings, examining the nuances of identified abnormalities and providing a thorough understanding of how FLIR tools enhance the accuracy and efficiency of structural inspections.

### 4.1 Preliminary results of the project for empennage part

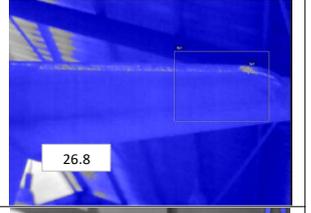
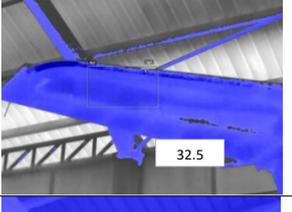
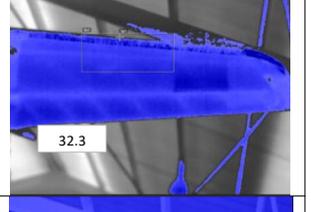
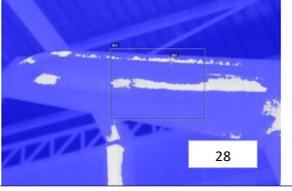
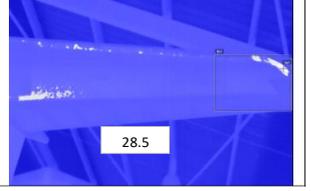
Table 1 Data collection for empennage part (day 1)

Date	Time	Average Temp °C in Hanger	Average Humandity (%)	Weather	Empennage	
					Right side (spot temp °C)	Left side (spot temp °C)
23/10/23	8.00 am	26.7	77.1	Cloudy		
	12.00 pm	33.4	56.2	Hot		
	8.00 pm	26.7	84.4	Cloudy		

**Table 2** Data collection for empennage part (day 2)

Date	Time	Average Temp °C in Hanger	Average Humidity (%)	Weather	Empennage	
					Right side (spot temp °C)	Left side (spot temp °C)
24/10/23	8.00 am	27.2	79.9	Cloudy		
	12.00 pm	34.2	52.9	Hot		
	8.00 pm	25	86.1	Rain		

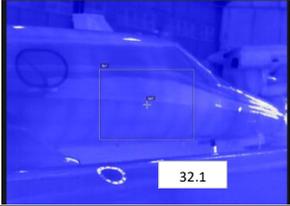
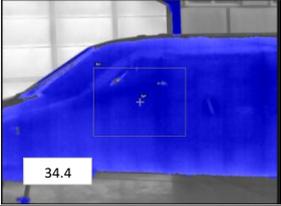
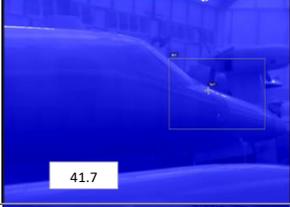
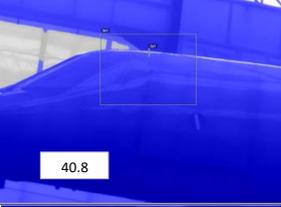
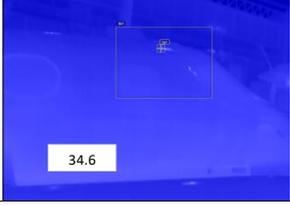
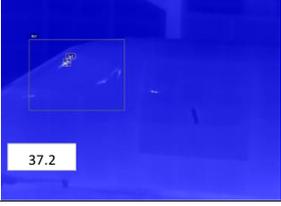
**Table 3** Data collection for empennage part (day 3)

Date	Time	Average Temp °C in Hanger	Average Humidity (%)	Weather	Empennage	
					Right side (spot temp °C)	Left side (spot temp °C)
25/10/23	8.00 am	25.4	85.1	Cloudy		
	12.00 pm	30.8	67.3	Hot		
	8.00 pm	26.8	84.8	Cloudy		

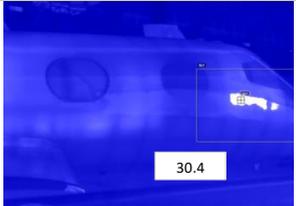
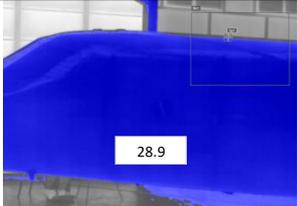
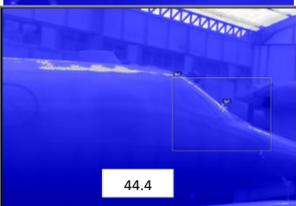
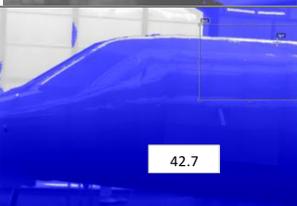
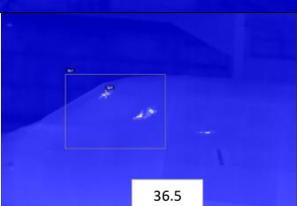
The conclusion at the empennage can be know at 12:00 PM shows that infrared thermography is effective enough to capture all structural details, and it may be a good instrument for the ongoing assessment of aircraft empennage. The comparison with 8:00 am and 8:00 pm indicates the strengths of using infrared thermography, especially at ideal daytime hours to have full evaluation on aircraft' composite structure

### 4.2 Preliminary results of the project for fuselage part

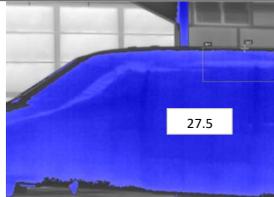
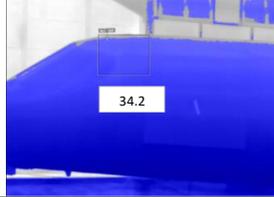
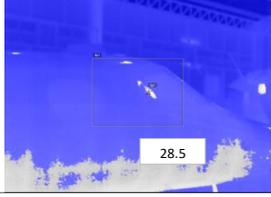
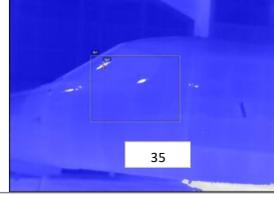
**Table 4** Data collection for fuselage part (day 1)

Date	Time	Average Temp °C in Hanger	Average Humandity (%)	Weather	Fuselage	
					Right side(spot temp°C)	Left side(spot temp°C)
23/10/23	8.00 am	26.7	77.1	Cloudy		
	12.00 pm	33.4	56.2	Hot		
	8.00 pm	26.7	84.4	Cloudy		

**Table 5** Data collection for fuselage part (day 2)

Date	Time	Average Temp °C in Hanger	Average Humandity (%)	Weather	Fuselage	
					Right side(spot temp°C)	Left side(spot temp°C)
24/10/23	8.00 am	27.2	79.9	Cloudy		
	12.00 pm	34.2	52.9	Hot		
	8.00 pm	25	86.1	Rain		

**Table 6** Data collection for fuselage part (day 3)

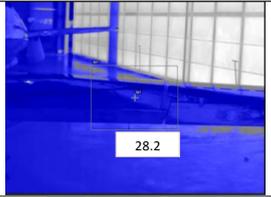
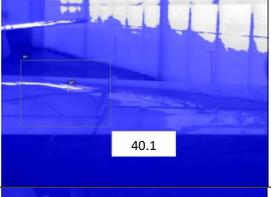
Date	Time	Average Temp °C in hanger	Average Humandity (%)	Weather	Fuselage	
					Right side (spot temp °C)	Left side (spot temp °C)
25/10/23	8.00 am	25.4	85.1	Cloudy		
	12.00 pm	30.8	67.3	Hot		
	8.00 pm	26.8	84.8	Cloudy		

In conclusion, part of the fuselage shows that infrared thermography is a useful tool for detecting moisture penetration at different stages of the fuselage. Morning and evening conditions pose their difficulties, but infrared thermography continues to internally detect temperature deviations associated with moisture issues.

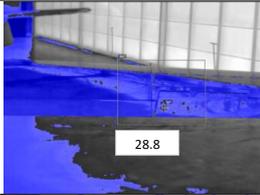
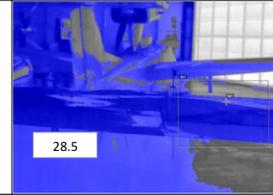
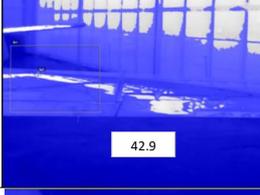
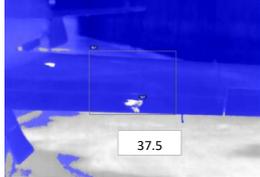
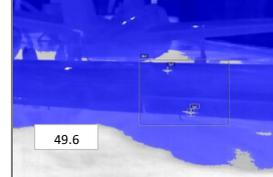
Comparatively, passive inspection methods may encounter limitations, especially at 12:00pm as the surface moisture could evaporate and become less visible. If infrared thermography is included as a part of the condition monitoring project, then it advances the capability to detect possible moisture-related issues with composite structures, leading toward proactive maintenance and structural health management for aircraft. On the other hand, dynamic thermography is an efficient methodology for scanning wide areas and detecting defects, such as impact damage and delaminations, to extend the part's service life [5].

### 4.3 Preliminary results of the project for the wings part

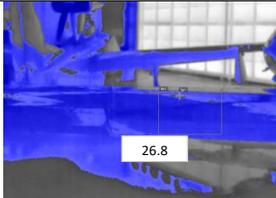
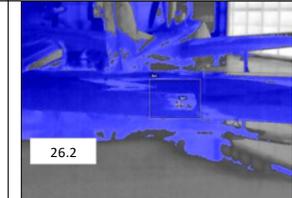
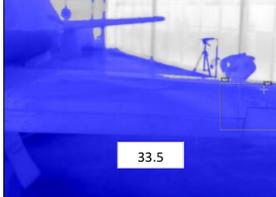
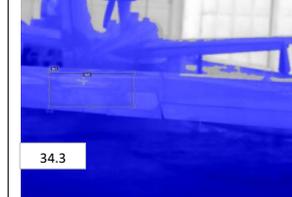
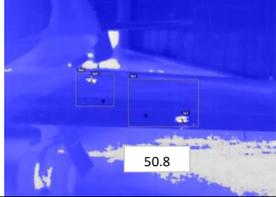
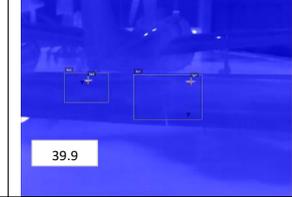
**Table 7** Data collection for wings part (day 1)

Date	Time	Average Temp °C in Hanger	Average Humandity (%)	Wings	
				Right side (spot temp °C)	Left side (spot temp °C)
23/10/23	8.00 am	26.7	77.1		
	12.00 pm	33.4	56.2		
	8.00 pm	26.7	84.4		

**Table 8** Data collection for wings part (day 2)

Date	Time	Average Temp °C in hanger	Average Humandity (%)	Weather	Wings	
					Right side( spot temp °C)	Left side( spot temp °C)
24/10/23	8.00 am	27.2	79.9	Cloudy		
	12.00 pm	34.2	52.9	Hot		
	8.00 pm	25	86.1	Rain		

**Table 8** Data collection for wings part (day 2)

Date	Time	Average Temp °C in hanger	Average Humandity (%)	Wings	
				Right side( spot temp °C)	Left side( spot temp °C)
25/10/23	8.00 am	25.4	85.1		
	12.00 pm	30.8	67.3		
	8.00 pm	26.8	84.8		

In conclusion for wings part that infrared thermography, particularly with the aid of FLIR tools would be a very effective solution for detecting delamination on aircraft wings at various stages. Morning and afternoon conditions do not considerably interfere with the ability to detect thermal differences related to delamination. The process of implementing a damage identification strategy for condition monitoring is known as Structural Health Monitoring (SHM) where damages are defined as changes to the material and geometric properties [6]. Infrared sensing and imaging systems for a wide range of applications have advanced significantly in recent years, notably for military, battlefield, airborne, and thermal non-destructive testing and evaluation procedures [7].

Passive methods at 12:00pm may be rather limited, and this suggests that infrared thermography should be

included as part of the condition monitoring project to ensure ongoing and trustworthy detection of anomalies in composite structures. Employing FLIR tools increases the analysis depth with which it becomes possible to study various deviations and visualize them more accurately for evidence-based action during maintenance or structural management.

## 5. Conclusion

In summary, the comprehensive analysis of data gathered from aircraft structure condition monitoring using infrared thermography, particularly in conjunction with FLIR tools, strongly suggests that employing active methods, especially at night, are more effective for inspections compared to passive approaches. The study indicates that infrared thermography consistently performs well in capturing crucial structural details, showing effectiveness at 12:00pm for the empennage and during morning and afternoon conditions for the wings. This implies the method is reliable daily and night, emphasizing its suitability for comprehensive evaluations during ideal daytime hours. In order to achieve an accurate temperature measurement, a few parameters have to be taken into consideration, such as the associated environment's effects, device situations, and the ability to capture the thermal picture [8].

The study highlights limitations in passive inspection methods, especially at 12:00pm when surface moisture may evaporate, becoming less visible. Therefore, the recommendation is to prioritize active infrared thermography, particularly at night, for aircraft structure inspections. The technology's superior ability to internally detect temperature variations related to moisture issues, even in challenging evening conditions, demonstrates its efficacy compared to passive methods. Integrating active infrared thermography into routine inspections, especially at night time, ensures a more thorough and reliable assessment of the aircraft's composite structure. This proactive approach not only enhances overall safety and structural integrity but also supports evidence-based decision-making in maintenance procedures, contributing to a robust strategy for aircraft condition monitoring.

## Acknowledgement

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