

DEVELOPMENT OF AN PORTABLE ACTIVE THERMOGRAPHY NDT SYSTEM FOR IN-SITU INSPECTION OF MATERIALS

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Engineering degree in Mechatronics

By

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BONAFIDE CERTIFICATE

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ABSTRACT

Non-destructive testing (NDT) is a technique utilized by industries to inspect materials, components, structures, or systems for any anomalies or flaws, such as welding imperfections and electronic heating problems, without causing harm to the original materials. Thermography, a form of NDT, employs infrared cameras to detect defects characterized by temperature variations and generate thermal images. There are two primary types of thermography: passive and active. Passive thermography is mainly used for condition monitoring, while active thermography focuses on defect detection. The setup involves an external heat source and an infrared detector to identify defects. In this project, a compact active thermography system was developed utilizing the FLIR Lepton 3.1R infrared camera in conjunction with a flash lamp and an induction coil as dual excitation source. This system effectively detected overheating issues in electronic PCBs, identifying CPU and filter malfunctions, as well as overheated areas in metal materials. Active thermography is applicable across various sectors including electronic PCBs, metals, and composites. The portability of this active infrared thermography system allows for the detection of defects in electronic components, including counterfeit ones prone to heating-related damage. By proactively identifying minor defects, it prevents damage caused by excessive heating before it occurs. Moreover, this system plays a crucial role in identifying machinery failures and system malfunctions, thereby improving reliability in fields such as electrical wiring, electronics, mechanical systems, and machinery.

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LIST OF ABBREVIATIONS

NDT	Non-Destructive Testing
AM	Additive Manufacturing
IRT	InfraRed Thermography
LT	Lock-in Thermography
VT	Visual Inspection
LPT	Liquid Penetrant Testing
RT	Radiographic Testing
MPT	Magnetic Particle Testing
PT	Dye Penetrant Testing
ET	Eddy Current Testing
AET	Acoustic Emission testing
UT	Ultrasonic Testing
LT	Leak Testing
DT	Destructive Testing
HOS	Higher-Order Statistics
CFRP	Carbon Fiber-Reinforced Plastic
FLIR	Forward Looking Infrared
TSR	Thermographic Signal Reconstruction
TC	Thermal Contrast
AI	Artificial Intelligence
BVID	Barely Visible Impact Damage
CNN	Convolutional Neural Networks
LST	Laser Spot Thermography
IBT	Imaging-Based Techniques
ETT	Electrical Testing Techniques
EL	Electroluminescence
GFRP	Glass Fiber Reinforced Polymer
ICA	Independent Component Analysis

PIT	Pulsed Inductive Thermography
LWIR	Long Wave Infrared
FOV	Field Of View
PCB	Printed Circuit Board
USB	Universal Serial Bus
RAM	Random Access Memory
HDMI	High-Definition Multimedia Interface
JPEG	Joint Photographic Experts Group
PNG	Portable Network Graphics
ATT	Active Transient Thermography
DATT	Double Active Transient Thermography
PPT	Pulsed Phase Thermography
PCT	Principal Component Thermography

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CHAPTER 1

INTRODUCTION

The exceptional demand for industrial machinery and goods that are more robust, resilient, and capable of withstanding greater stress underscores the need for rigorous monitoring and testing within industrial manufacturing processes. Non-destructive testing (NDT) techniques play a crucial role in various industries by evaluating materials, components, or systems without causing damage, aiming to detect flaws or irregularities that could compromise their integrity or performance. Over recent years, NDT has gained prominence for its non-intrusive and objective nature, offering faster data generation compared to traditional methods, leading to its widespread adoption across diverse industries. Infrared thermography (IRT) is a prominent NDT technique widely used for monitoring industrial machinery and assessing electronic failures due to its quick, contactless, and safe nature. It involves converting thermal radiation into visual images, with passive and active thermography being the two primary approaches. While passive thermography is mainly used for monitoring temperature anomalies, active thermography involves applying external thermal stimuli to the object, enabling thorough examination across various fields such as composite materials inspection, corrosion detection, and electronics testing. Active infrared thermography, particularly, shows promise in inspecting electronic printed circuit boards (PCBs) to analyse component failures caused by overheating, offering a cost-effective solution for defect identification and other applications.

1.1 IMPORTANCE OF TESTING METHODS

Testing methods are crucial in manufacturing because they ensure product quality, safety, and compliance with regulations. By identifying defects early, these methods prevent faulty products from reaching consumers, reducing costs associated with recalls and rework. Reliable testing builds customer trust, enhances brand reputation, and supports innovation. Additionally, it fosters efficiency in manufacturing processes and fosters confidence among supply chain partners. Overall, testing methods play a vital role in maintaining high standards and driving success in manufacturing industries.

1.2 DESTRUCTIVE TESTING

Destructive testing in manufacturing involves intentionally damaging test specimens to assess their properties. Methods include tensile testing for strength, hardness testing for durability, and impact testing for resilience. Despite altering specimens, these tests provide critical insights into material behaviour, aiding in product design and quality assurance.

1.2.1 Types of Destructive testing

Some common types of destructive testing methods include:

- **Tensile Testing:** This method involves pulling a material until it fractures, allowing for the assessment of strength, elasticity, and ductility.
- **Hardness Testing:** Hardness testing measures a material's resistance to indentation or scratching, providing information on durability and wear resistance.
- **Impact Testing:** Impact testing evaluates a material's ability to withstand sudden loading by subjecting it to high-velocity impacts, essential for assessing toughness and resilience.
- **Fracture Toughness Testing:** Fracture toughness testing measures a material's resistance to crack propagation, crucial for ensuring structural integrity.
- **Fatigue Testing:** Fatigue testing assesses how materials withstand cyclic loading over time, providing insights into durability under real-world conditions.
- **Bend Testing:** Bend testing determines a material's flexibility and ductility by subjecting it to bending forces until failure.

While these methods result in irreversible damage to test specimens, they offer valuable information for material selection, product design, and quality control processes, ensuring the reliability and performance of manufactured products.

1.2.2 Applications of Destructive testing

- Material Selection: Identifies suitable materials by testing their properties.
- Quality Control: Ensures products meet standards through performance testing.
- Product Design: Validates designs by testing prototypes for safety and performance.
- Failure Analysis: Investigates reasons for product failures through testing.
- Research and Development: Develops new materials and products by studying their behaviour.
- Forensic Investigations: Analyses failures to prevent future incidents.
- Structural Health Monitoring: Assesses the integrity of infrastructure.
- Training and Education: Provides hands-on learning opportunities in engineering programs.

1.3 NON-DESTRUCTIVE TESTING

Non-destructive testing is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed, the part can still be used.

1.3.1 NDT inspection technique

Here are some common types of non-destructive testing (NDT) methods:

- Visual Inspection (VT)
- Liquid Penetrant Testing (LT)
- Radiographic Testing (RT)
- Magnetic Particle Testing (MT)
- Dye Penetrant Testing (PT)

- Eddy Current Testing (ET)
- Acoustic Emission testing (AE)
- Ultrasonic Testing (UT)
- Leak Testing (LT)

1.3.2 Visual inspection (VT)

Visual inspection (VT) is a non-destructive testing (NDT) method that involves direct observation of surfaces and structures using the naked eye or with the aid of optical instruments such as magnifying glasses, borescopes, or cameras. This method is used to detect surface defects, irregularities, corrosion, or other visible indications of damage or deterioration in materials, components, or structures. Visual inspection is often the first step in NDT processes and is widely used across various industries due to its simplicity, versatility, and cost-effectiveness.

1.3.3 Liquid Penetrant testing (LT)

Liquid Penetrant Testing (PT) is a non-destructive testing (NDT) method used to detect surface defects in materials. It involves applying a liquid dye to the surface, allowing it to seep into any surface openings, and then removing excess dye before applying a developer to make defects visible. This method is effective for identifying small surface cracks, voids, or other discontinuities.

1.3.4 Radiographic testing (RT)

Radiographic Testing (RT) employs X-rays or gamma rays to produce internal structure images in materials, crucial for detecting defects like cracks or voids. Widely used in industries, RT ensures quality control and structural integrity assessment in manufacturing, aerospace, and construction. It provides detailed insights into material properties, aiding in identifying flaws and ensuring the safety and reliability of components and structures.

1.3.5 Magnetic particle testing (MT)

Magnetic Particle Testing (MT) is a non-destructive testing (NDT) method used to detect surface and near-surface flaws in ferromagnetic materials. A magnetic field is applied to the test object, and iron particles, either dry or suspended in a liquid, are applied to the surface. These particles accumulate at areas of magnetic leakage, indicating the presence of defects such as cracks or discontinuities. MT is commonly used in industries like aerospace, automotive, and manufacturing for quality control and weld inspection.

1.3.6 Dye Penetrant testing (PT)

Dye Penetrant Testing (PT) is a non-destructive testing (NDT) technique for detecting surface flaws in materials. A coloured dye is applied to the surface, allowed to penetrate surface discontinuities, and excess dye is removed. A developer is then applied to draw out the dye from defects, making them visible. PT is highly sensitive and widely used in industries such as aerospace, automotive, and manufacturing for quality control and weld inspection.

1.3.7 Eddy current testing (ET)

Eddy Current Testing (ET) is a non-destructive testing (NDT) method used to detect surface and subsurface defects in conductive materials. It works by inducing eddy currents in the material using a coil or probe. Changes in electrical conductivity caused by defects alter the eddy currents, which are detected and analysed to identify flaws. ET is commonly employed in industries such as aerospace, automotive, and electronics for flaw detection and material characterization.

1.3.8 Acoustic emission (AE) testing

Acoustic Emission (AE) testing is a non-destructive technique for detecting and analysing stress-induced acoustic signals emitted by materials undergoing deformation or damage. These signals, typically in the ultrasonic frequency range, are captured by sensitive sensors and analysed to identify changes indicative of defects or structural instability. AE is commonly used in industries such as aerospace, civil engineering, and structural health monitoring for detecting and monitoring damage in materials and structures.

1.3.9 Ultrasonic testing (UT)

Ultrasonic Testing (UT) is a non-destructive method for detecting internal defects or discontinuities in materials using high-frequency sound waves. A transducer emits ultrasonic waves into the material, and variations in wave reflection or transmission indicate defects. UT is widely used in industries like aerospace, automotive, and construction for flaw detection, thickness measurement, and material characterization. It provides detailed insights into material integrity without causing damage to the test specimen.

1.3.10 Leak testing (LT)

Leak Testing (LT) is a non-destructive method used to identify leaks or seal integrity issues in components or systems. It involves pressurizing the test object with a gas or liquid and monitoring for pressure drops, indicating leaks. Various techniques such as bubble testing, pressure decay testing, and tracer gas testing are employed. LT is crucial in industries like automotive, aerospace, and manufacturing for ensuring product quality and safety.

1.4 EFFECTIVITY OF NON-DESTRUCTIVE TESTING

Non-destructive testing (NDT) offers several advantages over destructive testing (DT), making it preferable in many situations:

- **Preservation of Tested Items:** NDT allows for the inspection of materials and components without causing damage, preserving the integrity of the tested items for further use or analysis.
- **Cost-Effectiveness:** NDT techniques are often more cost-effective than DT methods since they do not require the disposal or replacement of tested items.
- **Efficiency:** NDT processes are generally faster and more efficient since they can inspect large volumes of materials or components without the need for extensive sample preparation or testing.

- **Safety:** NDT is safer for personnel and the environment since it does not involve the handling or disposal of hazardous materials generated by destructive testing processes.
- **Continuous Monitoring:** NDT techniques can be used for continuous monitoring of materials, components, or structures, allowing for early detection of defects or changes in condition over time.
- **Non-intrusive Inspection:** NDT methods can be applied to inspect materials or components without altering their surface or structure, making them suitable for sensitive or delicate objects.
- **Versatility:** NDT offers a wide range of techniques suitable for various materials, components, and applications, providing flexibility in testing methods based on specific inspection requirements.
- **Overall,** NDT is preferred over DT in many scenarios due to its ability to provide reliable inspection results while preserving the integrity and functionality of tested items.

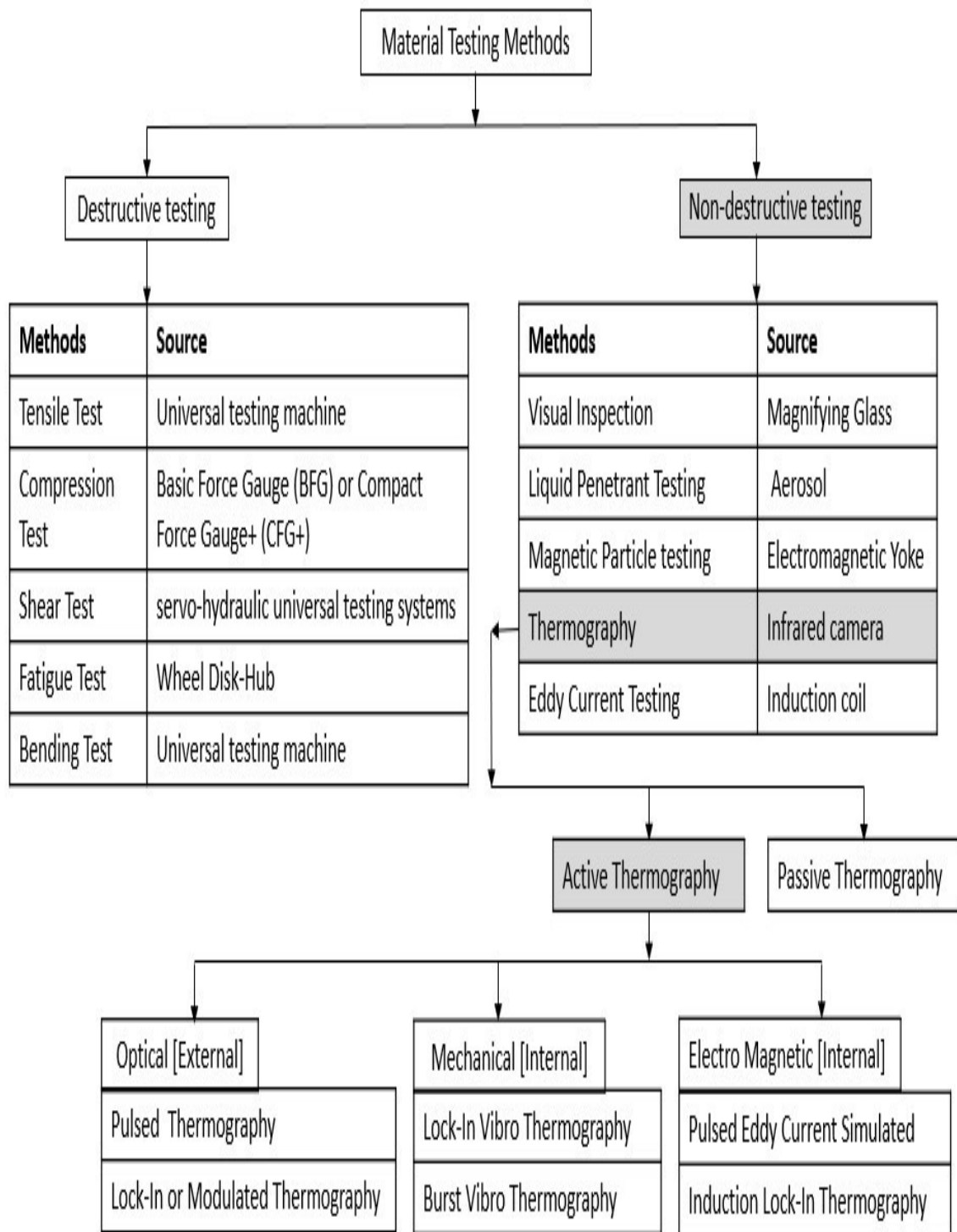


Fig:1.1: Classification of materials testing methods

1.5 SIGNIFICANCE OF NON-DESTRUCTIVE THERMOGRAPHY

Thermographic non-destructive testing (NDT) is a powerful technique used in various industries to assess the integrity, quality, and performance of materials, components, and systems without causing any damage. By analysing heat signatures emitted by objects, thermographic NDT provides valuable insights into their internal structures, defects, and anomalies. Here is how it works and why it is important

1.5.1 How Thermographic NDT works

Heat Emission: All objects emit infrared radiation (heat) as a function of their temperature. Thermographic NDT utilizes infrared cameras to capture these emissions.

Detection: The infrared camera detects the heat signatures emitted by the object's surface. Variations in temperature can indicate defects, anomalies, or structural inconsistencies within the material.

Analysis: The collected thermal data is processed and analysed using specialized software. This analysis involves comparing the observed heat patterns against reference data or predetermined criteria to identify abnormalities.

Interpretation: Skilled technicians interpret the thermal images to locate defects such as cracks, voids, delamination, or discontinuities within the material. By understanding the underlying causes of these anomalies, informed decisions can be made regarding maintenance, repair, or replacement.

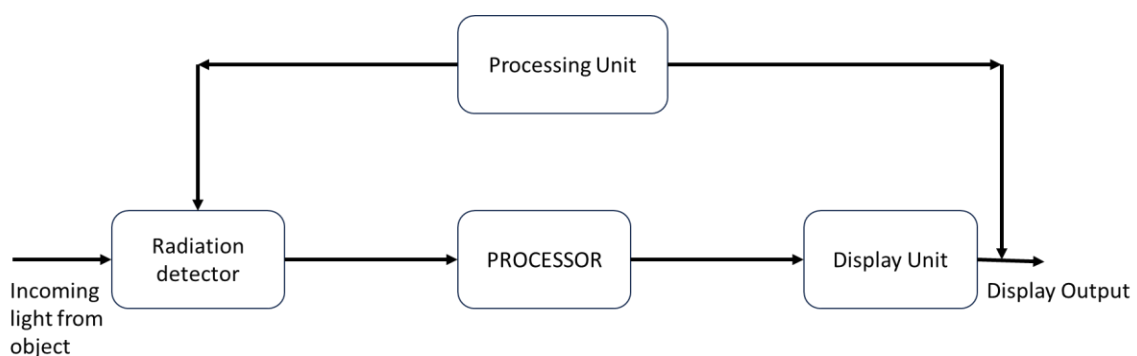


Fig:1.2: Infrared thermal imaging system

1.5.2 Importance of Thermographic NDT

Non-Destructive Nature: Unlike traditional testing methods that may require destructive sampling or disassembly, thermographic NDT allows for inspection without causing harm to the material or structure being tested. This preserves the integrity of the object and reduces downtime for repairs.

Early Detection of Defects: Thermographic NDT enables the early detection of defects before they escalate into more significant issues. This proactive approach can prevent costly failures, improve safety, and extend the lifespan of assets.

Versatility: Thermographic NDT can be applied to a wide range of materials, including metals, composites, plastics, ceramics, and even biological tissues. It is used in various industries such as aerospace, automotive, construction, electronics, and medicine.

Efficiency and Accuracy: With advancements in infrared camera technology and image processing algorithms, thermographic NDT offers high-resolution imaging, rapid data acquisition, and precise defect localization. This enhances the reliability and accuracy of inspection results.

Remote Inspection: Thermographic NDT can be conducted remotely, allowing for inspections of inaccessible or hazardous environments. This capability is particularly valuable in industries such as oil and gas, nuclear power, and infrastructure maintenance.

Thermographic non-destructive testing is a valuable tool for unlocking insights into the integrity and quality of materials and structures. By harnessing heat signatures, this technique enables early defect detection, enhances safety, and optimizes asset management across diverse industries.

1.6 THERMOGRAPHY

Thermography utilizes infrared cameras to capture and visualize temperature variations emitted by objects, generating images that represent thermal patterns across surfaces or within scenes. These thermal images, known as thermograms, display different temperatures as varying colours, enabling detection of anomalies

such as overheating components in electrical systems, insulation deficiencies in buildings, or abnormalities in medical conditions. Thermography finds applications in diverse fields including maintenance, diagnostics, security, and industrial processes.

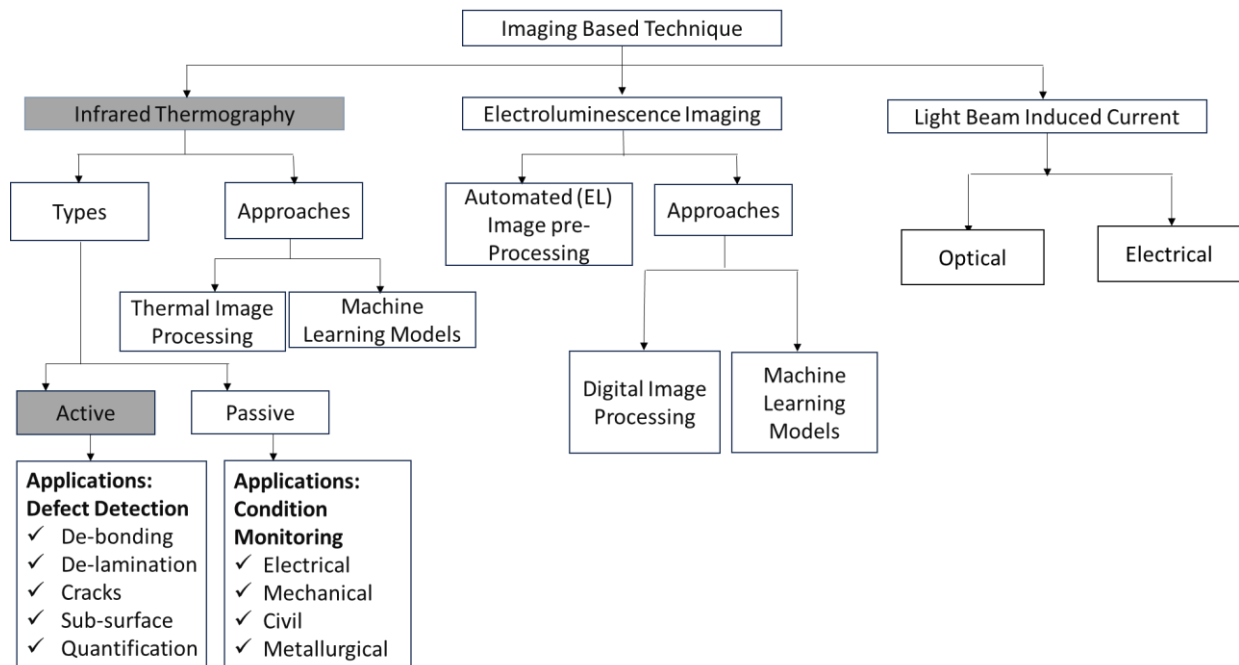


Fig:1.3: Classification of Image based technique

1.6.1 Types of Thermography

- PASSIVE THERMOGRAPHY

Passive thermography is a method of thermal imaging that captures infrared radiation emitted naturally by objects due to their temperature. It doesn't involve external stimulation; instead, it relies on detecting the heat signatures emitted by objects in its field of view.

- ACTIVE THERMOGRAPHY

Active thermography involves stimulating objects with external sources like heat to induce thermal responses for analysis. It detects changes in temperature caused by the applied stimulus, revealing defects or hidden features. Widely used in non-destructive testing, it identifies flaws in materials like cracks or delamination. Active

thermography is vital in industries like aerospace for assessing structural integrity and in electrical inspections for detecting faults in components.

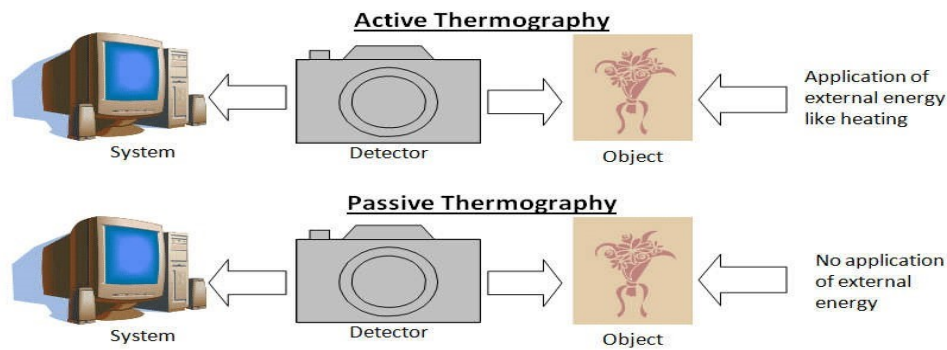


Fig:1.4: Working of Active and Passive Thermography

1.7 WORKING PRINCIPLE OF ACTIVE IR THERMOGRAPHY

Infrared thermography operates on the principle that any object with a temperature higher than absolute zero (-273.15°C) emits electromagnetic radiation. The intensity and spectral composition of this radiation are closely linked to the object's surface. By analysing the radiation intensity, one can accurately determine the temperature of an object without making physical contact.

Active thermography is a non-destructive testing technique used to inspect materials and structures. It involves applying external energy, like heat or light, to the material being tested. The material's response to this energy is then monitored and analysed to identify defects or irregularities. As energy is applied, the material heats up and the heat propagates through it, revealing variations in temperature caused by internal defects or inconsistencies. Thermal imaging cameras or sensors capture surface temperature distributions, which are processed and analysed to detect anomalies. Advanced techniques such as image processing and statistical analysis help interpret the thermal data, allowing for defect localization and characterization. Based on the analysis results, decisions can be made regarding the material's integrity and whether further action is needed.

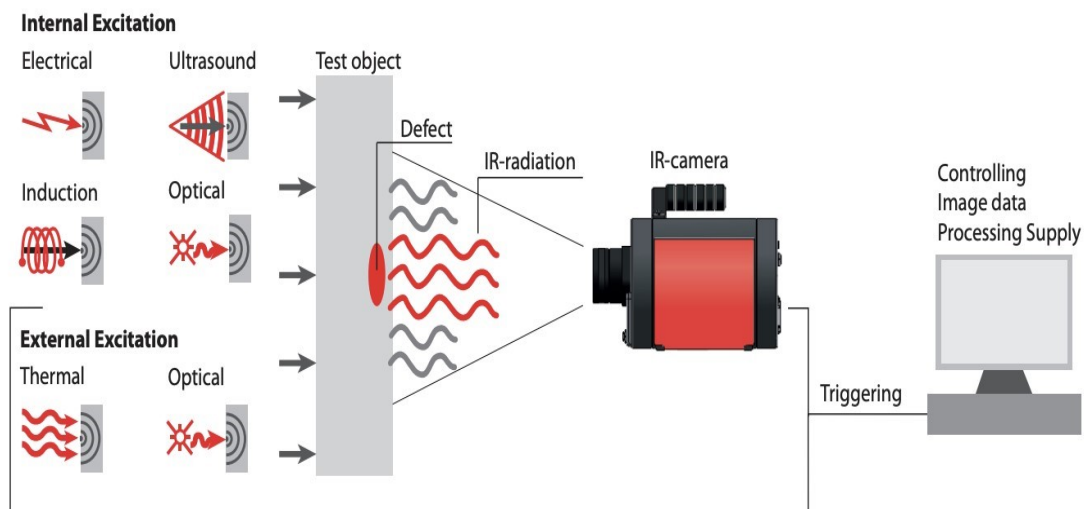


Fig:1.5: Representation of Active Thermography

1.8 ADVANTAGES OF INFRARED THERMOGRAPHY

Here are the advantages of thermography testing,

- This method is highly efficient and user-friendly.
- It is faster compared to many other inspection techniques and generates thermal images.
- Large areas can be scanned quickly, resulting in significant time and resource savings.
- Thermographic devices are safe to use as they do not emit radiation.
- Testing can be conducted both during the day and at night.
- It is a non-contact NDT technique, eliminating the need for couplant as in ultrasonic testing.
- Results are easily interpretable.
- It is a unique method for identifying open micro cracks in thermally sprayed coatings, which are challenging to inspect with other NDT methods.
- Relative comparison of surface temperature distribution can be performed over a wide area.

1.9 APPLICATION OF INFRARED THERMOGRAPHY

Infrared thermography, also known as thermal imaging, is utilized in various fields due to its versatility and effectiveness in temperature measurement and analysis. Some of the prominent fields that use infrared thermography include:

- **Building Inspections and Construction:** Infrared thermography is widely employed for building inspections to identify insulation deficiencies, moisture intrusion, electrical faults, and HVAC system performance issues. It helps assess the energy efficiency of buildings and detect structural anomalies without the need for invasive testing.
- **Electrical Maintenance and Power Systems:** Infrared thermography is extensively used in electrical maintenance to detect overheating in electrical components such as wires, breakers, switches, and connections. It helps identify potential failures, loose connections, and overloaded circuits in power distribution systems, thus preventing electrical fires and downtime.
- **Mechanical Systems and Predictive Maintenance:** In industries like manufacturing, automotive, and aerospace, thermal imaging is applied for predictive maintenance of mechanical equipment such as motors, bearings, pumps, and gearboxes. It enables early detection of friction, misalignment, and lubrication issues, minimizing unexpected breakdowns and optimizing equipment reliability.
- **Medical Diagnostics and Healthcare:** Infrared thermography is utilized in medicine for various diagnostic purposes, including detecting abnormalities in blood flow, inflammation, and tissue injuries. It's particularly useful in areas such as breast cancer screening, vascular assessments, sports medicine, and neurology, providing non-invasive and radiation-free imaging techniques.
- **Firefighting and Search & Rescue:** Thermal imaging cameras are essential tools for firefighters and search-and-rescue teams to locate individuals in smoke-filled environments or during nighttime operations. Infrared thermography helps identify hotspots, assess fire spread, and enhance

situational awareness, improving response effectiveness and firefighter safety.

- **Industrial Processes and Quality Control:** Infrared thermography is employed in industrial processes for temperature monitoring, quality control, and defect detection in materials such as plastics, metals, and composites. It aids in identifying manufacturing defects, monitoring product uniformity, and optimizing production processes.
- **Environmental Monitoring and Conservation:** In environmental science and conservation efforts, thermal imaging is used to study ecosystems, monitor wildlife populations, and assess habitat health. It helps researchers track animal movements, detect poaching activities, and evaluate thermal characteristics of landscapes and bodies of water.
- **Security and Surveillance:** Infrared thermography is utilized in security systems for perimeter surveillance, intrusion detection, and monitoring of critical infrastructure. It enables security personnel to detect trespassers, monitor crowd movements, and identify potential threats in low-light or adverse weather conditions.

1.10 LIMITATIONS OF INFRARED THERMOGRAPHY

Here are some limitations of thermography testing

- Limited penetration depth due to its reliance on infrared technology, reaching only a few millimetres.
- Thermal losses through convection and radiation may lead to false contrasts, impacting interpretation reliability.
- Surface painting is necessary for low emissivity materials to enhance and equalize emissions.
- Active thermography equipment tends to be pricier than ultrasound devices.
- It can only detect defects that cause a measurable change in thermal properties on the surface being inspected.
- Reflective surfaces that cannot be made more emissive may obscure

subsurface conditions.

- Thermography testing can only visualize the thermal characteristics of an object's surface.

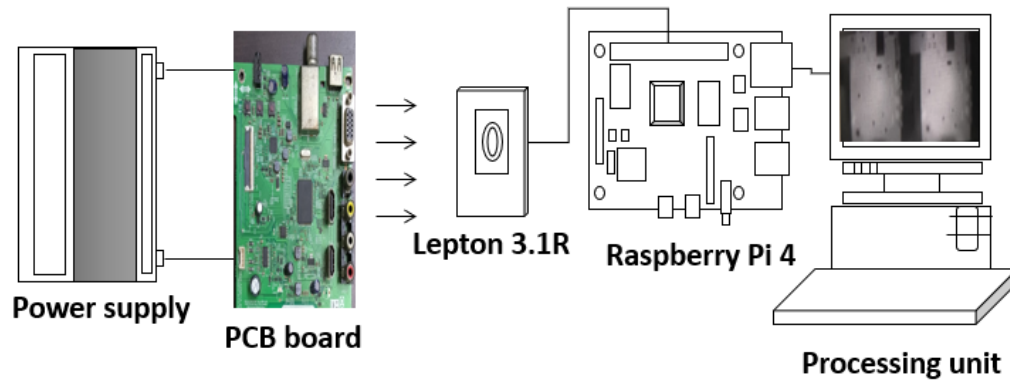


Fig:1.6: Thermography System for Electronic PCB Defect Analysis

CHAPTER 2

LITERATURE SURVEY

2.1 LITERATURE SURVEY BASED ON THERMOGRAPHIC INSPECTION TECHNIQUES

2.1.1 Automated dynamic inspection using active infrared thermography

Ruben Usamentiaga et.al (2018) in his research discusses the versatility of active thermography across various applications. It highlights the limitations of static configuration, particularly when inspecting large products and machines. Dynamic inspection is proposed as an alternative, offering better resolution despite its challenges in data reconstruction. The paragraph then focuses on analysing two dynamic inspection methods: the thermal photocopier and line scan. Additionally, it introduces automatic robust methods for calculating temperature-time history, facilitating defect detection through advanced data processing algorithms. Results validate the effectiveness of these methods in inspecting large products.

2.1.2 Infrared thermography processing based on higher-order statistics

Francisco J. Madruga et.al (2010) in his research discussed the Active thermography is widely acknowledged as an efficient non-destructive evaluation method, prized for its ease and speed of inspection. However, automating the processing of infrared (IR) sequences is crucial to reduce human intervention. Despite the challenge posed by the substantial data recorded by IR cameras during inspections, human involvement remains indispensable. This paper proposes the use of higher-order statistics (HOS) analysis to address this issue by condensing essential information from IR sequences into singular images for each inspection. The statistical behaviour of pulsed infrared thermographic temporal response is well-documented, and this study analyses its application to carbon fibre-reinforced plastic (CFRP) samples, presenting the results of the analysis.

2.1.3 Active Thermography Data-Processing Algorithm for Non-destructive Testing of Materials

Wellington Francisco da Silva et al (2020) in his research work provides information about the focus, techniques, experimental setup, data compression, and contributions of an active thermography algorithm using FLIR SC640 thermographic camera. Its integration with image processing techniques to improve thermal analysis. The algorithm utilizes several techniques, including Thermographic Signal Reconstruction (TSR), Thermal Contrast (TC), and principles of heat transfer. Defects in carbon fibre reinforced polymer (CFRP) were examined. The flash(pulse) is used as an excitation source.

2.1.4 Data Processing Scheme for Laser Spot Thermography Applied for Non-destructive Testing of Composite Laminates

Jakub Roemer et al (2023) in his research introduces a novel data processing scheme for laser spot thermography (LST) applied to non-destructive testing (NDT) of composite laminates. LST involves recording multiple thermographic sequences, resulting in large datasets that require cumulative processing to evaluate diagnostic information. The proposed scheme utilizes parameterization and machine learning to address major difficulties in LST signal processing, delivering valuable diagnostic insights. Effectiveness is demonstrated using an experimental dataset from a laminated composite sample with simulated delamination. The paper discusses theoretical aspects of the signal processing and inference algorithms proposed, along with the experimental setups required for data collection.

2.1.5 Semantic segmentation for non-destructive testing with step-heating thermography for composite laminates

Oscar D. Pedrayes et al (2022) in this paper evaluates and compares semantic segmentation networks, including UNet and DeepLabV3+, against traditional machine learning methods like Random Forest and Support Vector Machines in step-heating active infrared thermography for subsurface defect detection and localization. Post-processing methods such as PCT, PPT, Kurtosis, Skewness, and TSR are employed to condense information from digital recording sequences into images. Two datasets are created: one with 3-channel images using PCT, and another using all post-

processing methods to generate 30-channel images. The study demonstrates that DeepLabV3+ effectively detects defects in specimens with a similar structure to training samples, even for defects of varying depth and area, without false positives. UNet achieves similar results to DeepLabV3+ but requires the use of 30-channel images. In contrast, Random Forest and Support Vector Machines struggle to detect defects accurately compared to the newer methods.

2.1.6 A review of automated solar photovoltaic defect detection systems: Approaches, challenges, and future orientations

Ula Hijjawi et.al (2023) in this paper reviews defect detection methods for PV modules, categorizing them into Imaging-Based Techniques (IBTs) and Electrical Testing Techniques (ETTs). IBTs include Infrared Thermography (IRT) and Electroluminescence (EL) imaging, while ETTs encompass Current-Voltage (I-V) analysis and others. Advantages and disadvantages of each method are discussed, considering factors like scale, targeted defects, and location analysis. Challenges include data availability and computational efficiency, addressed through data preprocessing methods.

2.1.7 3D Defect detection using weighted principal component thermography

Seppe Sels et.al (2020) in his research work discussed the Quantitative infrared thermography, such as active thermography, is a non-destructive testing technique commonly used to inspect component surfaces for defects. However, misclassifications based on geometrically dependent measurement characteristics can occur, especially when inspecting complex 3D shapes. This paper proposes a new infrared quality control procedure that utilizes a quality map to model these geometrically dependent characteristics based on available CAD data and matching techniques. By combining this quality map with a modified version of principal component thermography post-processing, misclassifications are reduced. The proposed methodology was applied to prototype bicycle parts and plaster cast angel figurines, demonstrating its effectiveness in preventing false defect detection.

2.1.8 Experimental study on debonding defects detection in thermal barrier coating structure using infrared lock-in thermographic technique

Qingju Tang et.al (2016) in his study utilized the infrared lock-in thermographic (LT) technique to detect debonding defects in ZrO₂ coated Ni-based super alloy GH4169 plates. It described the basic principle of the infrared LT technique and the associated extraction algorithm of thermal wave signal features. Experiments were conducted to analyse the influence of parameters such as light source output power, number of analysis periods, and modulation frequency on detection results. Findings indicate that optimal detection results, characterized by greater total phase contrast CPh, were achieved with a light source output power of 1000 W, 4 analysis periods, and a modulation frequency of 0.2 Hz, within the specified size range of sample defects.

2.1.9 Thermographic methodologies used in infrastructure inspection: A review post-processing procedures

I. Garrido et.al (2020) in his research discussed the distinct thermal behaviour exhibited by defects compared to unaltered zones allows for the detection and characterization of superficial and subsurface defects, crucial for maintaining optimal structural conditions. InfraRed Thermography (IRT) emerges as a highly suitable non-destructive technique for capturing these thermal behaviours, visualized through temperature maps in thermal images, applicable across structures of varying sizes. Additionally, IRT finds utility in thermal characterization for purposes such as energy studies in buildings. Continuous advancements in thermal image processing algorithms underscore the significance of IRT in infrastructure inspections, particularly in the post-acquisition stage where these algorithms enhance inspection performance. This review provides a comprehensive overview of recent and significant thermographic procedures for infrastructure applications, with a focus on post-acquisition processing due to the lack of in-depth analysis in this area. The paper categorizes these techniques based on their theoretical post-acquisition approach, distinguishing between qualitative and quantitative analysis methods. Advantages, disadvantages, and recent IRT works associated with each technique are discussed, emphasizing the maturity of IRT in tackling infrastructure inspection challenges. However, the review also highlights existing limitations and outlines future trends for the field to pursue.

2.2 LITERATURE SURVEY BASED ON THERMOGRAPHIC APPLICATION

2.2.1 Introduction of active thermography and automatic defect segmentation in the thermographic inspection of specimens of ceramic tiling for building facades

Ivan Garrido et.al (2022) in his research discussed the InfraRed Thermography (IRT) has emerged as a valuable diagnostic tool due to its real-time, remote, and non-destructive capabilities, facilitating accurate detection of defect areas in ceramic tiling on building façades. Despite the widespread use of ceramic tiles in construction worldwide, challenges such as tile detachment and water infiltration persist. To address these issues, this paper proposes active infrared thermography as an acquisition mode, contrasting with passive methods. Additionally, it introduces defect segmentation and automation in thermal image processing, offering novel contributions to ceramic tiling inspection. Laboratory tests, simulating detachment with inserted corks and water infiltration through drilled holes, yield promising results under various conditions, including dry and wet surfaces with differing properties. This workflow presents a rapid initial inspection approach for ceramic tiling on building façades. Future research will focus on refining this methodology through real-world case studies.

2.2.2 Using active thermography for defects inspection of flip chip

Zhensong Xu et.al (2013) focuses on using active thermography as a non-contact and non-destructive method for inspecting flip chip solder joints. It outlines the experimental procedure, data processing techniques, and highlights the method's effectiveness in detecting defects such as missing bumps in flip chips. The external heating resource is mainly comprised of a semiconductor laser heating equipment (HLU32F400-808) is used along with IR camera.

2.2.3 Active Thermography for Non-invasive Inspection of Wall Painting:

Novel Approach Based on Thermal Recovery Maps

M. Rippa et.al (2023) in his research discussed the development of non-invasive diagnostic methods for artwork conservation is crucial for preserving human culture. Over the years, restoration efforts have been aided by various technologies, with digital imaging systems playing a significant role. There's a growing demand for non-invasive tools that can detect defects and compare their condition before and after conservation treatments. Infrared thermography stands out as a well-established, non-invasive, and contact-less imaging method that allows for low-cost, in situ analysis. This study explores the feasibility of an innovative active thermography approach, utilizing thermal recovery maps to detect detachments in wall paintings. The effectiveness of this approach is tested on an XVIII century artwork before and after consolidation work. The results demonstrate its potential to support restoration efforts by identifying critical areas and facilitating pre-post restoration comparisons.

2.2.4 Double active thermographic inspection of additive manufacturing composites: numerical modelling and validation

Henrique V. Silva et.al (2023) in his research work provided insights into a study that compares two thermography techniques ATT and DATT for inspecting 3D-printed fibre-reinforced polymers, highlighting the enhanced performance of DATT in terms of thermal contrast. It also emphasizes the importance of validated numerical models in understanding heat dissipation and optimizing inspection processes. Thermographic camera with HS lamp as excitation source is used.

2.2.5 Classification of barely visible impact damage in composite laminates using deep learning and pulsed thermographic inspection

Kailun Deng et.al (2023) in his research discussed the widespread use of Carbon Fiber-Reinforced Polymers (CFRP) in modern industries underscores the importance of defect detection and characterization in these materials, attracting significant research attention. Over the past decade, Artificial Intelligence (AI) technologies have gained traction in this domain due to their remarkable capability in complex data analysis tasks. However, current AI-based studies on damage characterization in

CFRP primarily focus on damage segmentation and depth measurement, hindered by a shortage of experimental data for model training.

This paper proposes a novel framework utilizing Deep Learning to explore the relationship between Barely Visible Impact Damage (BVID) features in typical CFRP laminates and their corresponding controlled drop-test impact energy. Through a parametric study involving one hundred CFRP laminates subjected to drop-impact tests at five energy levels, Pulsed Thermography is employed to reveal subsurface impact damage. Convolutional Neural Networks (CNNs) are then utilized to classify thermal images into groups based on impact energy levels. Evaluation of models trained using different time windows and lengths demonstrates a classification accuracy of 99.75%. Additionally, a salience map is introduced to enhance the interpretability of the proposed solution, aiding in understanding the learning source of the produced models.

2.2.6 Automatic Detection of Subsurface Defects in Composite Materials using Thermography and Unsupervised Machine Learning

Roberto Marani et.al (2016) in his paper introduces a comprehensive framework for non-destructive inspection of composite materials. Beginning with acquisition via lock-in thermography, the method progresses through a series of data processing blocks: input enhancement, feature extraction, classification, and defect detection. Experimental results demonstrate the methodology's effectiveness in detecting defects beneath the surface of a calibrated Glass Fiber Reinforced Polymer (GFRP) specimen. Additionally, comparisons with other techniques, employing different features and unsupervised learning methods, highlight the framework's ability to minimize false positives while accurately detecting subsurface defects.

2.2.7 Thermography methodologies for detecting energy related building defects

Matthew Fox et.al (2014) in his paper discussed Thermography is increasingly employed by construction professionals for energy-related defect detection in buildings. Traditionally, building thermography focused on walk-around or walkthrough methodologies. However, new approaches are emerging to address limitations like camera resolution and transient climatic conditions. This study reviews existing

literature on established and emerging building thermography methodologies, providing insights for researchers and practitioners. While various passive building thermography methods target specific issues, there's often a lack of correlation between them. The paper suggests the potential for combining multiple methodologies in a phased approach to building surveying, allowing for quick identification of defects followed by detailed surveys as needed.

2.2.8 Stainless Steel Weld Defect Detection Using Pulsed Inductive Thermography

Yuhua Cheng et.al (2016) in this paper introduces pulsed inductive thermography (PIT) as a non-destructive testing technique to detect concealed defects in stainless steel welds, which are crucial for structural integrity in various industries. The theory of detecting defects in stainless steel welds is outlined, followed by a series of experiments to validate the effectiveness of the proposed method in identifying different types of defects. Independent component analysis (ICA) is employed to mitigate the impact of weld inhomogeneity and enhance defect information. The experiments confirm that PIT, when combined with ICA, can effectively visualize defects in stainless steel welds.

2.2.9 Application of infrared thermography for predictive/preventive maintenance of thermal defect in electrical equipment

A.S. Nazmul Huda et.al (2013) in his research discussed the Internal heat in electrical equipment can lead to various issues like contact problems, unbalanced loading, or insulation cracks, eventually causing failure and unplanned outages. Detecting thermal abnormalities early is crucial to prevent failure. Infrared thermographic inspection systems offer a fast, reliable, and non-contact solution to identify internal and external defects without interrupting operations. Both preventive and predictive maintenance programs are used for defect diagnosis, depending on factors like thermal condition and equipment age. This article discusses preventive and predictive maintenance, thermal defects in electrical equipment, and introduces an intelligent thermal defect identification system. This system utilizes artificial neural networks and statistical features to monitor equipment's thermal condition and detect defects. Discriminant analysis helps select optimal features for the neural network, with the

comparison showing that the discriminant analysis classifier outperformed the neural network with an accuracy of 82.40%.

2.2.10 Development of miniaturized active thermography system for in-situ inspection

Wei Xiang Du et al (2020) in his research work developed a compact and affordable active thermography system for on-site inspection utilizing the FLIR Lepton camera module. The study focused on inspecting defects in carbon fibre reinforced polymer

(CFRP) using two cameras: a cost-effective camera and a high-end camera SC7600. They investigated the effective assessment of degradation using laser and flash excitation. The research findings highlighted the ability to differentiate thermal images of identical defective samples using the same excitation sources.

Table:2.1: Literature survey based on Camera module and defects identified

Author Year Reference	Materials tested	Heating source	Camera used	•Defects
A.P. Chrysafi et.al (2017) [1]	Flat CFRP laminates with multi layers- K63712 Fiber	Optical IR lamp 750 W	FLIR SC660	•Crack •Delamination
Hadi Sanati et.al (2018) [4]	Fiberglass composite wind turbine blade	Flash lamp 2400 W	FLIR T1030sc	•Flat-bottomed holes •Crack •Delamination
Henrique V. Silva et.al (2023) [5]	3D-printed Kevlar Fibre Reinforced Polymer (KFRP)	Philips PAR38 Infrared lamps 700 W	Fluke Ti400	•Delamination
Lawrence Tinsley et.al (2020) [7]	Counterfeit electronic components (CEC)	Xenon flash lamps with ~ 2 kJ flash energy applied	FLIR SC7000	•Heating issues
Mariusz Kaczmarek et.al (2016) [9]	Clinical environment (Medical application)	Lasers Source	FLIR (LW FPA, uncooled)	•Skin burn •Surgical wound.
Masashi Ishikawa et.al (2021) [10]	Concrete specimen	Xenon flash lamp (1000 J/flash), Halogen lamp 500 W	FLIR A315	•Void •Cracks
M. Rippa et.al (2020) [11]	Plant monitored under UV-B irradiation.	Halogen lamp 200 W UV-B lamp fluorescent tube (Philips TL20W/12)	FLIR X6580	•UV-B – plants interaction
M.R. Jolly et.al (2015) [12]	Thick-walled carbon fibre-integral part of flywheel.	Flash pulse Xenon lamps.	FLIR SC7600MR	•Delamination •Crack •Porosity
Shuanglu YU et.al (2019) [13]	Aluminium specimen	Diode laser 250W.	FLIR SC5200	• Back wall defects
Slawomir Grys (2012) [14]	Plexiglas, painted with mat black paint.	Two symmetrically placed incandescent lamps 2-250 W	FLIR PM595	•Bottom-holes
Thomas Lafargue-Tallet et.al (2022) [15]	Specular materials - Stainless steel and mirror.	Multispectral black body source temperature ranges from 20 to 500 °C	FLIR SC7000	•Rough surface
U. Netzelmann et.al (2015) [16]	Ferromagnetic metals (Group I) Non-magnetic metals (Group II) Metallic alloys (Group III) Electromagnetic skin depth (Group IV)	Induction coil with frequencies range from 1500Hz to 52MHz	IR Camera	•Cracks
Weixiang Du et.al (2020) [17]	Carbon fiber reinforced polymer.	Optical xenon flash lamp - Energy 2kJ, Laser-energy 15W	FLIR Lepton FLIR SC7600	•Flat-bottomed holes.
Wellington Francisco Da Silva et.al (2020) [18]	Carbon fiber reinforced polymer	Two Halogen lamps. 5.0 kW	FLIR SC640	•Holes
Zhen song Xu et.al (2014) [20]	Flip chip solder joint.	Semi-conductor laser heating equipment (HLU32F400-808)	Thermal imager-VH 680, Infratec.	•Missing bumps

CHAPTER 3

AIM AND SCOPE

3.1 AIM

The aim is to develop an Active thermography infrared Non-destructive system for inspection of materials.

3.2 OBJECTIVE

- Identifying the overheating spots on electronic Printed Circuit Boards to avoid the failure of the entire system.
- Finding minor defects in metal specimens such as spatter defects.
- Capturing thermal images to identify overheating defects in PCBs and displaying them on the screen.
- Classifying overheating in various kinds of components in printed circuit boards.

3.3 SCOPE OF THE SYSTEM

The scope of an active infrared thermography Non-destructive testing (NDT) system is broad and diverse, encompassing applications across industries such as aerospace, automotive, manufacturing, and construction. These systems are integral to quality control and assurance processes, enabling the early detection of defects in materials and structures without causing damage. They play crucial roles in material testing, structural health monitoring, maintenance, and predictive maintenance strategies, ensuring the integrity, reliability, and safety of products, components, and infrastructure. Researchers also utilize them for R&D purposes, studying material properties, developing innovative defect detection techniques, and exploring new manufacturing processes. With advancements in technology, active thermography NDT systems find applications in specialized areas such as electronics inspection, medical imaging, cultural heritage preservation, and environmental monitoring. In essence, these systems contribute significantly to improved product quality, safety and reliability across various sectors.

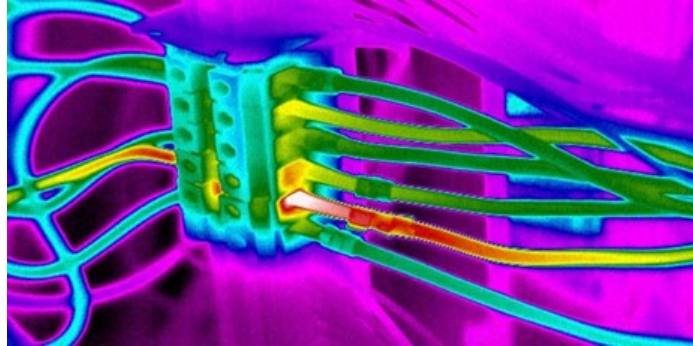


Fig:3.1: Poor electrical connection spotted during infrared thermography

CHAPTER 4

EXPERIMENTAL WORK AND SETUP

4.1 COMPONENTS USED IN ACTIVE THERMOGRAPHY NDT SYSTEM

4.1.1 FLIR Lepton 3.1 R camera

FLIR cameras, typically deployed in military and civilian aircraft, utilize a thermographic camera sensitive to infrared radiation. The Teledyne FLIR Lepton 3.1R HFOV Thermal Imaging Camera boasts 19,200 active pixels, offering superior sensitivity and resolution compared to standard thermopiles. Featuring a 95° horizontal field of view (HFOV), a 160x120 array size, a shuttered design, and a scene dynamic range spanning from -10°C to +400°C, this camera is well-suited for a diverse range of applications and environments, including work settings, mission critical tasks, and smart technologies. With its compact size and low power consumption, the Teledyne FLIR Lepton 3.1R HFOV Thermal Imaging Camera finds utility in various fields such as mobile smart devices, occupancy detection, HVAC control, smart lighting, and robotics.

Table:4.1: Specification of FLIR Lepton 3.1R

Specification	FLIR Lepton 3.1R with Radiometry
Resolution (h*v)	160*120 Progressive scan
Spectral range	Long-wave infrared, 8 μm to 14 μm
Full frame rate	8.7HZ
Thermal sensitivity	<50mk (0.050°C)
Pixel size	12μm
Control interface	CCI (I2C-like), CMOS IO voltage level
Lens type	f/1.1
Weight	1.0 Grams (without socket)
Package Dimensions (W*L*H)	11.5 x 12.7 x 6.9 mm (without socket) 11.8 x 12.7 x 7.2 mm (with socket)
Output Format	14-bit, 8-bit (AGC applied), or 24-bit RGB (AGC and colorization applied)

4.1.2 FLIR Lepton Breakout board V2

The FLIR Lepton Thermal Camera Breakout Board serves as a straightforward evaluation board for seamlessly interfacing all iterations of the FLIR Lepton camera module with popular platforms like Raspberry Pi or custom hardware like mobile development kits. It comes equipped with on-board power supplies, derived from a voltage range of 3 to 5.5V, as well as a master clock. Additionally, there's an option to bypass local power supplies, the master clock, and the power-up sequence components using a jumper.

4.1.3 Raspberry pi model 4b- 4GB Ram

The Raspberry Pi is a budget-friendly, credit card-sized computer designed to connect to a computer monitor or TV and utilize a standard keyboard and mouse. It serves as a versatile tool that empowers individuals of all ages to delve into computing and learn programming languages like Scratch and Python. The Raspberry Pi 4 Model B offers robust features including a high-performance 64-bit quad-core processor, dual-display support through two Micro HDMI ports with up to 4K resolution, hardware video decoding at up to 4Kp60, a maximum of 4GB of RAM, dual-band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0 connectivity, and Power over Ethernet (PoE) capability.

4.1.4 Jumper wires

Jumper wires are insulated wires featuring connectors at both ends, employed in electronics to establish electrical connections between components. They are available in a range of lengths, colors, and gauges, offering versatility for diverse applications such as prototyping and circuit testing. These wires allow for temporary or permanent connections, simplifying signal transmission, power distribution, and circuit modification with convenience.

4.1.5 Micro SD card

A 32GB SanDisk microSD card is utilized for both booting and storing output data in a Raspberry Pi.

4.1.6 Power cable

The Raspberry Pi receives power directly from the 5-volt USB output of the computer, while the infrared receiver is powered by the 3.3-volt output port of the Raspberry Pi.

4.1.7 Induction heating power supply module with heating coil

Induction coil is used as an external heating source. The induction heating power supply module operates with a DC power supply voltage ranging from 5V to 12V, supporting a maximum power of 120W specifically for 12V induction heating applications. This module is equipped with a high-quality board designed specifically for induction heating, ensuring reliable and efficient performance. With its adjustable voltage range and maximum power output, the module offers versatility and precision for various heating requirements.

4.1.8 Flash lamp

The external heating source relies on the utilization of a flash lamp, a specialized device engineered to emit intense bursts of light. In this configuration, the flash lamp draws its power from a 9V battery, providing the necessary electrical energy to initiate and sustain the heating process.

4.1.9 Battery

Two 9-volt batteries are utilized to power the external heating source, with each battery providing a nominal voltage of 9 volts, albeit actual voltage may vary between 7.2 and 9.6 volts depending on battery chemistry, with batteries available in different sizes and capacities.

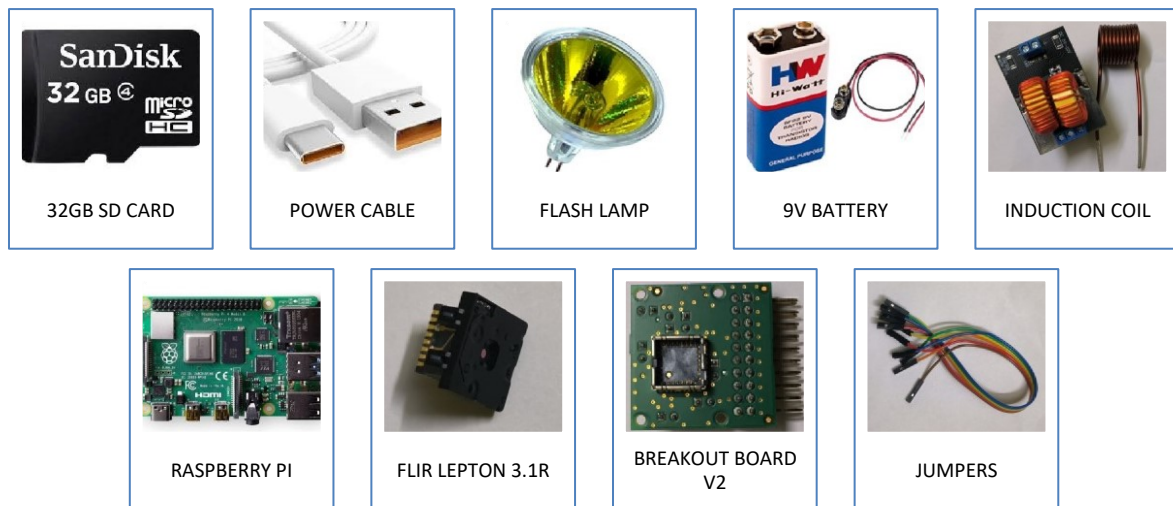


Fig:4.1: Components of Active Thermography NDT system

Table:4.2: Components and specification of Active Thermography system

NAME OF THE COMPONENT	SPECIFICATION
Camera module	FLIR LEPTON 3.1R
Breakout board	Breakout board V2
Raspberry Pi	Raspberry Pi 4 Model B-4GB RAM
Flash lamp	UVA/UVB Light Bulb
Induction coil	Mini ZVS Induction coil
Battery	9V Battery
Power cable	USB-C type

4.2 EXPERIMENTAL SETUP

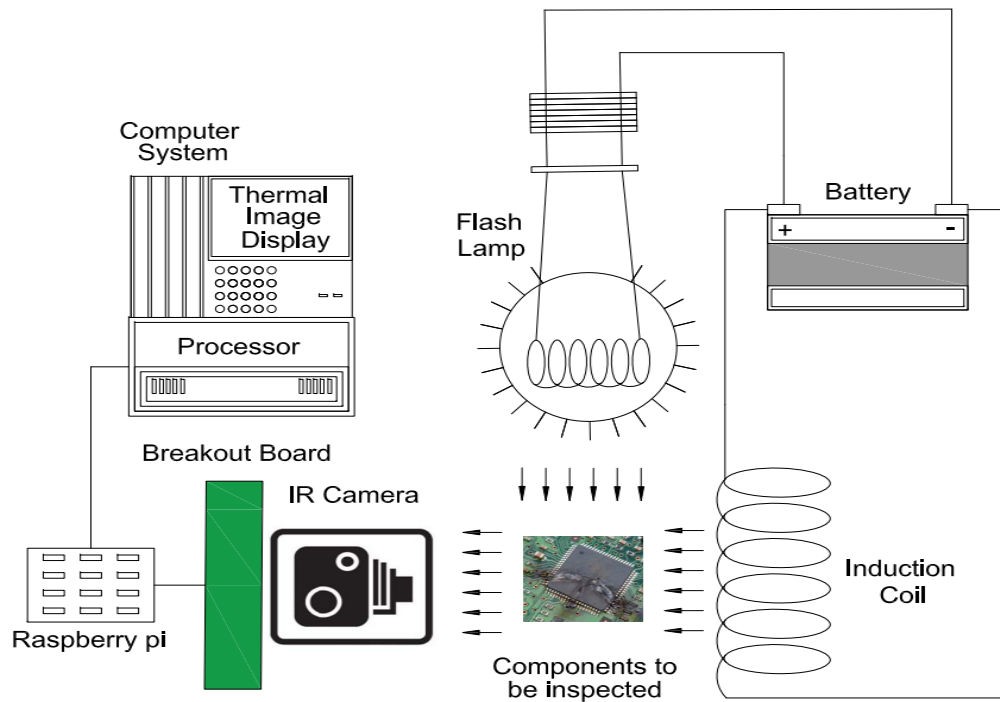


Fig:4.2: Experimental setup of Active Thermography NDT system

The setup comprises an LWIR (Long Wave Infrared) IR camera, specifically the Lepton 3.1R manufactured by FLIR, coupled with a Raspberry Pi for the purpose of gathering thermal data from samples. The Lepton camera boasts precise and calibrated temperature readings for each pixel in its 160x120 pixel array and 95-degree field of view (FOV), making it highly accurate for thermal analysis. Typically, the Lepton module is mounted on a breakout board requiring an input power of 3.3V, although it can be conveniently powered directly from any 3V or 5V microcontroller or PC, offering flexibility in its setup. Serving as the microprocessor in this system is the Raspberry Pi, specifically the Raspberry Pi 4 model, which integrates a powerful 64-bit quad-core cortex running at a speed of 1.5GHz, alongside 4GB of RAM for efficient data processing. Additionally, the Raspberry Pi 4 features 4 USB ports for data transfer, an SD card slot for memory storage and OS deployment, 2 HDMI ports for AV output, a type C port for powering the board, and a 3.5mm audio jack, rendering it a versatile and comprehensive platform for various applications.

Running on the Raspberry Pi is the Raspbian OS, an open-source OS derived from Linux, which is booted from a 32GB SanDisk micro-SD card using Raspberry Pi imager software for convenience. Jumper wires establish the necessary connection between the breakout board of the Lepton camera module and the Raspberry Pi, while power is supplied to the Raspberry Pi via a type C cable, directly from the 5volt USB output of a computer, with the infrared receiver deriving its power from the 3.3-volt output port of the Raspberry Pi board. For image processing, a Java-based program called ImageJ is employed to view and render grayscale images obtained from the camera, facilitating detailed analysis of thermal data.

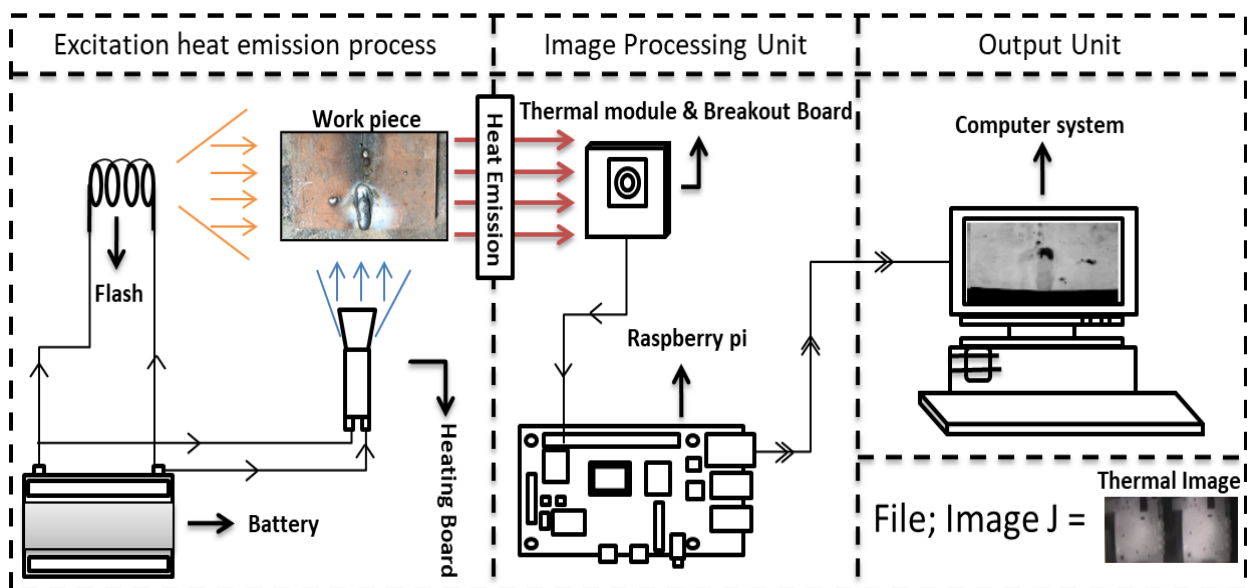


Fig:4.3: Working process of Active thermography NDT system

Moving beyond mere thermal imaging, the in-situ active thermography kit also includes dual excitation sources, both powered externally, to enhance the detection capabilities of the system. These excitation sources encompass both Optical and Electromagnetic methods. The Optical excitation source employs flash lamps for external heating, providing controlled and consistent heat generation, while the Electromagnetic source relies on a high-frequency induction coil positioned near the test object to generate eddy currents, typically lasting between 50 to 500 milliseconds. This combination of excitation sources offers versatility in detecting a wide array of defects, ranging from structural weaknesses to material inconsistencies, thereby enhancing the system's utility in various industrial and research applications.

During the thermal imaging process, the infrared camera records the surface radiation emitted by the samples both before and after the application of the heating pulse generated by the excitation sources. These thermal patterns, representing variations in temperature distribution across the samples, are captured by the radiometric micro thermal camera module with precision and accuracy. To further enhance the utility of the system, dedicated software has been developed and integrated with the Raspberry Pi for capturing, storing, and processing the thermal data obtained from the camera. This software facilitates real-time analysis and visualization of the raw thermal images, enabling users to identify and assess any anomalies or defects present in the samples under observation. As a result, the system offers a comprehensive solution for thermal imaging and defect detection, with potential applications spanning various industries, including but not limited to, materials science, engineering, and quality control.



Fig: 4.4: Infrared camera module with complete wiring

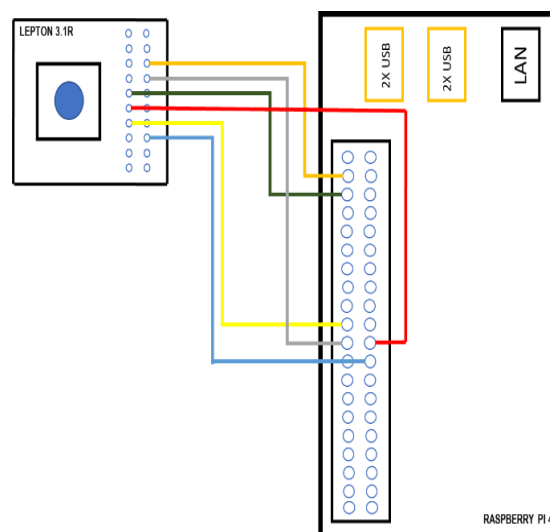


Fig: 4.5: Pin diagram of Active thermography NDT system

Table: 4.3: Pin configuration of Active thermography NDT system

SNO	COLOR	LEPTON 3.1R	RASPBERRY PI 4
1	BROWN	SCL	GPI03
2	RED	CS	GPI08
3	YELLOW	MISO	GPI09
4	PURPLE	SDA	GPI02
5	GREEN	CLK	GPI011
6	BLUE	VSYNC	GPI07

4.3 INTEGRATED SOFTWARE IN ACTIVE THERMOGRAPHY NDT SYSTEM

To set up the Raspberry Pi development environment, first, install the necessary build tools on a Linux build host. Next, gather the required source code and build information. Proceed to compile the Raspberry Pi kernel package. Additionally, on a separate Linux development workstation, perform cross-compilation of the Lepton driver. Once the driver is built, transfer it to the build host and compile the Lepton source code. Afterward, install the Lepton software onto the Raspberry Pi. Finally, conduct testing to ensure the functionality of the Lepton camera on the Pi.

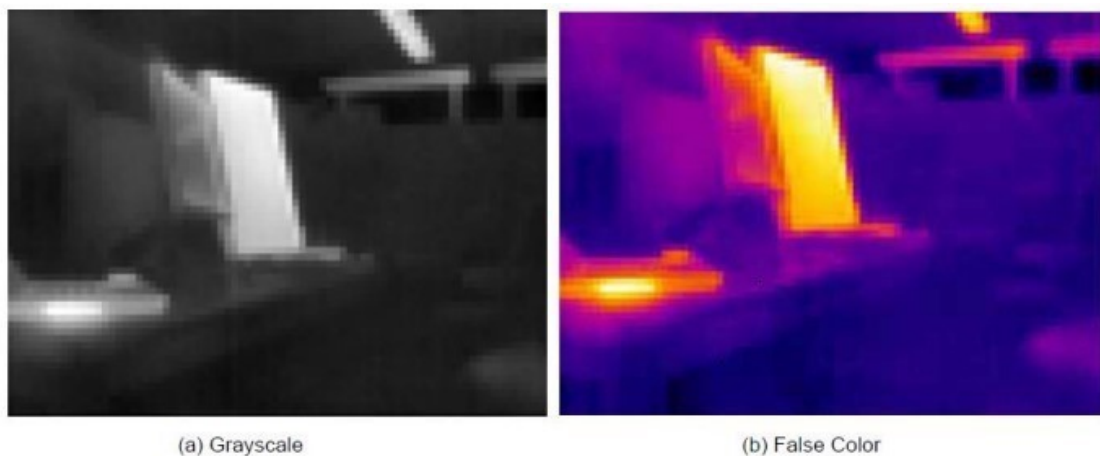


Fig: 4.6: Comparison of an Identical Image with Grayscale and a False-colour Palette

Upon collecting thermal data, the subsequent step involves storing the raw images collectively within a dedicated folder. To proceed, launch the ImageJ software and navigate to the open menu where the "raw" option is selected. Following this, locate the folder containing the raw data and open a file from within it. To efficiently sequence all raw frames captured from the camera into a video, ensure to activate the "open all files from the directory" checkbox. Before initiating the opening process, it is imperative to specify the format as 16-bit unsigned and the dimensions as 160x120 pixels through the provided popup window. Subsequently, ImageJ undertakes the conversion of raw data into a visually coherent grayscale image sequence. For enhanced accuracy in observing the image, consider utilizing the scale option available within the image menu to upgrade the video scaling. Upon completion, export the resultant image sequence as an AVI file through the file menu, facilitating ease of transfer and viewing across various devices. Moreover, to analyse individual frames with precision, grayscale images can be alternatively saved as JPEG or PNG formats.

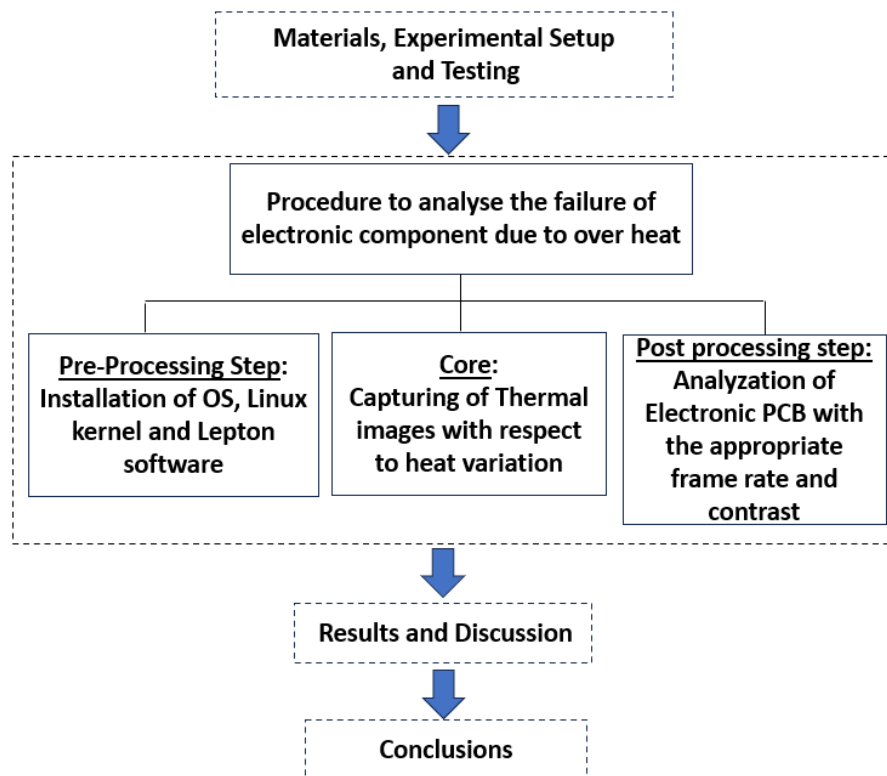


Fig:4.7: Methodology of Active thermography NDT system

CHAPTER 5

RESULT AND DISCUSSION

To demonstrate the above, an electronic printed circuit board is taken with chip and Filter over heating issue which affect the performance of the system.

5.1 RESULTS BASED ON METAL SPATTER DEFECT



Fig:5.1: Welded metal with spatter defect

A metal sample is employed to illustrate the techniques, wherein a 10 x 10 cm iron piece with weld spatter defects is utilized. An intense heating is generated using a UVA/UVB 2KJ flash lamp in conjunction with a Mini ZVS 5-12V induction coil, facilitating the effective identification of surface and sub-surface defects in the iron specimen. The experiment operates effectively within a working distance of 120mm.

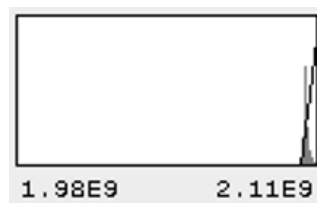


Fig:5.2: Thermal contrast of weld metal

5.2 RESULTS BASED ON OVERHEATING IN CPU-INTEGRATED CIRCUIT

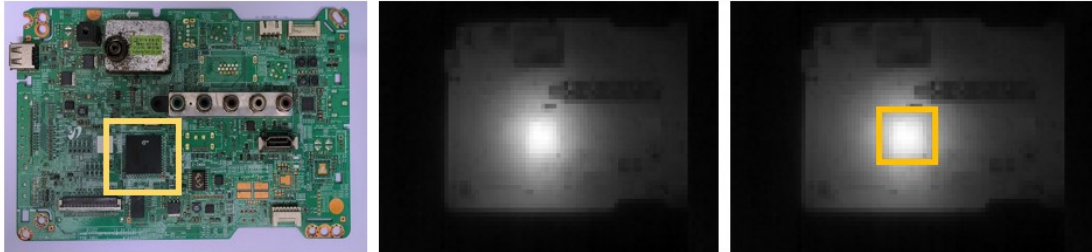


Fig:5.3: Electronic PCB with CPU IC overheating issue

The above Figure represents a high heating issue in the CPU chip from the television motherboard. Typically, the chip requires a power supply input of 1.2+3.3 V to produce its output of 3.3V adequately for its function. However, due to the chip's malfunction, the voltage exceeds 3.3V, impacting the system's performance. Through this active thermography NDT system, we identified that the chip surpasses its heating threshold, indicating a potential failure, subsequently halting its operation. The compact AT kit offers a clear view of the thermal image, highlighting the overheated component. To demonstrate the detectability of heat variation, the maximal temperature contrast of Sample 1 is depicted in the 27th thermal image frame from the AT kit, with a standard 7 μm frame rate and a 160 x 120 resolution format array. The contrast of all images has been enhanced using adaptive histogram equalization. Figure illustrates the thermal contrast of Sample 1.

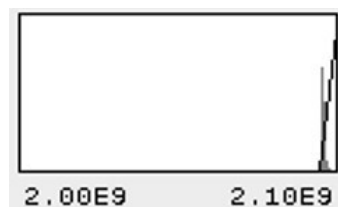


Fig:5.4: Thermal contrast of CPU chip set

5.3 RESULTS BASED ON FILTER OVERHEATING IN COMBINATION PCB

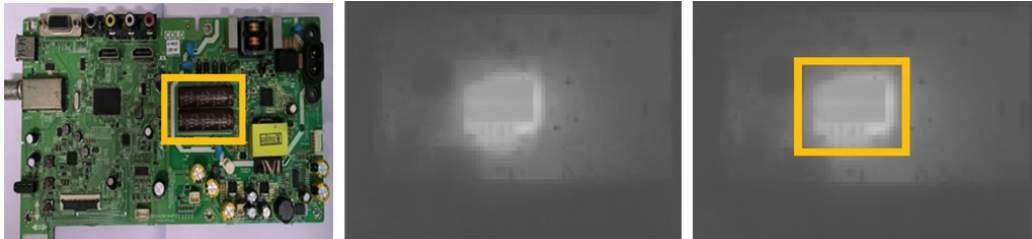


Fig 5.5: Electronic PCB with Parallel filter overheating issue

Figure 1.7 depicts the parallel filters located in the primary hot section, used for converting AC to DC in the television combo board. The standard power supply voltage is 230V. The voltage traverses through the copper winding and enters the filter, converting AC to DC, resulting in a voltage of 300V. If the power supply exceeds 440V, the filter cannot endure it and burns out. The filter's capacity allows it to withstand up to 450V. Sample 2 above represents the filter's overheating stage, indicated by temperature variation. This thermal image was captured at the 19th thermal frame using the standard resolution format array and frame rate. Figure 1.8 denotes the thermal contrast of sample 2.



Fig 5.6: Thermal contrast of Parallel filter

5.4 RESULTS BASED ON OVER-HEATING ISSUE IN MEDIA TEK ARM CPU CHIP SET

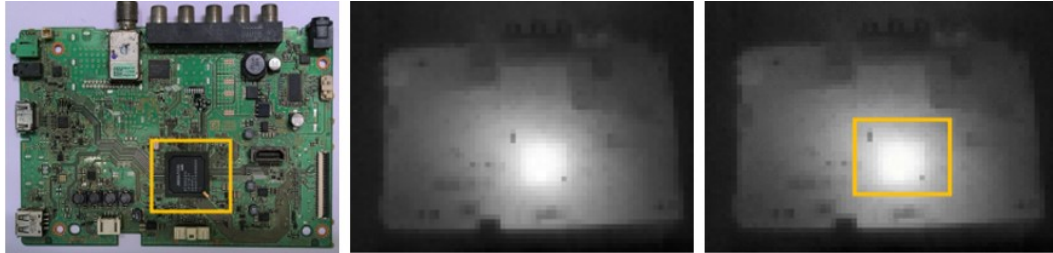


Fig 5.7: MEDIA TEK ARM CPU chip set with overheating issue

The MediaTek ARM CPU IC plays a crucial role in integrating all the components together. Without this CPU IC, the system will not switch on. Figure 1.9 illustrates the overheating of the CPU IC, which can result in the permanent shutdown of the system. To prevent this, we utilize the AT system to identify overheating spots before system failure occurs. This CPU IC is situated in the cold secondary section of the motherboard. The thermal contrast was adjusted using adaptive histogram equalization. The thermal image was captured at the 42nd thermal frame using the standard resolution format array and frame rate. Figure 1.10 depicts the thermal contrast of Sample 3.

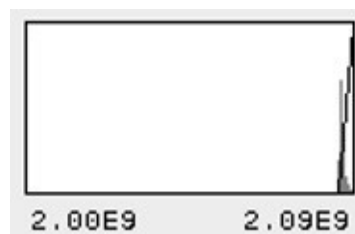


Fig 5.8: Thermal contrast of MEDIA TEK ARM CPU chip set

The table 5.1 shows the recommended activities based on rising temperatures over ambient, known as Delta T, as well as the values and actions related to them. The statistics show the severity of the temperature increase above ambient and the

essential precautions to take. Normal temperature increases require no correction, however excessive overheating necessitates prompt repair.

The table outlines a clear set of guidelines for addressing temperature rises above ambient levels in different fault categories. Here is the recommended actions based on the delta T (temperature rise above ambient) and the corresponding fault category:

- 1°C to 20°C (Delta T: 1 °C to 3 °C) - Normal: No need for repair.
- 20 °C to 40 °C (Delta T: 4 °C to 6 °C) - First Stage of Overheating: Monitor closely.
- 40 °C to 60 °C (Delta T: 7 °C to 9 °C) - Second Stage of Overheating: Monitor very closely.
- 60 °C to 80 °C (Delta T: 10 °C to 14 °C) - Excessive Overheating: Repair as soon as possible.
- Greater than 80 °C (Delta T: 15 °C) - Acute Overheating: Repair immediately.

This structured approach provides a clear framework for responding to temperature increases, ensuring appropriate actions are taken based on the severity of the overheating scenario.

Table:5.1: Thermography Survey Based on Temperature Rise and Recommended Actions

Temperature Rise Above Ambient	Delta T*	Fault Category	Recommended Action
1°C to 20°C	1 °C to 3 °C	Normal	No need to repair
> 20 °C to 40 °C	4 °C to 6 °C	First Stage of Overheating	Monitor closely
> 40 °C to 60 °C	7 °C to 9 °C	Second Stage of Overheating	Monitor very closely
>60 °C to 80 °C	10 °C to 14 °C	Excessive Overheating	Repair as soon as possible
Greater than 80 °C	15 °C	Acute Overheating	Repair immediately

CHAPTER 6

SUMMARY AND CONCLUSION

Active infrared thermography is a non-destructive testing technique used for detecting defects and anomalies in various materials and structures. It involves the application of heat to the surface of the object being inspected, typically through heat lamps, induction heating, or other methods. As the surface heats up, any defects within the material, such as cracks, delamination, or voids, will alter the way heat is transferred, causing temperature variations that can be captured using an infrared camera.

The process relies on the principle that different materials have different thermal properties, and defects or abnormalities will affect the flow of heat, leading to temperature differences that are detectable by the infrared camera. By analyzing the thermal images captured during heating and cooling cycles, trained technicians can identify and assess the severity of defects present in the material.

Active infrared thermography offers several advantages over traditional testing methods, including its non-contact nature, ability to inspect large areas quickly, and suitability for a wide range of materials, including metals, composites, ceramics, and more. Additionally, it can be used in various industries such as aerospace, automotive, construction, and manufacturing for quality control, structural health monitoring, and preventive maintenance purposes.

A proposal has been made for a compact active thermography (AT) system aimed at improving the usability and accessibility of AT technology while lowering inspection equipment expenses. This system targets the detection of overheating issues in Electronic Printed Circuit Boards (PCBs) both qualitatively and quantitatively. Utilizing Raspberry Pi and multiple excitation sources, this compact system can detect various component failure defects in PCBs. Unlike high-end infrared sensor-equipped systems, it offers significant cost savings and requires less space. Its adaptable design suits diverse industrial inspection scenarios, and the incorporation of multiple excitation sources enables the detection of different heating issues in components. Experimental findings demonstrate the system's effectiveness in identifying heating

issues in PCBs, presenting defects clearly with appropriate contrast. The system achieves satisfactory detection and analysis of heating defects in various PCB components, notably detecting a CPU IC and Filter issue through temperature variation. Filtering processes enhance detection accuracy by reducing noise interference.

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APPENDIX

FIRST PAGE OF REVIEW PAPER

1st International Conference on Advancement in Energy (ऊर्जाSangam-2023)
18th –20th December, 2023
MNNIT Allahabad, Prayagraj, Uttar Pradesh, India

DEVELOPMENT OF A PORTABLE ACTIVE THERMOGRAPHY NDT SYSTEM FOR IN-SITU INSPECTION OF MATERIALS

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Abstract

Thermography is a non-destructive testing (NDT) technique which uses sophisticated infrared cameras to capture images. The infrared radiation apprehended by thermal camera produces thermal images based on the heat absorbed and emitted by the object or the surface to be inspected. Thermography is classified into passive and active thermography. Based on the difference in temperature of various materials and the environmental temperature, passive infrared thermography captures thermal images without any heating source. Whereas active infrared thermography uses an external heating source and an infrared detector to detect the defects. In this research work, a portable active based thermography system is developed using a radiometric micro thermal camera module (FLIR lepton 3.1R), induction coil and a flash lamp as a dual excitation source integrated with Raspberry pi to process the captured thermal images of welded and corroded surface, surface tension, fractured surface etc. This portable active infrared thermography system is capable of detecting defects in electronic components and counterfeit electronic components, as they are prone to have heating issues, which damages the electronic components. This system diagnoses minor defects of any system before even getting damaged due to excess heating. This portable active based thermography system can identify machine failure, malfunctioning of systems and improves reliability in various fields like electrical wiring, electrical, mechanical, and electronic machines.

Keywords: NDT, Thermography, Active thermography, Infrared cameras.

1. INTRODUCTION

In the world of modern industry, the quality and reliability of materials and structures play a vital role in assuring safety, performance, and durability. Several materials testing techniques are used to determine the physical and mechanical properties of various materials and components. As new industries evolve, the demand for efficient and accurate non-destructive testing (NDT) techniques has increased. The Non-Destructive Testing (NDT) technique is used to accurately detect defects on any material without damaging or undermining performance [17]. Hence, the applications of NDT extend to various fields such as the electronics and semiconductor industry, automobile industry, aerospace, aviation sector, railway sector, marine sector, quality control in manufacturing industries, nuclear sector, renewable energy sector, petroleum industry, oil and gas industry, construction, power sector, medical and healthcare, and food and processing industry [3].

Various non-destructive testing (NDT) methods include Visual Inspection Testing, Liquid Penetrant Testing, Magnetic Particle Testing, Ultrasonic Testing, and

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PORTABLE ACTIVE INFRARED THERMOGRAPHY: A NON-DESTRUCTIVE TECHNIQUE FOR IN-SITU INSPECTION APPLICATION

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ABSTRACT:

Non-destructive testing (NDT) is a method used by industries to examine materials, parts, structures, or systems for any differences or defects, such as welding issues and electronic heating issues, without causing damage to the original materials. Thermography, a type of NDT, employs infrared cameras to detect defects characterized by temperature variations and produce thermal images. Thermography encompasses two main types: passive and active thermography. Passive thermography is primarily utilized for condition monitoring, while active thermography is geared towards defect detection. The kit involves an external heating source and an infrared detector to identify defects. In this project, a compact Active thermography system was developed employing the FLIR Lepton 3.1R infrared camera alongside a flash lamp and an induction coil as dual excitation source. This system successfully identified overheating issues in electronic PCBs, pinpointing CPU, and filter malfunctions, as well as overheated regions in metal materials. Active thermography finds applications across various sectors including electronic PCBs, metals, and composite materials. The portable nature of this active infrared thermography system enables the detection of defects in electronic components, including counterfeit ones prone to heating issues leading to damage. By preemptively identifying minor defects, it prevents damage caused by excessive heating before it occurs. Furthermore, this system proves instrumental in identifying machine failures and system malfunctions, thereby enhancing reliability across fields such as electrical wiring, electronics, mechanical systems, and machinery.