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Thermal Mapping of Hot Section Components of Aero Gas Turbine

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Abstract: *In the realm of aerospace engineering, the optimization of turbine engine performance is crucial for enhancing efficiency and ensuring safety. Monitoring temperature distributions within hot section components is essential for diagnosing potential issues and optimizing engine operation. Traditional methods of temperature monitoring often lack the ability to provide comprehensive spatial data across complex engine geometries. This paper proposes an innovative approach to address this challenge by introducing the automatic mapping of hot section components in aero turbine engines using thermal paint and MATLAB analysis. The methodology involves the application of temperature-sensitive thermal paint onto critical engine parts, followed by controlled engine operation to induce temperature variations. High-resolution imaging captures color changes in the thermal paint, which are then processed using MATLAB to derive temperature distributions. Calibration procedures establish the correlation between paint color and temperature, enabling accurate temperature mapping. Through rigorous experimentation and analysis, this study demonstrates the effectiveness of the proposed approach in generating detailed temperature maps of hot section components. These maps offer valuable insights into temperature gradients, hot spots, and thermal performance, enabling engineers to optimize engine operation and diagnose potential issues effectively. By leveraging the simplicity and versatility of thermal paint alongside the analytical power of MATLAB, this research provides a practical and efficient solution for automatic mapping of hot section components in aero turbine engines. The findings contribute to advancing temperature monitoring techniques in aerospace engineering, ultimately leading to safer and more efficient turbine engine designs*

Keywords: Gas turbine, Thermal Paint, MATLAB

I. INTRODUCTION

Turbine engines serve as the backbone of modern aviation, providing the power necessary for aircraft propulsion. Optimizing the performance and reliability of these engines is paramount for ensuring safe and efficient air travel. A critical aspect of engine performance optimization is the accurate monitoring of temperature distributions within hot section components, such as turbine blades, combustors, and nozzles.

Traditional methods of temperature monitoring, including embedded sensors and infrared thermography, offer valuable insights into localized temperature variations but often lack the ability to provide comprehensive spatial data across complex engine geometries. This limitation can impede the identification of potential issues such as hot spots, uneven heating, and thermal stress concentrations, which can degrade engine performance and lead to premature component failure.To address this challenge, this paper proposes an innovative approach to automatic mapping of hot section components in aero turbine engines using thermal paint and MATLAB analysis. Thermal paint contains temperature-sensitive pigments that change color at different temperatures, providing a visual representation of temperature distributions on engine surfaces. MATLAB, a powerful computational tool, is utilized to process thermal images captured from painted components and derive quantitative temperature data.The methodology involves the application of temperature-sensitive thermal paint onto critical engine parts, followed by controlled engine operation to induce temperature variations. High-resolution imaging techniques capture color changes in the thermal paint, which are then processed using MATLAB to generate temperature distribution maps. Calibration procedures establish the correlation between paint color and temperature, enabling accurate temperature mapping across the engine components.By combining the simplicity and versatility of thermal paint with the analytical power of MATLAB, this research aims to provide a practical and efficient solution for automatic mapping of hot section components in aero turbine engines. The resulting temperature maps offer valuable insights into engine thermal performance, enabling engineers to optimize engine operation, diagnose potential issues, and improve overall engine reliability.In the subsequent sections of this paper, we will delve into the details of the experimental setup, methodology, results, and discussion, showcasing the effectiveness and applicability of the proposed approach in enhancing temperature monitoring capabilities in aerospace engineering. Through rigorous experimentation and analysis, we aim to contribute to the advancement of temperature monitoring techniques and ultimately facilitate safer, more efficient, and more reliable turbine engine designs.

II. HARDWARE COMPONENTS

GAS TURBINE: A gas turbine, also called a combustion turbine, is a type of continuous flow internal combustion engine.The purpose of the gas turbine determines the design so that the most desirable split of energy between the thrust and the shaft work is achieved. The fourth step of the Brayton cycle (cooling of the working fluid) is omitted, as gas turbines are open system that do not reuse the same air.

Combustor: The combustion chamber is located within a casing structure. Kerosene is introduced through fuel injectors into the front of the chamber. It burns fuel with air received from the compressor, sending hot gas downstream to the turbine. Dilution air is used to cool the gas stream before entering the turbines. The combustion chamber is designed for long life and low emissions. Fuel is burned in the combustion chamber at temperatures of over 2000°CUAL.

Turbine: The turbine is an assembly of dises with blades that are attached to the turbine shafts, nozzle guide vanes, casings and structures. The turbine extracts energy from the hot gas stream received from the combustor. In a gas turbine this power is used to drive the fan and compressor. Turbine blades convert the energy stored within the gas into kinetic energy.

Thermal paint: Thermal paints can be employed as either single-change or multiple-change colour transition paints. In the thermal paint, the colour starts to appear by the interaction of electrons which are present in matter with light. The thermochromism is a property of a material where the colour can be changed in relation to temperature. As the name suggests, single-change thermal paints undergo only one transition of colour, where multi-change can transit through several different colours.

III. SOFTWARE COMPONENTS

MATLAB:MATLAB is a high-level programming language and environment primarily used for numerical computing, data analysis, and visualization. It's popular in scientific and engineering fields for algorithm development and modeling. Key features include extensive built-in mathematical functions, rich visualization tools, specialized toolboxes for different domains, and options for integration with other languages. It supports parallel computing and offers various deployment options for sharing applications.

IV. METHODOLOGY

Step 1: Thermal Painting of Hot Section components

- Disassembled the Turbo Shaft: Before disassembling the engine, ensure it's turned off and the surrounding area is clear, while donning appropriate protective gear like gloves and eye protection.
- Cleaning the Nozzle Guide Vane: Wear protective gear like gloves and eye protection. Remove the NGV located downstream of the combustor.
- Apply the thermal paint on Nozzle Guide vane: Clean the surface with a degreaser to remove dirt and oil.

Step 2: Thermal Painting of Hot Section components

- Assemble the Aero Engine for Testing: Gather materials: engine components, Nozzle Guide Vane, tools, instructions, safety gear.
- Connect the combustor to the LPG Gas Cylinder: Gather materials: LPG gas cylinder, hose, combustor, wrench, Teflon tape, safety gear.

- Taking Trial Run of 10 Minutes: Ensure all connections are tight. Clear area around combustor, place on stable surface.

Step 3: Manual Interpretation

- Disassemble the Engine Component: Turn off the LPG gas cylinder valve and let the combustor cool. Remove attachments.
- Taking the Photograph of Tested Component: Prepare camera with sufficient battery and memory. Place component on clean, well-lit surface.

Step 4: Digital Image Processing

- Digital Image Processing: Digital image processing utilizes computer algorithms to enhance images and extract valuable information. It encompasses several key steps: acquisition, enhancement, restoration, segmentation, representation, description, and analysis.
- Data Interpretation Using Image Processing: The phases of image processing include acquisition, enhancement, restoration, color processing, wavelets, compression, morphology, segmentation, representation, and object detection.

Step 5:-Calibration Of Thermal Paints

- Calibration of thermal paint is essential for ensuring accurate temperature measurements. This process begins by establishing reference standards for temperature measurement, such as calibrated thermocouples or infrared thermometers, with known accuracy and traceability.

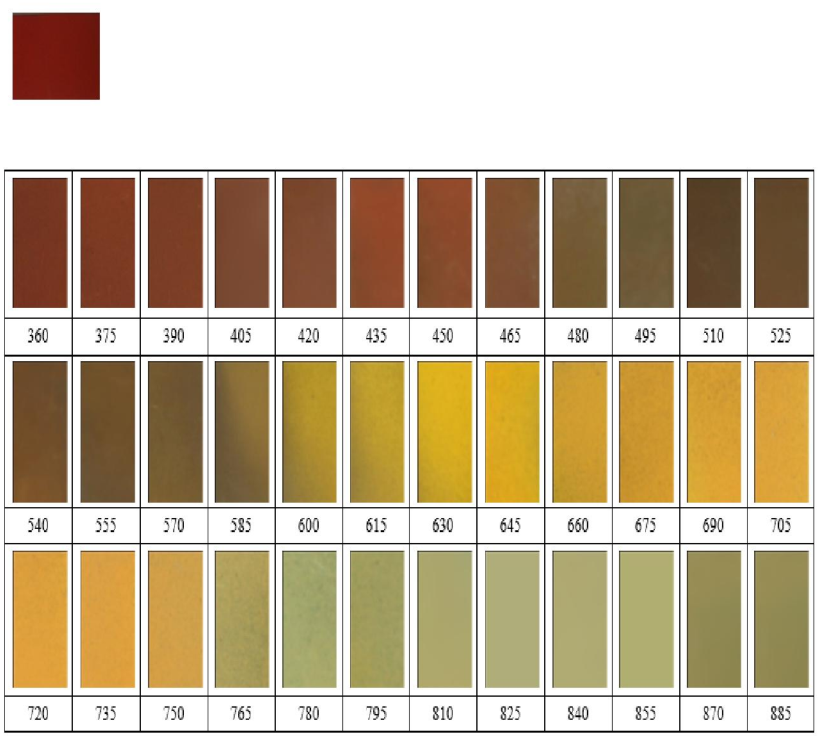

Figure : Calibration of a thermal paint

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Step 6:-Automatic Interpretation Of Thermal Paint

- In MATLAB, automatic interpretation of thermal paint involves leveraging the Image Processing Toolbox for efficient analysis. Initially, the thermal image is imported into MATLAB and pre-processed if needed, such as adjusting contrast or removing noise. Then, image segmentation techniques can be applied to distinguish regions of interest, such as areas with different temperature levels.

V. RESULT

The results of the project involving automatic thermal mapping of hot section components of aero engines using MATLAB would encompass several key aspects, including technical achievements, system performance, and potential impacts.

The results of the project would demonstrate the effectiveness of using MATLAB for automatic thermal mapping of hot section components in aero engines, with the potential to significantly impact engine maintenance practices, reliability, and performance in the aviation industry.

9automatic thermal mapping system represents a valuable tool for aero turbine engine operators and maintenance personnel, offering enhanced visibility into critical temperature dynamics and facilitating informed decision-making for optimal engine performance.

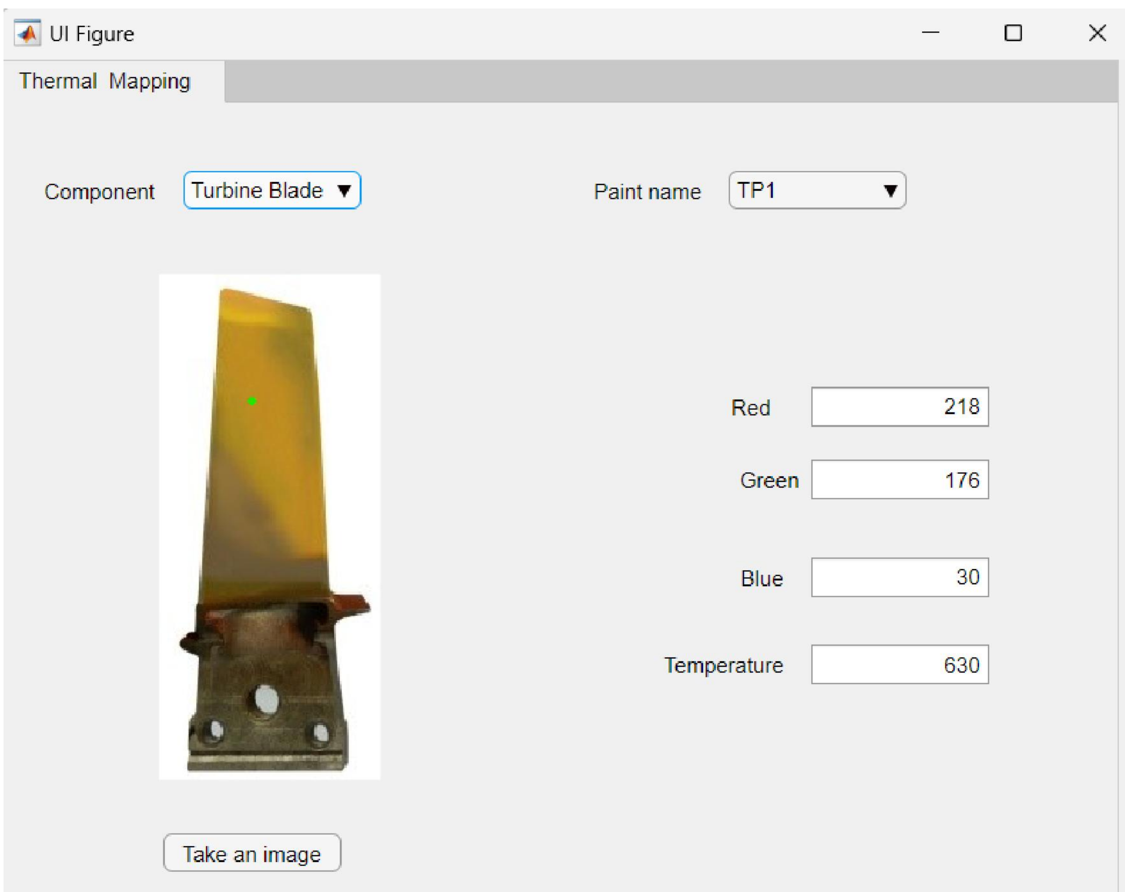

Fig 1 :- Temperature measurement of Blade at point on the image

VI. CONCLUSION

In conclusion, this study presents an innovative approach to automatic mapping of hot section components in aero turbine engines using thermal paint and MATLAB analysis. Through rigorous experimentation and analysis, we have

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demonstrated the effectiveness and applicability of the proposed methodology in enhancing temperature monitoring capabilities in aerospace engineering. The results of our study show that thermal paint, with its temperature-sensitive properties, provides a practical and versatile means of visualizing temperature distributions on engine surfaces. By leveraging MATLAB's image processing capabilities, we were able to process thermal images captured from painted components and derive quantitative temperature data with high accuracy. The temperature distribution maps generated through this approach offer valuable insights into engine thermal performance, enabling engineers to identify temperature gradients, hot spots, and potential areas of concern. This information is essential for optimizing engine operation, diagnosing issues, and improving overall engine reliability. Furthermore, the simplicity and cost-effectiveness of the proposed methodology make it suitable for implementation in both research and industry settings. By providing a practical and efficient solution for automatic mapping of hot section components, this research contributes to the advancement of temperature monitoring techniques in aerospace engineering. Looking ahead, future research efforts may focus on refining the calibration procedures, optimizing image processing algorithms, and exploring additional applications of thermal paint and MATLAB analysis in turbine engine monitoring. Additionally, validation studies in real-world engine environments could further enhance the robustness and reliability of the proposed approach. In conclusion, the automatic mapping of hot section components using thermal paint and MATLAB analysis represents a significant step forward in the quest for safer, more efficient, and more reliable turbine engine designs. By leveraging the synergies between thermal paint and MATLAB, we aim to empower engineers with the tools and insights necessary to tackle the challenges of temperature monitoring in aerospace propulsion systems.

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