

Field Study of Car Discs Brake Temperature at Highway Exit Using Infrared Thermography

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Abstract

This study investigates the operating temperatures of car brake discs under real-world driving conditions on the PLUS Highway using infrared thermography (IRT). The primary objective was to measure and analyze brake disc temperatures during regular driving scenarios, specifically focusing on the Yong Peng PLUS Toll segment. Infrared thermographic cameras, particularly the FLIR T640, were used to capture real-time temperature data at emissivity values of 0.95 and 0.35, with the latter providing more accurate temperature readings by accounting for surface emissivity. The study aimed to evaluate the thermal performance of Proton car disc brakes, investigating temperature distribution across different weather conditions (morning, afternoon, evening), and understanding the relationship between driving conditions and thermal behavior. Data were collected through 300 thermal readings, with 100 samples per session for each time period (morning, afternoon, evening). The findings revealed significant differences in thermal behavior, with some vehicles experiencing higher temperatures due to more intense braking forces or design limitations. In contrast, others maintained lower and more stable temperatures, reflecting better thermal management. These insights, drawn from the FLIR Thermal Studio software, underline the importance of accurate emissivity calibration and provide actionable data to improve the thermal performance and reliability of braking systems, ensuring enhanced safety and performance. These results also demonstrate the critical role of environmental factors, such as time of day, in influencing brake temperatures. The study highlights how advanced brake technologies, including optimized heat dissipation systems, can mitigate thermal risks in high stress driving scenarios. In the future, incorporating predictive thermal diagnostics could further improve vehicle safety, ensuring that inspected models perform efficiently and safely across diverse environmental conditions.

1. Introduction

Disc brakes are a vital component in the automotive industry, responsible for converting kinetic energy into heat to slow down or stop a vehicle. This study investigates the operating temperature of Proton car disc brakes under real-world driving conditions on the PLUS Highway using infrared thermography. The focus of the study is on high-speed driving and frequent braking, particularly at toll plazas, to assess brake temperature variations under

active traffic conditions. The disc brake system works by applying friction between the brake pads and the rotating disc, generating heat in the process. If the temperature becomes too high, it can cause problems like brake fade, disc warping, and increased wear, all of which can compromise vehicle safety and performance [1]. Traditional methods of measuring temperature in such systems can be time-consuming and disruptive. Infrared thermography offers a non-contact solution to monitor and record real-time temperature variations across the brake discs, making it ideal for this field study [2].

The results will offer valuable information that could lead to improved brake system designs, enhancing both safety and performance. Furthermore, this study will focus on understanding how various traffic conditions, such as high-density and stop-and-go situations, affect the thermal behavior of the braking system. By capturing and analyzing temperature fluctuations during actual highway driving, the research will provide insights into how heat accumulation can lead to a reduction in braking efficiency and increased wear over time. The findings from this study aim to guide design modifications that will enhance the durability and safety of Proton car brake systems.

2. Brake Function and Thermal Performance

The primary function of a disc brake is to transfer mechanical force and dissipate heat generated, necessitating operation at both medium and high temperatures. The rotor serves as a friction surface for the brake pads to contact when brake force is exerted [3]. Friction brakes must handle significant mechanical and thermal stress, with mechanical loads arising from gripping, friction, rotational forces, and acceleration in multiple directions.

Thermal loads, caused by the heat generated from friction, are often more challenging to predict and manage. Excessive temperature increases can lead to brake fade, disc warping, and premature wear of the brake components [4]. Predicting the temperature of the brake surface is difficult due to thermal movement and surface wear. When the temperature rises too much, it can lead to hot spots that cause surface cracks, thermal distortion, and other issues that affect braking efficiency [5]. To optimize braking performance, it is essential to design brakes that can effectively manage heat dissipation and prevent overheating, ensuring safety under high-speed, high-stress conditions [6].

3. Methodology

Figure 1 illustrates the workflow of this research. It begins with the identification of the study's focus and the research problem.

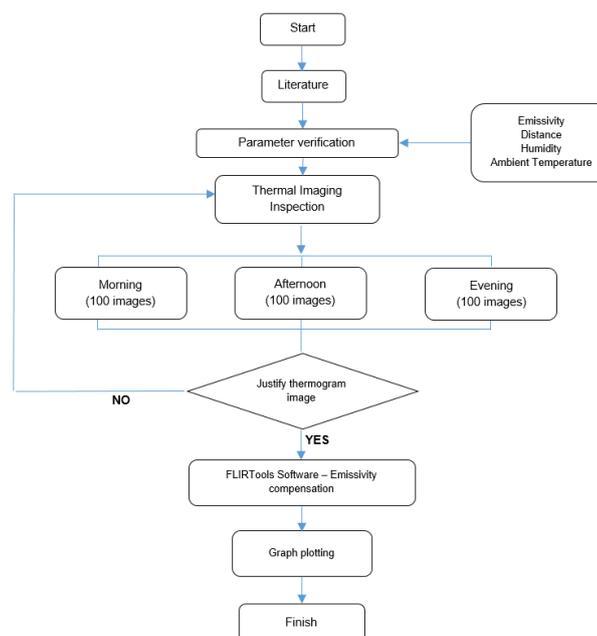


Fig. 1 Flow chart of study

3.1 Thermographic Data Measurement Instrument

3.1.1 Infrared Thermal Camera

Infrared thermography (IRT) is a non-contact, non-invasive method used to monitor equipment conditions and detect potential issues like overheating or imbalances before they lead to failures [7]. By capturing infrared radiation, IRT provides real-time temperature data from a distance without damaging the equipment, making it ideal for assessing thermal performance in automotive components such as brake discs [8]. Hence, the inspection was conducted at Yong Peng Utara PLUS Highway Exit toll booth to capture the thermal image.

One advanced tool for IRT is the FLIR T640, which features high thermal sensitivity ($<0.035^{\circ}\text{C}$) and a resolution of 640×480 pixels as shown in Figure 2. Temperature range from -40°C to 150°C was selected and sophisticated features like real-time image processing had made the T640 is perfect for precise temperature monitoring in various industrial applications. Its ergonomic design, touchscreen interface, and compatibility with FLIR Tools software enhance user experience and improve data analysis, making it a reliable option for studying the thermal behavior of disc brakes in real-world conditions [9].



Fig. 2 FLIR T640 Thermal Imaging Camera

3.1.2 Teledyne FLIR Software

FLIR Thermal Studio software as shown in Figure 3 is a comprehensive and sophisticated software suite designed to enhance the functionality of FLIR thermal cameras, enabling users to streamline their thermal image analysis and reporting processes. This versatile software is ideal for professionals who rely on thermal imagery for condition monitoring and maintenance planning. It allows users to efficiently import, edit, and analyze thermal images captured by FLIR infrared cameras, with a focus on improving the workflow from data capture to result presentation. Once the images have been analyzed, FLIR Tools makes it easy to convert them into high-quality PDF reports that can be shared with clients or decision-makers, facilitating quick approval for necessary repairs or actions.

The software offers a range of advanced features that make thermal analysis precise and customizable to the user's needs. It enables the adjustment of critical thermal parameters, such as thermal levels, spans, and color palettes, allowing for enhanced visualization and interpretation of temperature variations. Additionally, factors like emissivity and reflective temperature can be fine-tuned, ensuring that the thermal analysis accurately reflects the material properties and environmental conditions of the monitored systems. These customizable features guarantee that users can optimize their analysis and reporting to meet the specific requirements of each project or application [10].

Thermal images captured by the FLIR cameras can be transferred to the software via a USB cable or by downloading files from the camera's SD card. Once in the software, users have access to a variety of powerful tools that enable them to search, filter, and visualize the thermal images effectively. These tools make it easier to organize large datasets, helping users quickly locate and focus on the most critical areas of concern. Furthermore, FLIR Tools provides the capability to create customized inspection reports that feature tailored headers, footers, logos, and GPS data, making the reporting process more professional and streamlined. This flexibility allows for the creation of clear and detailed documentation that supports professional decision-making and enhances communication with clients and stakeholders [11].

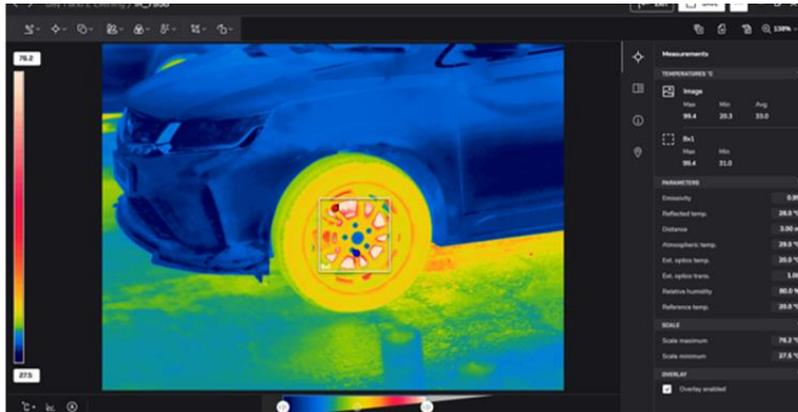


Fig. 3 Teledyne FLIR Thermal Studio Software Interface

FLIR Thermal Studio is an essential software solution for users who require precise and effective thermal analysis. Its powerful features, combined with its user-friendly interface and customization options, make it an invaluable tool for professionals working with thermal imaging technology. By simplifying the process of data capture, analysis, and reporting, FLIR Tools significantly improves the efficiency of thermal inspections and supports high-quality decision-making for equipment maintenance and repair.

4. Results and Discussion

4.1 Parameter Settings

Table 1 presents the parameters used for capturing thermal images during the evening. These values represent typical environmental conditions observed during the evening sessions, including ambient temperature, humidity, road surface temperature, and atmospheric conditions. It is important to note that these parameters may change depending on the time of day and weather conditions, and they should be adjusted accordingly for other environmental scenarios.

Table 1 Parameter settings of Evening Thermal Imagery

Parameter	Value (Unit)
Ambient Temperature	32.0 °C
Humidity	80 %
Road Surface Temperature	35.0 °C
Emissivity	0.95
Distance from Object	7 meters

4.2 Comparative Report Analysis of Different Emissivity Values ($\epsilon = 0.95$ and $\epsilon = 0.35$)

4.2.1 Analyzing data using FLIR Tools Thermal Studio

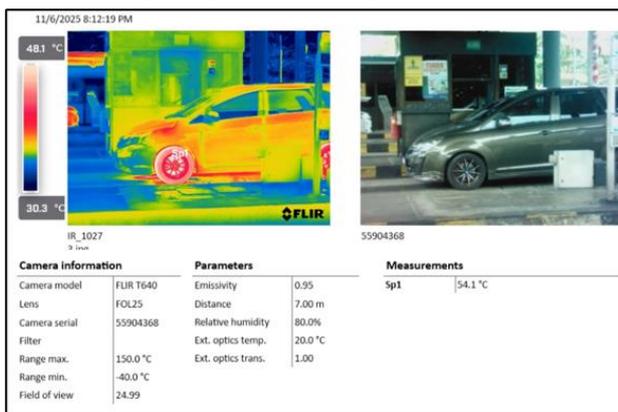


Fig. 4 Example Report of Emissivity ($\epsilon = 0.95$)

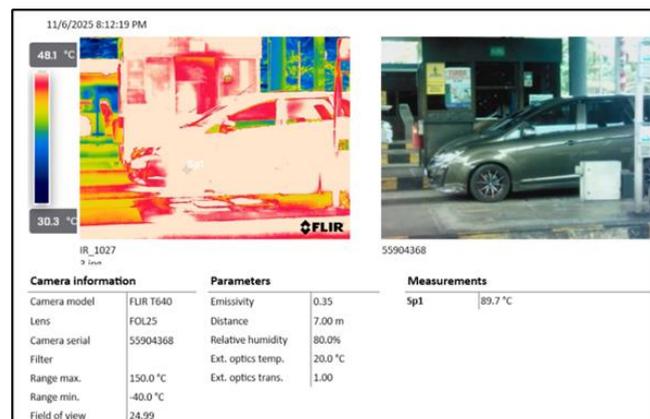


Fig. 5 Example Report of Emissivity ($\epsilon = 0.35$)

By utilizing FLIR Thermal Studio Software as shown in Figure 4 and Figure 5, able to pinpoint the exact location of the disc brake on the vehicle and measure the temperature at that precise spot. The software allows accurate identification and tracking of thermal patterns across the brake system. However, during the analysis of the initial thermal images, it was noticed that using an emissivity value of 0.95 resulted in incorrect temperature readings for the disc brake. This discrepancy arose due to the material properties of the disc brake, which do not match the standard emissivity value of 0.95 commonly used for general materials. Emissivity values are crucial in thermal imaging because they determine how much infrared radiation a surface emits. Materials with high reflectivity, like the disc brake, need a lower emissivity value to ensure accurate temperature readings.

After further testing and analysis, it concluded that an emissivity value of 0.35 provided the most accurate temperature readings for the disc brake. This value is more suitable for materials with low emissivity, such as metals used in automotive components. With this adjustment, the software showed the correct thermal profile for the brake disc, and the temperature readings became consistent with expected values. After finalizing the correct emissivity value of 0.35, it was proceeded to apply this setting to all subsequent sample images, ensuring that each thermal image accurately reflected the temperature distribution across the brake disc.

4.2.2 Normal Distribution of Proton Disc Brake Temperatures at Emissivity ($\epsilon = 0.35$)

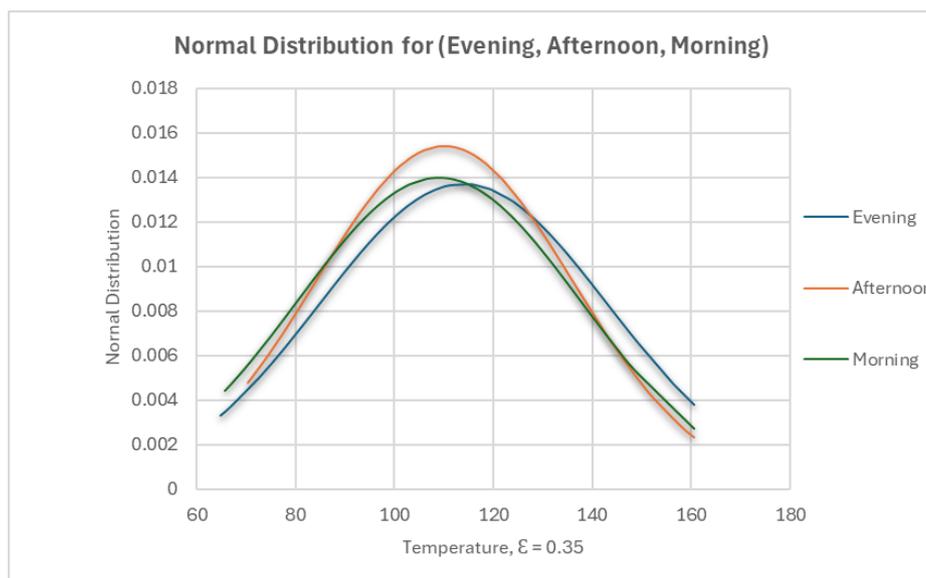


Fig. 6 Normal Distribution for all weather conditions

The normal distribution curve for evening disc brake temperature readings, as shown in the plotted bell curve Figure 6, illustrates the statistical spread of thermal values measured across 100 data points. The distribution forms a typical bell-shaped curve centered around approximately 115°C, indicating that most disc temperatures cluster near this mean, with fewer readings in the extremes. The symmetrical shape confirms that the data follows a normal distribution pattern, with temperature values gradually decreasing in frequency as they move away from the center. The peak of the curve corresponds to the most probable temperature range during evening driving, while the tail ends represent rare occurrences of unusually low or high temperatures. This pattern highlights the thermal consistency across different Proton car models during evening traffic, suggesting the presence of operational uniformity under similar environmental and braking conditions. The use of an emissivity value of 0.35 throughout ensures accuracy in surface temperature estimation under evening lighting and reflective conditions.

Similarly, the afternoon temperature readings display a normal distribution, with most values concentrated between 110°C and 120°C. The bell curve's symmetry indicates that extreme temperatures below 80°C or above 150°C are uncommon. This suggests stable brake thermal performance across different Proton vehicles during afternoon driving. Outliers may reflect specific design factors, braking intensity, or traffic load. The distribution helps identify common operating temperatures, useful for safety design and performance monitoring.

For the morning session, the bell curve shows disc brake temperatures mainly between 100°C and 130°C, peaking near the mean. The symmetric shape confirms a standard Gaussian distribution with limited extreme values. This implies that braking performance in the morning remains steady across most vehicles. Notably, Exora, Saga, and Wira models recorded higher temperature readings, while X70 and Preve stayed closer to average values. The overall trend indicates balanced braking conditions with minimal variation during morning traffic.

4.2.3 Comparison of High and Normal Disc Brake Temperatures Across Car Models

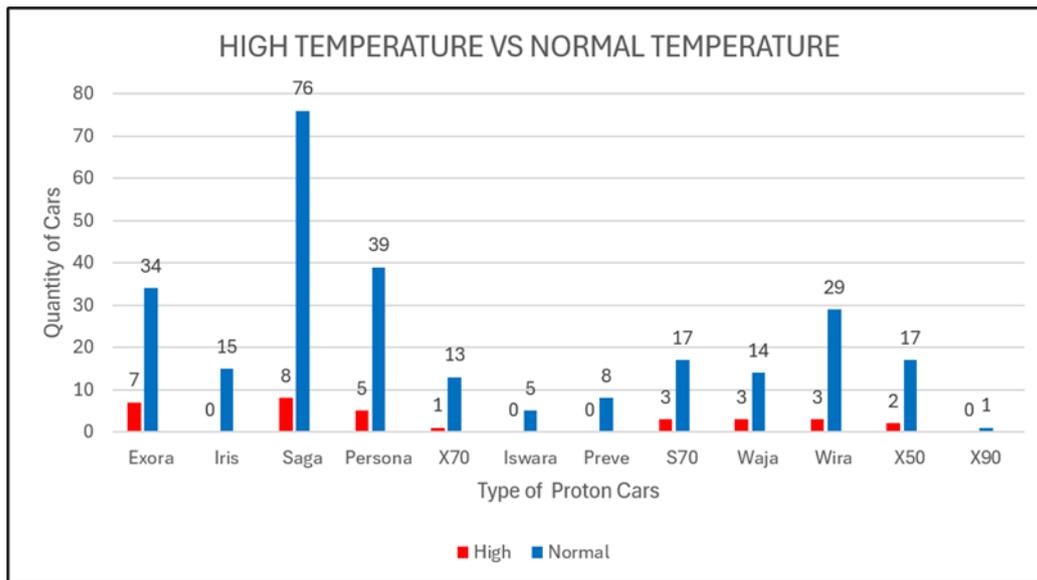


Fig. 7 Comparison of High and Normal Disc Brake Temperatures Across Proton Car Models

The bar chart as in Figure 7 presents the two categories which falls within camera range of setting, $-40\text{ }^{\circ}\text{C}$ to $150\text{ }^{\circ}\text{C}$ which classified as Normal and exceeding the limits as High, while offering insight into their thermal performance. Models like the Saga demonstrate strong thermal stability with 76 normal and only 8 high-temperature events, suggesting efficient brake system design, moderate vehicle weight, and steady driving behavior. Similarly, models such as Iris, Iswara, Preve, and X90 recorded zero or near-zero high-temperature occurrences, indicating effective thermal control likely due to superior braking materials, low-speed operation, or optimal cooling mechanisms.

Conversely, Exora, Persona, and Wira showed relatively more high-temperature cases (7, 5, and 3 respectively), though these remain low compared to their normal readings. For instance, Exora had 34 normal versus 7 high events, implying the system generally operates safely but may experience thermal stress under heavier loads or frequent braking. These findings highlight potential areas for improvement through engineering adjustments like ventilated rotors, better airflow design, and enhanced friction materials to reduce heat buildup.

Overall, the analysis confirms that most Proton models maintain disc brake temperatures within safe limits. However, monitoring occasional spikes in certain models is essential for long-term safety and performance. Applying real temperature measurements using an emissivity value of 0.35 ensures data accuracy and supports further enhancements. Future designs should consider integrating thermal monitoring and real-time alerts to help prevent brake fade, wear, or failure, aligning with modern automotive safety standards. The S70 and Exora consistently show the highest temperatures under $\epsilon = 0.35$, suggesting higher thermal loads due to aggressive braking or vehicle load. In comparison, the X70 and Iris show lower temperatures, indicating better thermal management and less risk of overheating. To enhance safety and performance, Proton could improve cooling systems or use advanced materials for models like the Exora and S70 to better heat.

5. Conclusion

Firstly, the operating temperatures of selected car disc brakes were effectively captured and recorded using infrared thermography under various real-world conditions at the PLUS Highway. The use of a high-resolution FLIR T640 camera, together with adjustments for key operating parameters such as ambient temperature, humidity, road surface temperature, reflected temperature, emissivity values (0.95 and 0.35), and object distance, ensured precise and representative thermal imaging of the brake discs. The systematic data collection across morning, afternoon, and evening sessions further allowed for capturing the thermal response under differing environmental and traffic conditions.

Secondly, the 300 thermal data samples were comprehensively analyzed using FLIR Tools software to evaluate temperature distribution and thermal behavior across various selected car models. The results demonstrated that most brake disc temperatures clustered around a mean of $\sim 110.9^{\circ}\text{C}$, with variations influenced by time of day, emissivity settings, and vehicle type. Evening conditions yielded the highest temperatures, likely due to increased braking demand. Notably, models such as the S70 and Exora exhibited higher thermal stress,

suggest design vulnerabilities under load. In contrast, models like X70 and Iris maintained lower and more consistent temperatures, indicating better thermal performance.

In conclusion, the project not only achieved accurate thermal measurement under varied operational parameters but also provided critical insights into the heat behavior of car disc brakes, supporting the need for model-specific engineering enhancements. These findings offer a valuable reference for improving disc brake safety, durability, and design in future passenger vehicles.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Natesh Kannan Maznan Ismon; **data collection:** Natesh Kannan; **analysis and interpretation of results:** Natesh Kannan; **draft manuscript preparation:** Natesh Kannan, Maznan Ismon. All authors reviewed the results and approved the final version of the manuscript

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