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Design and Experimental Evaluation of a Light Cut-off (Baffle) Plate for Aftermarket LED Motorcycle Headlamps

Dwi Prasetyo[1], Elky Fakhriza[1], Beni Setya Nugraha[1*]

[1]Department of Mechanical and Automotive Engineering, Faculty of Vocational, Universitas Negeri Yogyakarta, Kulon Progo, Yogyakarta 55652, Indonesia

*Corresponding author: beni_setyanugraha@uny.ac.id

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ABSTRACT

This study aims to determine the impact of replacing halogen lights with LED lights on two-wheeled vehicles, focusing on energy efficiency, light brightness levels, and operational temperatures of the lights to support road safety in areas with minimal road lighting, as well as on adjusting the light distribution of the applied LED lights. The method used was an experiment conducted on variables for which data were unavailable, necessitating manipulation of the research object. The experiment was conducted using a Honda Supra 125 FI motorcycle, with measurements of light intensity (lux), power consumption (watts), battery current (V), electric current (A), and operating temperature (°C). The known impact became a reference for regulating LED light distribution. The test shows that applying a barrier plate design to LED lights can provide focused lighting through its light distribution patterns. The application of the baffle plate design to LED lights provided focused lighting through its light distribution patterns. The use of LED lights provided a slightly higher intensity (6.4%) and an energy consumption efficiency 60% higher, with a reduction in operating temperature of 64%. The application results show that the light control plate successfully forms a bright-dark cut-off, with a uniform light distribution and consistent light intensity of 1854 lux. This indicates that the tested LED lamp maintains stable lighting performance without a decrease in brightness.

1. Introduction

Motorcycles are the most widely used means of transportation in Indonesia due to their efficiency in daily mobility. Based on data from the Indonesian Motorcycle Industry Association (AISI), national motorcycle sales reached more than 5 million units in 2023, far exceeding car sales of about 1 million units. In rural areas such as Gunungkidul Regency, Special Region of Yogyakarta, motorcycles are the primary mode of transportation for the community due to limited public transportation and varied road conditions. Data from the Gunungkidul Central Statistics Agency shows that more than 40% of households own at least one motorcycle, totaling 324,494 vehicles out of a population of 776,580. This high number makes motorcycles not only a means of transportation but also an important part of rural communities' social and economic activities.

In the context of driving safety, the lighting system plays a vital role because it serves not only as an illuminant but also as a medium of visual communication between road users. Previous studies have shown that light-emitting diode (LED) technology has been increasingly applied in various transportation lighting systems due to its potential to improve electrical efficiency compared to conventional lamps. Research on runway and airfield lighting systems indicates that LED lamps can reduce electrical power consumption while maintaining adequate illumination levels for safety applications [1], [2]. According to Rizki et al. [3], an optimal lighting system, including the use of stabilizer technology, can improve visibility and reduce light glare for other drivers, thereby increasing safety. This condition is critical in areas with minimal public street lighting, such as Gunungkidul, where drivers depend entirely on vehicle headlights for nighttime visibility. In areas with hilly topography and inadequate road access, such as Gunungkidul, a good lighting system is a necessity that cannot be ignored [4]. The limited availability of public street lighting facilities exacerbates the risk of accidents. The Jogja Daily Report states that the South Cross Road (JJLS) in Gunungkidul requires an additional 4,000 street lights to meet lighting needs. As a result, drivers must rely on motorcycle headlights with a limited light range. In such situations, a well-designed lighting system is crucial to reducing traffic accident rates.

Along with the development of automotive technology, vehicle lighting systems have also evolved, from incandescent, halogen, and HID lights to LEDs (Light Emitting Diodes). Halogen lights, which have been in use since the 1970s, are inefficient and have a short lifespan. In contrast, LED lights offer advantages in light intensity, energy efficiency, and lifespan. Previous studies have reported that the operational lifespan of LED lamps is influenced by their switching characteristics and operating conditions, indicating more stable long-term performance compared to conventional lighting technologies [5]. According to Vorlane (2023), LED lights can operate for 15,000-50,000 hours, far exceeding the 500-1,000 hours of halogen lights. However, using aftermarket LEDs is not always optimal due to differences in design and light beam direction, which can affect light distribution. Previous research has shown that the application of control systems in LED matrix headlamps can improve light beam direction and distribution, thereby enhancing visibility while reducing glare [6]. If the lighting is not focused, the driver's visibility will be reduced, potentially causing accidents. Data from Kompasiana shows that nighttime accidents account for up to 70% of all fatal accidents, with 80% involving dark-colored vehicles or insufficient lighting.

Thus, an effective and targeted lighting system is a key factor in supporting driver safety. The use of LED lights as a replacement for halogen lights is increasingly popular due to their ability to produce brighter light and save energy. However, additional designs, such as light diffusion plates, are needed to direct the spotlight in accordance with safety standards and to avoid disturbing other drivers. Several recent studies have evaluated the performance of different headlamp technologies, including halogen and LED lamps, under various operating conditions, emphasizing the importance of light distribution control and thermal considerations in practical applications [7]. Based on this background, the researchers sought to establish a solid foundation for identifying problems and formulating appropriate solutions to improve traffic safety. In motorcycle electrical systems, the stability of voltage and current supply affects the performance and reliability of lighting components. Studies have reported that improvements in charging systems and the use of stabilizer technologies can enhance electrical stability, thereby supporting more consistent lamp operation [8].

2. Methodology

2.1 Research Method.

This research method uses an experimental approach, which involves manipulating variables for which data do not yet exist by applying treatments to the research object, which is then observed and measured for its impact. According to Akbar & Saragi [9], the experimental method is important in research because it can show a direct cause-and-effect relationship through the manipulation and control of variables. In this study, a series of modifications were made to the main headlights of motorcycles. The main objective of this study was to analyze and understand the impact of these changes, particularly on the headlights (main lights). These changes were made by comparing the light distribution, energy consumption, and temperature of LED and halogen lights.

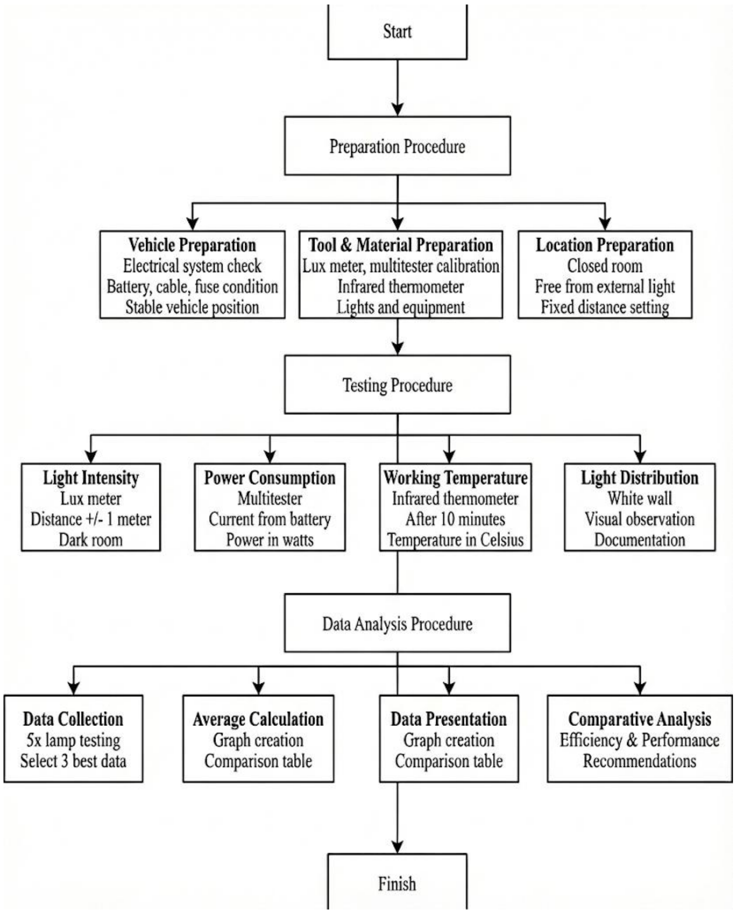


Figure 1. Research Procedure

2.2 Research Time and Place

The research was conducted at Mas Bagio's workshop, located at Keruk 4, Banjarejo Tanjungsari. The research was conducted from April to July 2025.

2.3 Research Subject

The subjects used in this study were Honda Supra 125 FI motorcycles, standard halogen lights, aftermarket LED lights, and LED lights with modified reflectors.

2.4 Technique, Data Collection Instruments, and Product Testing

Data collection techniques in this study were carried out by filling out measurement result tables according to the designed procedures. Data collection included measurements of light intensity (lux), power consumption (watts), lamp operating temperature (°C), and visual observations of light distribution. The data were then averaged to yield more objective and significant results.

Table 1. Data Collection

No	Type of Data	Instrument	Description
1	Light Distribution	White screen, Camera	To see the distribution pattern
2	Light Intensity	Digital Lux Meter	Distance 1 m, in a dark room
3	Power Consumption	Digital Multitester	Current from the motorcycle battery
4	Surface Temperature	Thermometer	15-minute measurement

2.5 Data Analysis Technique

Data analysis techniques in this study were carried out based on predetermined procedures. The data analyzed were the results of measurements of three main variables, namely light intensity (lux), power consumption (watts), and lamp operating temperature (°C). The processed data were then presented as comparisons between the types of lamps tested, namely standard halogen lamps and aftermarket LED lamps. Researchers were able to visually and systematically observe the performance patterns of each lamp type, resulting in an analysis that was more accurate, objective, and scientifically accountable.

3. Result and Discussion

3.1 Results

3.1.1 Light Distribution

The results show that LED lights have higher light intensity than halogen lights at the same distance. LED lights provide better illumination on the road, thereby improving driving visibility.

Table 2. Lux Meter Testing

No	Light Type	Distance	Lux
1	Halogen	1 Meter	1775 lux
2	LED	1 Meter	1854 lux

3.1.2 Power Consumption

Halogen lamps have very high power consumption, namely 101.16 watts and 145.2 watts. Meanwhile, LED lamps have much lower power consumption, namely 12 watts and 24 watts, indicating that LEDs are much more energy efficient than halogen lamps.

Table 3. Power Consumption Testing

Object	Volt	Amperes	Consumption
Halogen 1 lamp	12 V	8.43 A	101.16 W
Halogen 2 lamp		13.2 A	145.2 W
LED 1 lamp	12 V	1 A	12 W
LED 2 lamp		2 A	24 W

3.1.3 Temperature Results

Data were collected every 15 minutes up to the 75th minute, for a total of 6 observation points. Temperature measurements were taken with a digital thermometer, and power consumption was measured according to the lamp specifications. The LED lamp consumes 12 watts, demonstrating its efficiency and stability despite increased temperature.

Table 4. Temperature Testing

No	Time (Minutes)	Lamp Surface Temperature
1	0	0 °C
2	15	60 °C
3	30	83 °C
4	45	96 °C
5	60	100 °C
6	75	100 °C

3.1.4 Energy Efficiency Results

Overall, replacing halogen lamps with LED lamps shows a very high increase in energy efficiency. LED lamps can produce a slightly higher light intensity of 6.14% and consume about 60% less power than halogen lamps.

Table 5. Energy Efficiency Testing

Aspect	Halogen	LED	Efficiency (%)
Distribution	1775 lux	1884 lux	6.14
Energy Consumption	35 W	12 W	60

3.1.5 Adjusting the Height of the Light Beam on the Motor

Based on the LED light source being 1 meter above the road surface, and given a height of 7 meters due to space limitations, the concept of a straight line equation or a right triangle was used. The measurement results obtained a value of 0.825 meters from the road surface at a distance of 7 meters.

3.1.6 Light Barrier Design

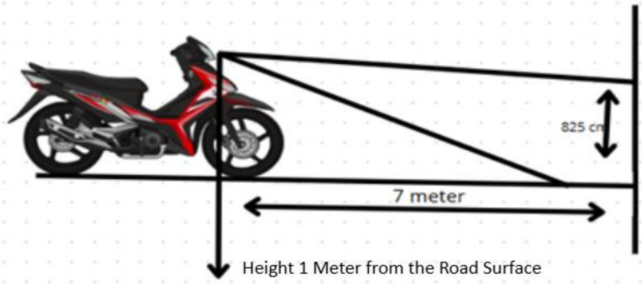


Figure 2. Adjusting the Height of the Spotlight

Adjusting the height of the spotlight, the application of LED lights requires an additional component in the form of a plate to regulate the lighting from the LED. The main objective is to create a clear lighting boundary so that the light is focused on the road surface and does not dazzle oncoming drivers. This plate is positioned so that it covers part of the LED surface and prevents light from spreading directly to the top of the reflector. Using this plate, only light directed downward toward the reflector is emitted, according to the lighting pattern. The following image shows the plate design for controlling the lighting.

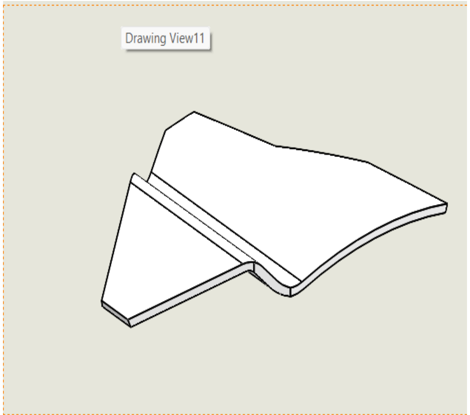


Figure 3. Light Limiting Plate Design

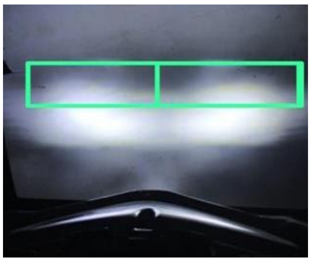
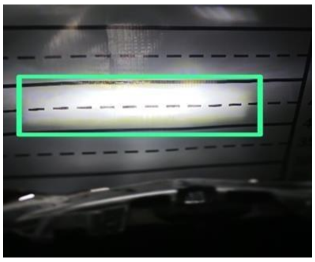
The light-limiting plate design consists of a large folded horizontally. The dimensions indicate that the plate is precisely designed to follow the shape inside the reflector housing.

a. Total height of the plate: ± 5.5 cm
b. Lower width: 2.5 cm – 2.5 cm (for the sloped side following the reflector's posture).
c. 1 cm horizontal fold: used as the mounting section to the reflector's inner bracket

3.1.7 Application of the Plate Design to the Reflector

The limiting plate is mounted on the reflector side near the light source to form the desired light-cutting or light-blocking surface.

Table 6. Light Pattern Produced

Light Distribution Pattern	
Before Limiting	After Limiting
	

After installing the light barrier plate, the light pattern becomes more focused and directed. The result shows a more even horizontal light distribution and a clearer cut-off line (light boundary line). The light no longer spreads freely upwards, thereby minimizing the potential for glare to drivers coming from the opposite direction.

3.2 Discussion

Test results for Halogen and LED lights were conducted to determine light intensity, power consumption, operating time without recharging, and operating temperature for each light. The objective was to determine the type of light that is safe to use, especially in electrical systems with limited power sources, such as a 12-volt 3-ampere battery.

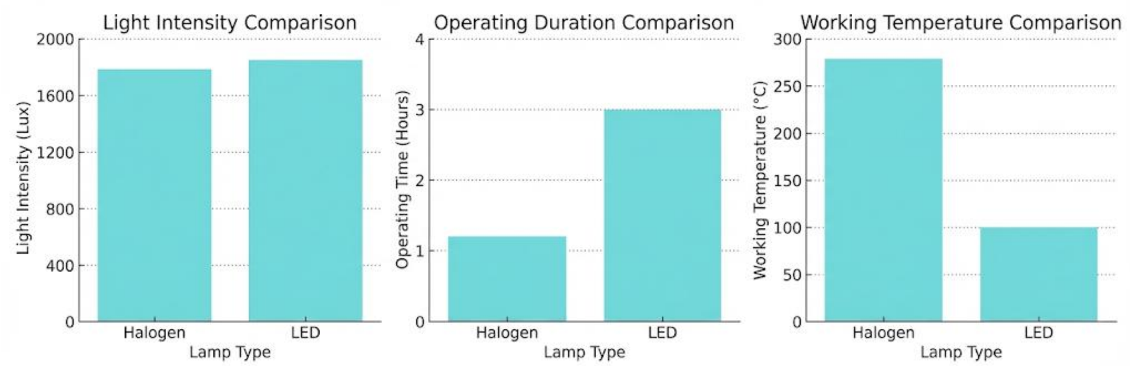


Figure 4. Test Graph

Test results show that halogen lamps have a light intensity of 1775 lux. Meanwhile, LEDs show an intensity of 1854 lux. Despite using less power, both LED lamps can produce higher illumination. This shows that LED lamps provide higher illumination than halogen lamps. LED lamps are more durable than halogen lamps. Halogen lamps last about 1.2 hours, while LEDs can last up to 3 hours without recharging. This shows that LEDs have 60% better energy efficiency, resulting in more efficient use of battery power. This supports the literature that LEDs are more energy-efficient and reduce heat load compared to halogens, which generate higher heat and consume more power [10]. Thus, LEDs are more advantageous in terms of operational duration and power savings.

Halogen lamps have a very high operating temperature of 278°C, while LEDs only reach 100°C. The high temperatures of halogen lamps can damage surrounding components, especially the built-in plastic reflector, which has a low melting point. On the other hand, LED lights are 64% safer because they generate less heat, thereby minimizing the risk of damage to the reflector. As discussed in the literature, LEDs face significant thermal challenges. However, with proper design and an appropriate cooling system, or by imposinghysical limits, temperatures can be controlled below hazardous levels [10].

4. Conclusion

The results of this study show that LED lights in motorcycle lighting systems provide better lighting performance and energy efficiency than halogen lights. The highest light intensity was measured with LED lights at 1854 lux, higher than halogen lights at 1775 lux, indicating that LED lights provide better visibility, especially in low-light conditions. In terms of power consumption, LED lights are highly energy-efficient, with 12 watts (one light) and 24 watts (two lights), which is much lower than halogen lights, which require 101.16 watts and 145.2 watts, respectively. Thus, LED lights have up to 60% higher energy efficiency and 6.4% greater light output than halogen lights. The application of a light diffusion limiter plate in the LED lighting system has been proven to produce a more focused lighting pattern with a clear cut-off, as well as a stable light distribution of 1854 lux without any decrease in intensity. Overall, it can be concluded that LED lights with a light-diffusion limiter plate design provide brighter lighting, higher energy efficiency, and lower operating temperatures, making them a safer, more efficient, and more energy-friendly choice than conventional halogen lighting systems.

Conflict of interest

The authors declare no conflict of interest.

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