

## Research Paper

## Study on Cooling System for Parked Cars using Mini Air Cooler and Exhaust Fan

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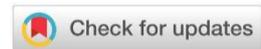
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### Abstract

Deaths among children and pets, as well as damage to car interior components, have been widely reported as a result of parking under direct sunlight for a long time. Rising car cabin temperatures in this condition trigger the formation of benzene gas, but it is not possible to turn on the AC due to security and energy consumption. Therefore, this article reports the experimental study on cabin cooling system for parked car under direct sunlight by applying a mini air cooler and exhaust fan powered by a solar cell on small car Bajaj Qute RE60. Two thermocouples were installed inside and outside the cabin to monitor the temperature for 7 hours, expressing daytime heat conditions. The results showed that this cooling system could reduce the temperature to 10 K by removing 8982 kJ (0.356 kW) of heat. In conclusion, this prototype is very promising to be developed and if implemented on a larger scale will reduce car interior damage while parking under direct sunlight.

**Keywords:** Parked car; Mini air cooler; Exhaust fan; Solar cell; Cabin temperature

### Abstrak

Kematian anak-anak dan hewan peliharaan, serta kerusakan pada komponen interior mobil, telah dilaporkan secara luas sebagai akibat dari parkir dibawah sinar matahari langsung untuk waktu yang lama. Naiknya suhu kabin mobil dalam kondisi ini memicu pembentukan gas benzena, tetapi tidak mungkin untuk menyalakan AC karena keamanan dan konsumsi energi. Oleh karena itu, artikel ini melaporkan studi eksperimental pada sistem pendingin kabin untuk mobil yang diparkir dibawah sinar matahari langsung dengan menerapkan pendingin udara mini dan kipas dengan daya dari sel surya pada mobil kecil Bajaj Qute RE60. Dua termokopel dipasang di dalam dan di luar kabin untuk memantau suhu selama 7 jam, yang menunjukkan kondisi panas siang hari. Hasil penelitian menunjukkan bahwa sistem pendingin ini dapat menurunkan suhu hingga 10 K dengan memindahkan energi panas 8982 kJ (0,356 kW). Sebagai kesimpulan, prototipe ini sangat menjanjikan untuk dikembangkan dan jika diimplementasikan dalam skala yang lebih besar akan mengurangi kerusakan interior mobil saat parkir di bawah sinar matahari langsung.

**Kata-kata kunci:** Mobil yang diparkir; Mini air cooler; Exhaust fan; Sel surya; Temperatur kabin

## 1. Introduction

Growth in the number of vehicles results in the lack of covered and shady parking areas. As a

result, car owners will inevitably park their vehicles in open parking lots, which is exposed to direct sunlight (some examples are shown in [Figure 1](#)). Parking in the open space for a long time



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**Figure 1.** Cars parked under direct sunlight: (a) captured in Kertajati international airport by gridoto.com; and (b) captured in Juanda international airport by detik.com

would increase the temperature inside the cabin. In summer, even in tropical countries throughout the year-round, the temperature inside the cabin when it parked under direct sunlight reach of 60 °C - 89 °C [1]-[5]. The high temperature would cause discomfort and lead to driving fatigue [6]. In addition, Allnutt and Allan [7] reported that rising temperatures in the vehicle also concerned passenger safety. Therefore, thermal comfort is one of the most important criteria for assessing vehicle performance, in driving and parking [8].

High temperatures may accelerate the damage or life of various components in vehicles, especially electronic devices [9], as well as the car interior compartment [10]. Children may also be endangered by the appearance of benzene gas from interior components that have been exposed to heat and evaporation. This gas can cause hyperthermia, anaemia, a reduction in the body's immune system, and even cancer [11]. Driely Costa and Andrew Grundstein have studied the analysis of children left in vehicles parked in Brazil. This study reports 21 children's deaths in the parked vehicle cab from 2006 to 2015 [12]. Similar cases have also occurred in the United States with 556 deaths between 1998 and 2012, with 33 cases occurring in 2011 and 29 cases occurring in 2012 [13].

Several previous studies have been conducted to reduce the temperature of vehicles parked in open spaces. MA Jasni and F.M Nasir [5] conducted research using the sunshade, ventilator and window tint method. The results concluded that the use of window tints was, in general, the best way to reduce interior temperatures in the cabin. Further research was also carried out by Basar [14] using a portable car cooling system powered by a 12V battery. It was concluded that the use of a portable car cooling system could reduce the average temperature of the cabin from

25 °C to 30 °C when parked under direct sunlight. The research used thermoelectric power to prevent the battery from running out of power. However, the voltage generated is too low and therefore unable to supply the batteries due to the drain voltage of the battery and needs another more powerful source of voltage. Lahimer [15] also experimented with the effect of solar reflective cover on cabin temperatures and fuel consumption.

In addition, Kolhe [16] also conducted research using a photo voltaic-powered ventilation system on the Toyota Prius PHV. This research was carried out by installing a photovoltaic power ventilation system on the roof of the vehicle. The system can operate two 10W and 12W fan motors, which can reduce temperatures, especially during the summer. Sudhir and Dhali [17] also carried out experiments on parked cars with independently designed and developed cabin ventilation systems powered by solar photovoltaic energy. This experimental investigation showed that the vehicle cabin temperatures were lower when the ventilation system was switched on. It also showed a reduction in the time needed to cool cabin temperatures to an acceptable level with a twofold effect, a reduction in fuel consumption and an increase in the level of thermal comfort in the car cabin. Setiyo [18] has also reported some research on passive air conditioning. Recently, a research team from Universitas Muhammadiyah Magelang has also reported the use of cooling fans for vehicles parked under the hot sun on Nissan Livina [19].

Comfort and safety in the cabin are strongly influenced by temperature and air humidity, demanding the existence of air conditioning (AC) systems. However, the AC system in the car requires a high power to drive the compressor [18]. Meanwhile, super small cars such as the 217

cc Bajaj Qute RE60 are not equipped with an AC system and cannot be loaded with an AC compressor. Therefore, the mini cooler and exhaust fan could be alternative equipment to reduce the temperature of the cabin in this vehicle.

## 2. Method

Experimental studies have been conducted in Magelang, Central Java Province, Indonesia (110°12'30" -110°12'52" Longitude and 7°26'28"-7°30'9" Latitude, link location: [click here](#)). Tests were carried out on a small car 217cc Bajaj Qute RE60. Model and specification of a small car used in this work are presented in [Figure 2](#) and [Table 1](#), respectively. Data collection was carried out when the vehicle was parked in open space under sunlight all day. The environmental conditions during the test are shown in [Table 2](#).



**Figure 2.** Photographic view of Bajaj Qute RE60

**Table 1.** Bajaj Qute RE60 specifications

Item	Specification
Engine	217 cc Petrol
Transmission	Constant Mesh
	5 Forward
	1 Reverse
Max Speed	70 kmph
Kerb Weight	399 kg
Seating Capacity	Driver + 3
Length	2752 mm
Width	1312 mm
Height	1652 mm
Wheel Base	1925 mm
Wheel Track	1143 mm
Ground Clearance	180 mm – unladen
Turning Circle Radius	3.5 m

**Table 2.** Environmental parameters

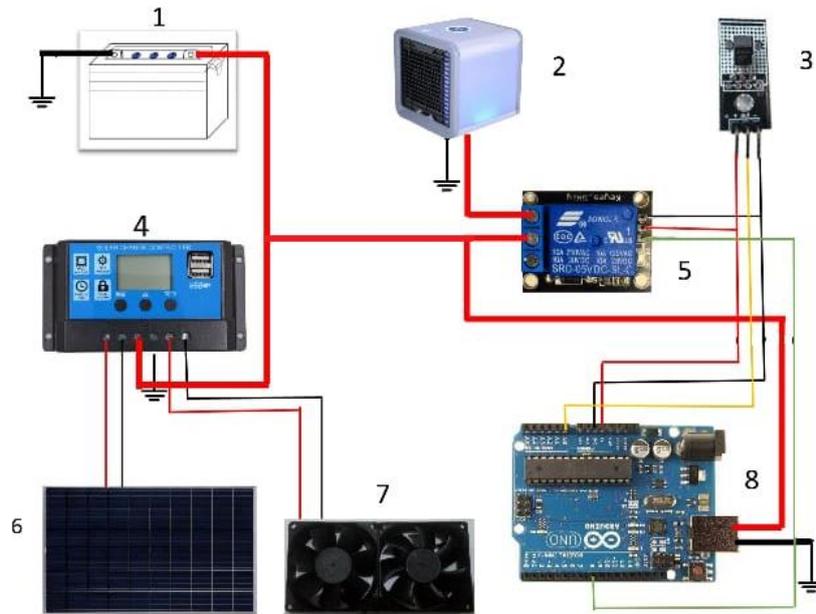
No	Environmental Parameters	Value
1.	Temperature	35 °C
2.	Relative Humidity	70%
3.	Wind velocity	≤5 m/s
4.	Solar radiation	≥800W/m <sup>2</sup>

The mini air cooler and exhaust fan are powered by the ST32M100W-FLP solar cell mounted on the car roof with the specifications shown in [Table 3](#). The resulting voltage and current are transmitted to the battery via the solar charge controller, which is then used to activate the mini air cooler and exhaust fan. Then, [Figure 3](#) shows the schematic of the cooling system in this study.

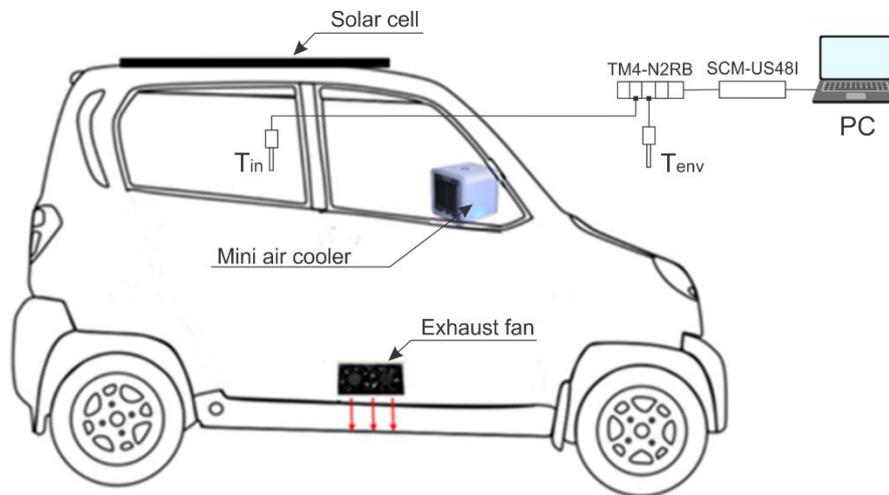
Data were collected by measuring the temperature inside and outside the Bajaj Qute RE60 cabin in 2 circumstances, i.e. with and without a mini air cooler and exhaust fan. One thermocouple was placed both in the centre of the cabin and outside the car to determine the air temperature inside and outside the cabin, as shown in [Figure 4](#). All thermocouples were connected to a multi-channel temperature controller (TM4-N2RB) sent to the DAQ Master from Autonics through a serial communication converter (SCM-US48I) module. In the set-up of this study, a mini air cooler was installed in the cabin to cool the cabin space. It works by circulating air to penetrate the pores of wet foam. In addition, an exhaust fan was also installed on the floorboard to circulate the air in the cabin to the environment.

**Table 3.** Solar cell specifications (ST32M100W-FLP)

Item	Specification
Dimension	1065x540x3/20 mm
Max power	100 watt
Power tolerance	5%
Max voltage	16.1 V
Max current	6.21 A
Open circuit voltage	19.16 V
Short circuit current	6.77 A
Max system voltage	600 v DC
Normal operating temp.	45 °C
Range temp.	-40 °C- 85 °C
Weight	1.8 Kg
Max fuse rating	10 A



**Figure 3.** Cooling system circuit scheme (1. Battery, 2. Mini air cooler, 3. Temperature sensor, 4. Solar charge controller, 5. Relay, 6. Solar cell, 7. Exhaust fan, and 8. Micro-controller)



**Figure 4.** Experimental set up

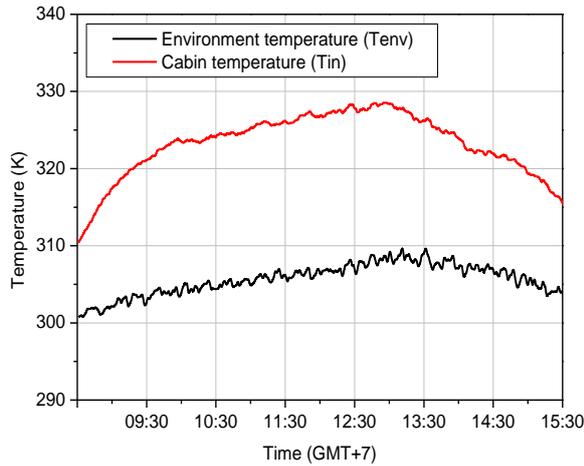
### 3. Result and Discussion

**Table 4** shows the measurement results of the airflow mass that passes through the mini air cooler and discharges the exhaust ventilator into the environment. The dimensions of the cabin space of the Bajaj Qute RE60 are estimated to be in the form of a block with 1300 mm wide, 1450 mm length, and 950 mm height, and volume by 1.79 m<sup>3</sup>.

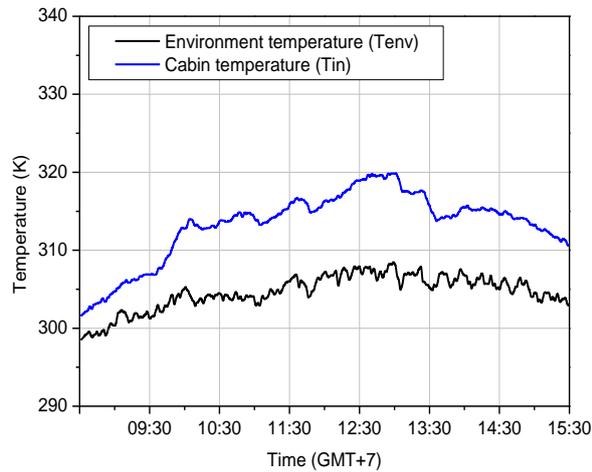
Measurement data for the temperature of the air inside the cabin ( $T_{in}$ ) and in the environment ( $T_{env}$ ) are shown in **Figure 5** and **Figure 6**. The red line shows the temperature trend in the cabin and the black line shows the environmental temperature trend during the test from 08.30 to 15.30 GMT+7 which represents the sun's blazing conditions during the day, with a total testing time of 7 hours.

**Table 4.** Air mass flow rate passes through the mini air cooler and exhaust fan

No.	Component	Area	Air velocity	Debit	Air mass flow
1.	Exhaust fan	0.01125 m <sup>2</sup>	4 m/s	0.045 m <sup>3</sup> /s	0.0558 kg/s
2.	Mini air cooler	0.0110 m <sup>2</sup>	2 m/s	0.022 m <sup>3</sup> /s	0.02728 kg/s

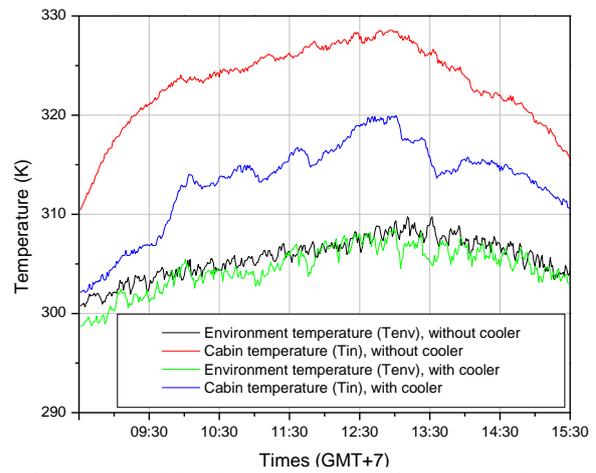


**Figure 5.** Profiles of the temperature inside the cabin and in the environment without a mini air cooler and exhaust fan



**Figure 6.** Profiles of the temperature inside the cabin and in the environment with a mini air cooler and exhaust fan

**Figure 5** shows that as long as the sun shines the cabin, the temperature of the air in the cabin has been observed to rise sharply compared to the environmental temperature. The air inside the cabin accumulates heat energy from the walls and roof of the cabin, which means that the addition of energy is far greater than the energy coming out of the cabin. The exhaust fan is not activated in this condition. The temperature increase peaked at 12.26 West Indonesia Time at 328.35 K, while the ambient temperature was 308.28 K ( $\Delta T = 20.07$  K). Meanwhile, with the implementation of a mini air cooler and exhaust fan (**Figure 6**), the peak temperature dropped to 319.05 K at an ambient temperature of 308.05 K ( $\Delta T = 11$  K). For further details, the temperature inside the cabin with and without a mini air cooler and exhaust fan is shown in **Figure 7**.



**Figure 7.** Profile of temperature difference inside the cabin with and without a mini air cooler and exhaust fan

The exhaust fan pulls out hot air from inside the cabin and discharges it into the environment, replaced by environmental air that enters through the slit of the car window and other small holes. With an air density assumed to be  $1.24 \text{ kg/m}^3$  and an air flow circulated by an exhaust fan of  $0.045 \text{ m}^3/\text{s}$ , a mass flow of  $0.0558 \text{ kg/s}$  was entered into the cabin. Mini air cooler also helps reduce the temperature of the air inside the cabin through partial circulation. The airflow in the air cooler evaporates the water that sticks to the foam in the air cooler box. Assuming an air density of  $1.24 \text{ kg/m}^3$  and a mini air cooler of  $0.022 \text{ m}^3/\text{s}$  circulated, a mass flow of  $0.02728 \text{ kg/s}$  circulated in the cabin. A mass flow of  $0.08308 \text{ kg/s}$  will therefore affect the temperature drop in the cabin. The amount of heat dissipated may be estimated by the Equation (1).

$$Q = m \cdot C_p \cdot \Delta T \tag{1}$$

As the air mass in the cabin changes with temperature fluctuations, the ideal gas equation was used to obtain the magnitude of the air mass, which is calculated by the Equation (2) to Equation (4).

$$P V = m R T \tag{2}$$

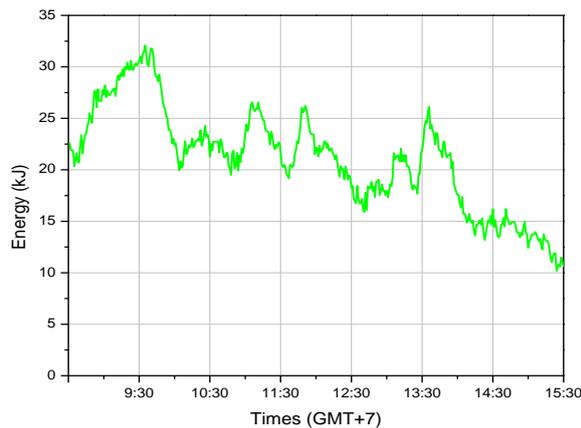
$$R = \frac{\bar{R}}{M} \tag{3}$$

$$m = \frac{P V M}{R T} \tag{4}$$

Where,  $Q$  = the amount of heat released (kJ);  $m$  = air mass in the cabin ( $\text{m}^3$ );  $C_p$  = air specific heat (kJ/kg K, for air at 303 K is  $1,006 \text{ kJ/kg K}$ );  $T$  =

Temperature (K);  $\bar{R}$  = Universal gas constant (8.314 kJ/kmol K);  $R$  = Gas constant (kJ/kmol K); and  $M$  = Molecular weight (kg/kmol, for air is 28.97 kg/kmol).

In addition, **Figure 8** shows the trend of energy release from the cabin during the cooling process. The performance of this cooling system was determined by comparing the total energy accumulated in the cabin, without and with the mini cooler used during data collection. To find out this power, the area on the energy curve in **Figure 9** was calculated using Origin version 6.0, obtaining 8982 units of area, as shown in **Figure 10**. This 8989 area represents 8982 kJ all the time from 8.30 to 15.30 (7 hours) and therefore the cooling power was 0.356 kW.

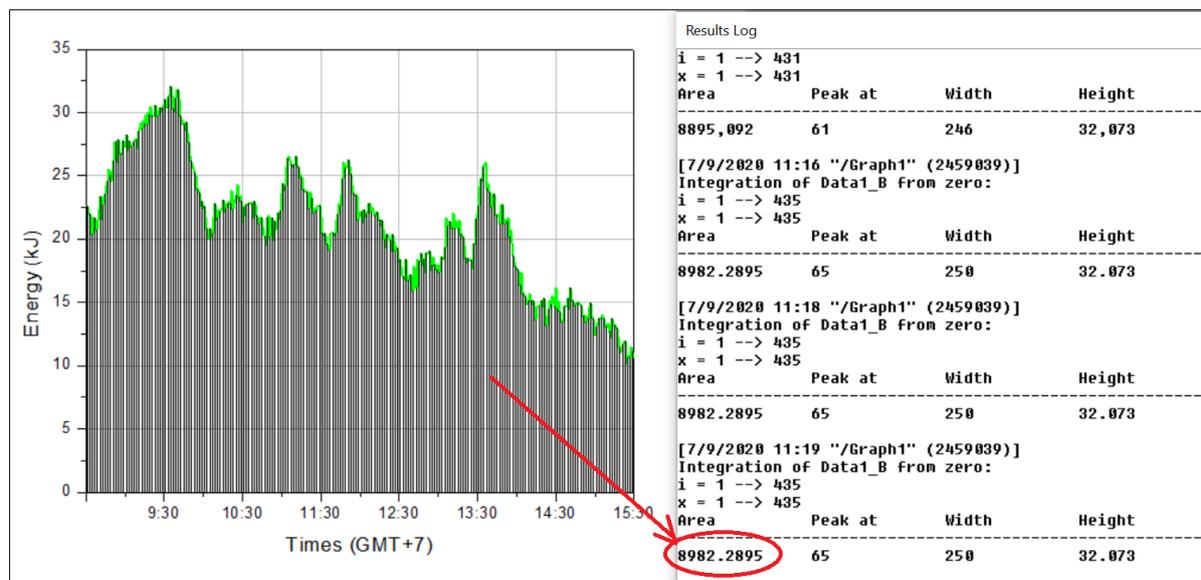


**Figure 8.** Energy savings with the use of a mini air cooler and exhaust fan

In other studies, cabin temperature decreases were reported due to the addition of cooling equipment, but they did not report overall COP [4], [6], [20]. In this study, we found a cooling effect of 0.356 kW from two devices, namely a mini air cooler and exhaust fan that discharged hot air from the cabin into the environment. With a maximum power of 100 Watt solar cell, the COP of this cooling system is 3.56. This shows the performance of the cabin cooling system when parking in an open area with a mini cooler and exhaust fan driven by solar cells is very promising to apply.

#### 4. Conclusion

In this study, the installation of a mini air cooler and exhaust fan had a positive effect on the cooling process in the Bajaj Qute RE60 cabin by reducing the temperature to 10 K. The heat that could be discharged for 7 hours of testing was 8982 kJ, with an average power of 0.356 kW. Although the temperature of the air inside the cabin can not match the temperature of the environment, this temperature reduction allows reducing the risk of damage to the interior of the car. In conclusion, this prototype is very promising to be developed and applied on a larger scale to reduce car interior damage when parking under direct sunlight.



**Figure 9.** Profile of cooling effect area from the cabin with Origin version 6.0

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## Author's Declaration

### Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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### Availability of data and materials

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### Competing interests

The authors declare no competing interest.

### Additional information

No additional information from the authors.

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