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THE VARIATION OF TEMPERATURE IN PARKED CAR'S CABIN IN THE SUMMER

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Abstract

This study aimed to investigate the inside temperature variation of two cars with different colours (black vs. white) in the conditions: doors fully closed vs. doors partially opened; sunny parking area vs. shaded parking area. Several temperature devices - Maxim Integrated DS1921 Hygrochron iButton were used to measure continuously and simultaneously both outdoor and indoor temperatures of the black and white cars. The results of this study showed that the temperature of a black car's cabin was higher than that of white car's cabin because the black colour absorbs sunlight more than the white colour. The results reported that the increase in temperature of the car's cabin under the condition of closed doors and un-shaded parking area was higher than that in other conditions. After 30 min (from 3:10 PM to 3:40 PM) of exposing to sunlight, the highest temperature of the black car's cabin was 40.5 °C, meanwhile that of the white car's cabin was 37.5 °C. Therefore, during the time of stationary, the automobile should be parked in shaded parking area in the summer.

Keywords: cabin; parked car; temperature; shaded parking; black colour; white colour.

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1. Introduction

Nowadays, a car (or automobile) is a wheeled motor vehicle that is popularly used for transportation. During the day time of motion or stationary, the car is often exposed to the sun. When a car is in motion, the temperature inside the car will be decreased by the cooling systems or air conditioning. However, after certain hours of parking outside in open air or un-shaded parking area are conducted, the temperature in the car cabin increases [1]. Under parking conditions, the temperature in the car cabin goes up rapidly [2]. The increase of temperature inside the vehicle would result in the interior parts to be degraded because the heat can cause damage to materials inside the cabin. On the other hand, this heat can even create the toxic chemicals from materials upholstery evaporating [1]. This degradation can reduce the life span of the various constituents inside the car. Besides, the driver and passengers are also impacted by the thermal condition inside the car. So the car often is cooled down the interior condition either by rolling down the window or running the air condition around 2-5 min before using [2].

In recent years, the number of private vehicles in Hanoi and Ho Chi Minh City has been growing rapidly. It's one of the most convenient means of transportation in those two cities. The high density of private vehicle (such as cars) results in a lack of parking space at government offices, universities,

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shopping areas, etc. Therefore, many people are unable to park their cars in shaded area and have to park them in open parking spaces. Parking a car in an unshaded area leads to greenhouse problem, in which the solar radiation enters through the windows of a car, traps inside the car cabin and causes temperature increase of cabin components [3]. Therefore, the use of cardboard or coloured glass to decrease the temperatures inside cars is becoming popular. The interior temperature of the cabin plays an important role in providing the comfort to the passengers. When the car's engine is in operation, the temperature can be adjusted by using the air conditioning system. Nevertheless, when the car is left or parked directly in the sunlight, the temperature inside the car cabin will increase significantly. A sealed car has a commonly high interior temperature, and this temperature creates a tremendously uncomfortable feeling for the passenger and driver.

The increase in cabin temperature can jeopardize property and harm children or pets left in the car. Saidur et al. [4] studied the performance of an improved solar car ventilator. They found that many children die of (hyperthermia) heatstroke every year after being left unattended in vehicles. Similarly, Dadourr et al. [5] investigated the serious threat to lives of children or pets left in stationary vehicles on a hot summers day. Their study showed that when a vehicle was parked in the sun, the temperature levels in the cabin was more than 20 °C above the ambient temperature. However, they did not study the effect of car's colour to the increase in cabin temperature. Besides, in other studies, children or pets left in a parked vehicle for around 30 minutes may experience heat stress, and a number of deaths are reported in the US each year as a result [6]. King et al. [7] have studied the heat stress in automobiles to prevent the death of infants in the vehicle cabin in summer. They found that infants left in a high temperature environment (around 60 °C) will lose fluid quickly from sweat and can become as much as 8% dehydrated in four hours. Roberts and Roberts [8] have worked to reduce the heat stress in automobile cabins. This study also showed that the thermal burden of poorly ventilated parked cars can be significant, particularly when the cars are exposed to direct sunlight. Surpure et al. [9] evaluated the heat burden in parked cars. They reported that the heat burden of poorly ventilated, parked automobiles exposed to direct sunlight can be huge. Leaving infants, toddlers, elderly people, and pets in these vehicles under these disadvantage conditions can jeopardize them tremendous heat stress.

From abovementioned analyses, this study was conducted to quantify the indoor temperatures of two cars under different conditions in order to provide recommendations for proper car parking during the hot and high solar radiation in the monsoon climate regions like Hanoi, Vietnam.

2. Materials and method

Two cars (white and black cars) were parked at the campus of Hanoi University of Civil Engineering and had no interference from local shadows during the entire measurements. They were located in the same place and orientation to gain stability during experiments. The test vehicles were oriented to face south to ensure maximum sun load on the front windscreen. The white vehicle chosen in this study was a 1500 cc, Mazda car, 2015 while the black car chosen in this study was a 2000 cc, Honda Civic car, 2008. In the car cabin, the temperature was measured at four places: the front seat, above of the front seat, behind the seat, and above of the behind seat. The temperatures were measured by the Maxim Integrated DS1921 Hygrochron iButton.

The measurement was recorded on a clear sky summer day during the time from 1:20 PM till 4:45 PM. The variation of temperature was investigated in a parked car's cabin under the conditions: closed door and shaded parking area was checked (1:20 PM to 1:50 PM); opened door 5% and shaded parking area (from 2.20 PM to 2.50 PM); closed door and un-shaded parking area (from 3:10 PM to

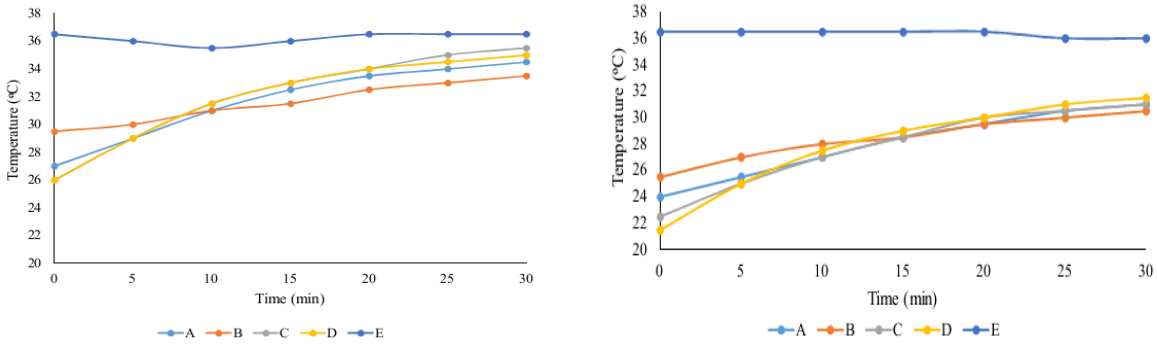
4:00 PM); opened door 5% and un-shaded parking area (from 4:15 PM to 4:45 PM). Before measuring the temperature in car's cabin in each condition, the vehicle's air conditioning system was switched on to reduce the air temperature in the vehicle to approximately 25 °C.

Figure 1. Maxim Integrated DS1921 Hygrochron iButton and data loading devices

3. Results and discussion

3.1. The variation of temperature in a parked car's cabin under the conditions: closed door and shaded parking area

Fig. 2 and Table 1 show the temperature variation inside the cabin in four cases: front seat, above of front seat, behind seat, and above of behind seat. It is noted that the temperature of these measuring points increased significantly while the ambient temperature was 36.5 °C during the observed time. During 30 min (from 1:20 PM to 1:50 PM) of exposure under the conditions: closed door and shaded parking area, the temperature of the black car's cabin increased to 35.5 °C, while that of the white car's cabin rose to 31.5 °C. Fig. 2 and Table 1 also report that the temperature of the black car's cabin



(a) Black car (b) White car

A- the variation of inside temperature at front seat; B- the variation of inside temperature at above of front seat; C- the variation of inside temperature at behind seat; D- the variation of inside temperature at and above of behind seat

Figure 2. The variation of ambient temperature and inside temperature of car's cabin during 30 min (from 1:20 PM to 1:50 PM)

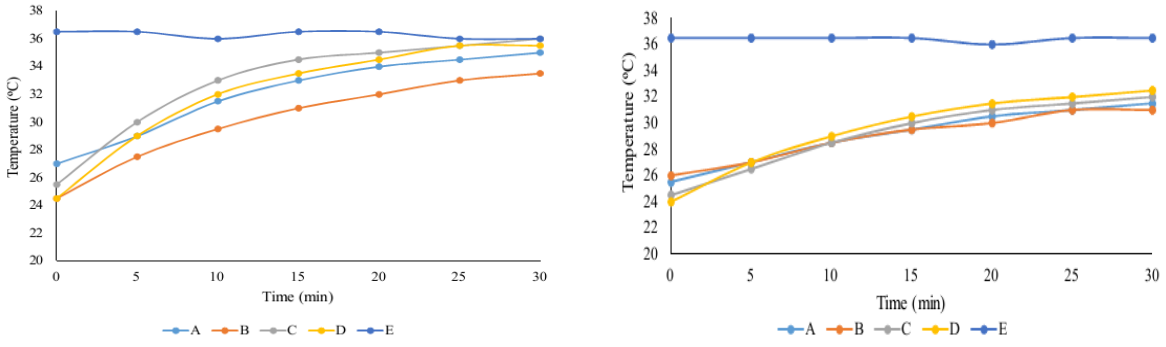
was higher than that of the white car's cabin because black colour absorbs sunlight more than white colour. In other study, Dadour et al. [5] used two Ford sedan vehicles with different colors (black vs. white), exposed to the same environmental conditions (they were parallel parked). According to their findings, the black vehicle's cabin had a much greater temperature during daylight hours than the white vehicle. Due to the relative higher absorptivity of the black surface, more solar radiation is absorbed in the metal skin of the black vehicle than the white vehicle.

Table 1. The variation of ambient temperature and inside temperature of car's cabin from 1:20 PM to 1:50 PM under the case of closed door and shaded parking area

Time (PM)	Inside temperature of black car (°C)				Inside temperature of white car (°C)				Outside temperature (°C)
	A	B	C	D	A	B	C	D	
1:20	27	29.5	26	26	24	25.5	22.5	21.5	36.5
1:25	29	30	29	29	25.5	27	25	25	36.5
1:30	31	31	31.5	31.5	27	28	27	27.5	36.5
1:35	32.5	31.5	33	33	28.5	28.5	28.5	29	36.5
1:40	33.5	32.5	34	34	29.5	29.5	30	30	36.5
1:45	34	33	35	34.5	30.5	30	30.5	31	36
1:50	34.5	33.5	35.5	35	31	30.5	31	31.5	36

3.2. The variation of temperature in parked car's cabin under the conditions: opened door 5% and shaded parking area

Fig. 3 and Table 2 report the temperature variation of four cases: front seat, above of front seat, behind seat, and above of behind seat under the conditions: opened door 5% and shaded parking area. The temperature of these measuring points rose significantly while the ambient temperature was approximately 36.5 °C. After 30 min (from 2:20 PM to 2:50 PM) of exposure under these conditions,



(a) Black car (b) White car

A- the variation of inside temperature at front seat; B- the variation of inside temperature at above of front seat; C- the variation of inside temperature at behind seat; D- the variation of inside temperature at and above of behind seat

Figure 3. The variation of ambient temperature and inside temperature of car's cabin during 30 min (from 2:20 PM to 2:50 PM)

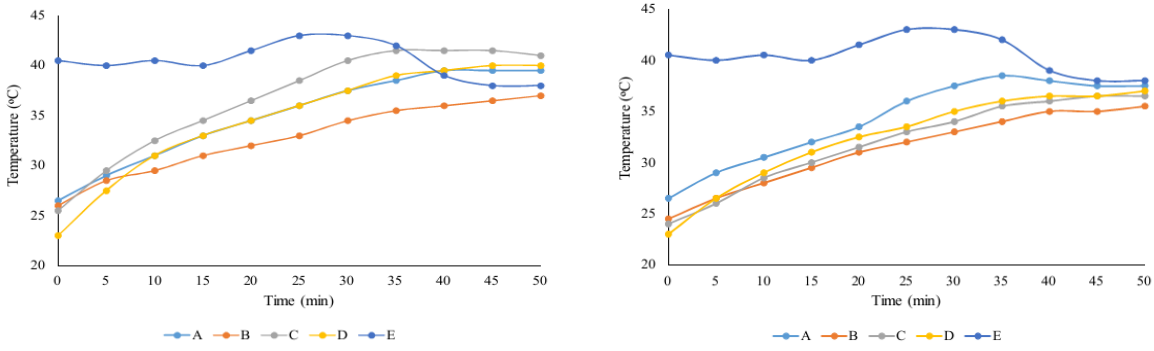
the inside temperature of the black car's cabin increased to 35.5 °C, while that of the white car's cabin rose to 32.5 °C. As can be seen in Fig. 3 and Table 2, the inside temperature of the black car's cabin was also higher than that of the white car's cabin. The results show that the increase in inside temperature of the car's cabin under the condition of opened door 5% and a shaded parking area was nearly the same as that of the condition of a closed door and shaded parking area.

Table 2. The variation of ambient temperature and inside temperature of car's cabin from 2:20 PM to 2:50 PM under the case of opened door 5% and shaded parking area

Time (PM)	Inside temperature of black car (°C)				Inside temperature of white car (°C)				Outside temperature (°C)
	A	B	C	D	A	B	C	D	
2:20	27	24.5	25.5	24.5	25.5	26	24.5	24	36.5
2:25	29	27.5	30	29	27	27	26.5	27	36.5
2:30	31.5	29.5	33	32	28.5	28.5	28.5	29	36.5
2:35	33	31	34.5	33.5	29.5	29.5	30	30.5	36.5
2:40	34	32	35	34.5	30.5	30	31	31.5	36
2:45	34.5	33	35.5	35.5	31	31	31.5	32	36.5
2:50	35	33.5	36	35.5	31.5	31	32	32.5	36.5

3.3. The variation of temperature in parked car's cabin under the conditions: closed door and un-shaded parking area

Fig 4 and Table 3 demonstrated the temperature variation of four cases: front seat, above of front seat, behind seat, and above of behind seat under the conditions: closed door and un-shaded parking area. It is also observed that the temperature of these measuring points increased significantly meanwhile the ambient temperature increased to 43 °C at 3:40 PM and then decreased to 38 °C at 4:00 PM. During 30 min (from 3:10 PM to 3:40 PM) in exposure to sunlight, the temperature of the black car's



(a) Black car (b) White car

A- the variation of inside temperature at front seat; B- the variation of inside temperature at above of front seat; C- the variation of inside temperature at behind seat; D- the variation of inside temperature at and above of behind seat

Figure 4. The variation of ambient temperature and inside temperature of car's cabin during 50 min (from 3:10 PM to 4:00 PM)

cabin was 40.5 °C, while that of the white car's cabin was 37.5 °C. After that 10 min, the temperature of the black car's cabin went up to 41.5 °C, while that of the white car's cabin increased to 38 °C. The results report that the increase in temperature of the car's cabin under the conditions of closed door and un-shaded parking areas was higher than that of closed doors, opened doors 5% and shaded parking areas.

Table 3. The variation of ambient temperature and inside temperature of car's cabin from 3:10 PM to 4:00 PM under the case of closed door and un-shaded parking area

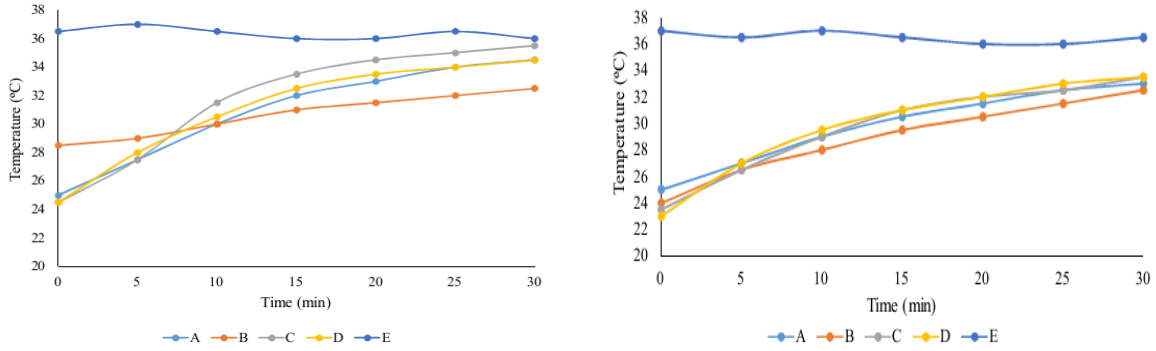
Time (PM)	Inside temperature of black car (°C)				Inside temperature of white car (°C)				Outside temperature (°C)
	A	B	C	D	A	B	C	D	
3:10	26.5	26	25.5	23	26.5	24.5	24	23	40.5
3:15	29	28.5	29.5	27.5	29	26.5	26	26.5	40
3:20	31	29.5	32.5	31	30.5	28	28.5	29	40.5
3:25	33	31	34.5	33	32	29.5	30	31	40
3:30	34.5	32	36.5	34.5	33.5	31	31.5	32.5	41.5
3:35	36	33	38.5	36	36	32	33	33.5	43
3:40	37.5	34.5	40.5	37.5	37.5	33	34	35	43
3:45	38.5	35.5	41.5	39	38.5	34	35.5	36	42
3:50	39.5	36	41.5	39.5	38	35	36	36.5	39
3:55	39.5	36.5	41.5	40	37.5	35	36.5	36.5	38
4:00	39.5	37	41	40	37.5	35.5	36.5	37	38

Sunawar and Garniwa [1] recorded the difference between the temperature inside a parked car and the outside temperature from 8:00 AM to 4:00 PM. They also positioned a temperature sensor outside the driver's door and placed the first sensor near the steering wheel. It can be seen that the average temperature rise starts right away when the car starts in the parking lot, and it continues to rise until it slowly stabilized and started to fall, but the final drop temperature is still significantly higher than the temperature starting in the morning. Their results showed that the maximum average temperature obtained in the cabin reaches 48 °C at 11 AM. The temperature varies depending on the weather and cloud covering the sun. Musthaq and Jamshid [10] recorded the outdoor and indoor temperature of Perodoa Kancil 800 cc Malaysia car from 4th September to 8th September on interval one hour from morning 9 AM to 4 PM. All doors and windows were closed, and there was direct sunlight shining through the windscreen and on the back windows from all directions. Their findings suggest that the outdoor temperature rose gradually, reaching its peak at two o'clock (39.8 °C). Additionally, the indoor temperature is higher than the external temperature and progressively rises throughout the day. At 2 PM, when the outside temperature was 39.8 °C, the peak average temperature of 54.2 °C was recorded.

3.4. The variation of temperature in parked car's cabin under the conditions: opened door 5% and un-shaded parking area

Fig. 5 and Table 4 show the temperature variation of four cases: front seat, above of front seat, behind seat, and above of behind seat under the conditions: opened door 5% and shaded parking area. The temperature of these measuring points rose significantly while the ambient temperature

was approximately 36.5 °C. After 30 min (from 4:15 PM to 4:45 PM) under these conditions, the temperature of the black car's cabin increased to 35.5 °C while that of the white car's cabin rose to 33.5 °C. As can be seen in Fig. 4 and Table 4, the temperature of the black car's cabin was also higher than that of white car's cabin. The results report that the increase in temperature of the car's cabin under the condition of opened door 5% and un-shaded parking area was lower than that of closed door and un-shaded parking area.



(a) Black car (b) White car

A- the variation of inside temperature at front seat; B- the variation of inside temperature at above of front seat;
C- the variation of inside temperature at behind seat; D- the variation of inside temperature at and above of behind seat

Figure 5. The variation of ambient temperature and inside temperature of car's cabin during 30 min (from 4:15 PM to 4:45 PM)

Table 4. The variation of ambient temperature and inside temperature of car's cabin from 4:15 PM to 4:45 PM under the case of opened door 5% and un-shaded parking area

Time (PM)	Inside temperature of black car (°C)				Inside temperature of white car (°C)				Outside temperature (°C)
	A	B	C	D	A	B	C	D	
4:15	25	28.5	24.5	24.5	25	24	23.5	23	37
4:20	27.5	29	27.5	28	27	26.5	26.5	27	36.5
4:25	30	30	31.5	30.5	29	28	29	29.5	37
4:30	32	31	33.5	32.5	30.5	29.5	31	31	36.5
4:35	33	31.5	34.5	33.5	31.5	30.5	32	32	36
4:40	34	32	35	34	32.5	31.5	32.5	33	36
4:45	34.5	32.5	35.5	34.5	33	32.5	33.5	33.5	36.5

4. Conclusions

This study investigated the inside temperature distribution pattern of two black and white cars parked in different conditions: 1) parking places: sunny vs. shaded; 2) door status: fully closed vs. 5% door opened. The temperature of parked car's cabin will increase gradually when exposed to sunlight and rise slightly in a shaded parking area. The results of this study show that the inside temperatures

of the black car were significantly higher than those of the white car. The max inside temperature of the black car's cabin was 40.5 °C, while that of the while car's cabin was 37.5 °C. These findings strongly suggest that cars should be parked in the shading areas with 5% door opened.

References

[1] Sunawar, A., Garniwa, I. (2017). Maximum potential of the car cabin temperature in the outdoor parking conditions as a source of energy in thermoelectric generator. *IOP Conference Series: Materials Science and Engineering*, 180:012104.

[2] Al-Kayiem, H. H., Sidik, M. F. B. M., Munusammy, Y. R. A. L. (2010). Study on the thermal accumulation and distribution inside a parked car cabin. *American Journal of Applied Sciences*, 7(6):784–789.

[3] Aljubury, I. M. A., Farhan, A. A., Mussa, M. A. et al. (2015). Experimental study of interior temperature distribution inside parked automobile cabin. *Journal of Engineering*, 21(3):1–10.

[4] Saidur, R., Sattar, M. A., Masjuki, H. H. (2009). Perfromance of an improved solar car ventilator. In *International conference on sustainable development: Issues and prospects for the GMS*, Kuala Lumpur, Malaysia, 1–6.

[5] Dadour, I. R., Almanjahie, I., Fowkes, N. D., Keady, G., Vijayan, K. (2011). Temperature variations in a parked vehicle. *Forensic Science International*, 207(1-3):205–211.

[6] Guard, A., Gallagher, S. S. (2005). Heat related deaths to young children in parked cars: an analysis of 171 fatalities in the United States, 1995-2002. *Injury Prevention*, 11(1):33–37.

[7] King, K., Negus, K., Vance, J. C. (1981). Heat stress in motor vehicles: A problem in infancy. *Pediatrics*, 68(4):579–582.

[8] Roberts, K. B., Roberts, E. C. (1976). The automobile and heat stress. *Pediatrics*, 58(1):101–104.

[9] Surpure, J. S. (1982). Heat-related illness and the automobile. *Annals of Emergency Medicine*, 11(5): 263–265.

[10] Ahmad, M., Turi, J. A. (2018). Study of air temperature propagation of parked car. *International Journal of Scientific & Engineering Research*, 9(3):1503–1513.