Experimental Study of Interior Temperature Distribution Inside Parked Automobile Cabin

Issam Mohammed Ali Aljubury
Instructor
Mech. Eng. Dept.
Eng. Coll. - Baghdad Univ.
juburyima@gmail.com

Ammar Ali Farhan
Instructor
Mech. Eng. Dept.
Eng. Coll. - Baghdad Univ.
ammarali@uobaghdad.edu.iq

Munther Abdullah Mussa
Instructor
Mech. Eng. Dept.
Eng. Coll. - Baghdad Univ.
munthermech@yahoo.com

ABSTRACT

Temperature inside the vehicle cabin is very important to provide comfortable conditions to the car passengers. Temperature inside the cabin will be increased, when the car is left or parked directly under the sunlight. Experimental studies were performed in Baghdad, Iraq (33.3 ^{o}N, 44.4 ^{o}E) to investigate the effects of solar radiation on car cabin components (dashboard, steering wheel, seat, and inside air). The test vehicle was oriented to face south to ensure maximum (thermal) sun load on the front windscreen. Six different parking conditions were investigated. A suggested car cover was examined experimentally. The measurements were recorded for clear sky summer days started at 8 A.M. till 5 P.M. Results show that interior air temperature in unshaded parked car reaches 70^{o}C and dashboard temperature can approach 100 ^{o}C. While, cardboard car shade inside the car not reduce the air temperature inside it. Suggested car cover with 1 cm part-down side windows reduced temperature of cabin components by 70 % in average compare to the base case.

Key words: automobile cabin, temperature distribution, thermal comfort, greenhouse problem.

دراسة عملية لتوزيع درجات الحرارة داخل مقصورة سيارة متوقفة

عصام محمد علي الجبوري
مدرس
قسم الهندسة الميكانيكية
كلية الهندسة – جامعة بغداد

عمار علي فرحان
مدرس
قسم الهندسة الميكانيكية
كلية الهندسة – جامعة بغداد

منذر عبد الله موسى
مدرس
قسم الهندسة الميكانيكية
كلية الهندسة – جامعة بغداد

الخلاصة

تعتبر درجة الحرارة داخل مقصورة السيارة ضرورية لتوفير ظروف مريحة للركاب داخلها. تزداد درجة الحرارة داخل السيارة عندما تُترك متوقفة مباشرة تحت أشعة الشمس. أجريت دراسة تجريبية في مدينة بغداد، العراق (خط طول 44 وخط عرض 33) لمعرف تأثير الإشعاع الشمسي الساقط على مكونات السيارة الداخلية (لوحة القيادة، المقود، المقعد، الهواء الداخلي). وضعت سيارة الإختبار مواجهة لجهة الجنوب لضمان أقصى قدر من الإشعاع الشمسي الساقط على الزجاج الأمامي للسيارة وكذلك للحصول على أكبر حمل حراري داخل المقصورة.أختبرت ستة حالات مختلفة للسيارة المتوقفة. سُجلت القياسات لأيام الصيف والسماء صافية من الساعة 8 صباحاً وحتى الخامسة بعد الظهر. بينت النتائج أن درجة حرارة الهواء الداخلي في السيارة المتوقفة غير المظللة يصل 70 درجة مئوية وإقتربت درجة حرارة لوحة القيادة من 100 درجة مئوية . أما عند وضع واقية شمسية المصنعة من ورق الالمنيوم من داخل السيارة فإنها لم تقلل من درجة حرارة الهواء داخل المقصورة . وعند إستعمال غطاء السيارة

المقترح مع فتح الزجاج الجانبي 1 سم، فإنه ساهم في خفض درجة حرارة مكونات المقصورة بنسبة 70٪ مقارنة إلى الحالة الأساسية (سيارة مجردة وبدون أي غطاء).

الكلمات الرئيسية: مقصورة السيارة، توزيع درجات الحرارة، الراحة الحرارية، مشكلة الاحتباس الحراري.

1. INTRODUCTION

Recently, after 2003, the private passenger vehicles number in Iraq has been growing significantly. It's the most convenient means of transportation in the country. The high density of private passenger vehicles leads to lack of parking space. This is much clearer at the government offices, universities, and shopping areas. Moreover, the available shaded parking areas do not match the existing numbers of vehicles; hence the alternative choice for those who are unable to park under shaded area is to park in an open parking space.

Parking in an unshaded area gave rise of greenhouse problem. It is the problem of conversion of solar radiation entering through the windows of a car into long wave thermal radiation and trapped inside car cabin causes temperature increase of cabin components. Thereby, use of cardboard car shades to reduce the interior temperatures inside parked automobile has become popular in Baghdad and other hot regions in Iraq.

Temperature inside the vehicle cabin is very important to provide comfortness to the car passenger. The temperature can be controlled by using air conditioning system that can be operated when the car engine is in operation. However, when the car is left or parked directly under the sunlight, temperature inside the cabin will be increased. Sealed automobiles commonly encounter interior temperature conditions that are tremendously uncomfortable to the passengers.

The cabin temperature of unshaded parked car can quickly rise to a level that may damage property and harm children or pets left in the car. According to the findings of **Saidur, et al., 2008** in USA, every year many children die of (hyperthermia) heatstroke after being left unattended in vehicles. Hyperthermia is an acute condition that occurs when the body absorbs more heat than it can handle. Annually, hundreds of children experience varying degrees of heat illness from being left in cars. Similar experimental studies carried out in Australia show that rising air temperature +20 ^{o}C inside a parked car compared to the outside temperature on a hot summer day for periods of the order 30 minutes, children or pets left in such a parked car suffer heat stress and a number of deaths ,**Dadour, et al., 2011**.

Many car users are faced a hot interior after a certain hours of parking in open space or unshaded parking area. The heat under such parking conditions causes the car cabin and interior temperature to reach up to 80 ^{o}C average. The accumulation of thermal energy inside the vehicle with undesired temperature rise would cause the interior parts to degrade because they normally are subjected to wear and tear. Degradation may shorten the life span of the various components inside the car, especially electronic devices. Passengers are also being affected with the thermal condition inside the vehicle itself. The car user is forced to wait for a period of time around 2 – 5 minutes before getting into car to let the interior condition cool down either by rolling the window or running the air conditioner system (A/C) at high speed that really affect the fuel consumption ,**Al-Keyiem, et al.,2010**. The increased of fuel consumption by the A/C system subsequently increased CO_2 emissions , **Jasni** and **Nasir, 2012**.

,Abd-Fadeel and **Hassanein, 2013,** showed that the opening window about 1 – 3 cm during one hour, from 12 P.M. to 1 P.M. reduced the temperature inside the car because the flow rate of fresh air entering the car insufficient and its velocity inside the car approximately neglected. Whereas, the inside car sunshade reduces the temperature at front dashboard by about 40 – 60 ^{o}C compared with closed car. **Al-Kayiem, et al., 2010,** showed that, the effect of sunshades application to the interior windshield on the temperature was significant during six hours of parking time from 9 A.M. to 4 P.M. The maximum dashboard temperature of the parked vehicle with sunshade was found to be 25 ^{o}C lower than the other vehicle without any shades.

The objective of this research is to determine the most technically feasible passive method in reducing the car interior temperature. Six cases were experimentally studied: unshaded, partial shaded (inside and outside), total shaded (shelter and novel cap), and windows part-down by 1 cm. The obtained improvements from suggesting method were increasing in passenger comfort and less thermal stress on car interior components. Also, lower initial automobile air conditioner loads and reduction in fuel consumption and CO_2 emissions.

2. EXPERIMENTAL SETUP (MATERIALS AND METHODS)

2.1 Experimental Procedure: The car was parked in an open parking space and care was taken such that there was no interference from local shadows during the measurements. It was located in the same place and same orientation during the entire experimental measurements so as to obtain consistency during experiments, as in **Fig. 1** Experimental were performed in Baghdad, Iraq (33.3 ^{o}N, 44.4 ^{o}E). The test vehicle was oriented to face south to ensure maximum sun load on the front windscreen. The vehicle chosen in this study was 2000 cc, Daewoo car, 1997. There were no modifications done on the chosen car, and all the factory settings were retained all throughout the experiments.

2.2 Experimental Methodology: Six different parking conditions were investigated consisting of closed and opened glass windows, inside and outside front shield shading and normal parking conditions. The cases are described in **Table 1**. The temperature variation at four places inside the car cabin is measured. Four places are front dashboard, front seats, steering wheel, and inside air. The temperatures were measured by thermocouple wire type K in junction with 12 channel data logger. Only 10 channels were used for the cabin interior surfaces (2 measuring points for dashboard, front sets and 1 for steering wheel), cabin air (4 measuring points) and ambient (1 measuring point) temperatures. The measurements were recorded for clear sky summer days started at 8 A.M. till 5 P.M. and the data was recorded on 30 min. step interval. Hourly solar radiation was measured during the day with a Kipp and Zonen pyranometer model CMP22 having a measuring range of up to 4000 W m^{-2} (error < 5 W m^{-2}).

The suggested cover is consisted from many cardboard car shades which were sew with each other to make cap. A cap is covered the roof and windows of car only as shown in **Fig. 2.** Car windows and roof had the main effect on the car cabin temperature so that it is covered. The cardboard has 5 mm thickness with a silver foil front and back which is available in the markets. More benefits can be achieved from this suggested cover as compared with classical car cover made from leather or cloth. These benefits are: 1. Less in weight and small in size. 2. Cheap and easy to installation 3. Reflect solar radiation. 4. Thermal insulation.

3. RESULTS AND DISCUSSION

All methods of exploitation of solar energy required the knowledge of the average values of the intensity of solar radiation incident on the structure. The intensity of solar radiation on the car cabin in summer was measured with a Kipp and Zonen pyranometer model CMP22. The amount of irradiative heating in Baghdad from 5 A.M. to 7 P.M. in June is shown in **Fig. 3** It could be seen that irradiation increases with time to maximum values between 11 A.M. to 3 P.M. The maximum irradiance reading was 954 W/m^2 approximately at 1 P.M.

Fig. 4 presents the temperature variation of base case for front dashboard, steering wheel, seat, inside air, and ambient. The temperature of measuring points rises in the morning more rapidly than does the ambient. It is also observed that the temperature of these measuring points cools in the afternoon more rapidly than does the ambient. Solar radiation absorptance by the cabin components and greenhouse effects behind the rapidly increase of cabin temperature in the morning. At noon, these measuring reach its maximum temperature due to the maximum value of solar radiation occurs at this time. Dashboard has the maximum temperature between the cabin's components due to the largest projected area of glass is facing to the sun's rays. The maximum temperature of dashboard, inside air, seat, and ambient recorded in June were 99 ^oC, 70 ^oC, 68 ^oC and 44 ^oC, respectively. The experimental results of ,**Abd-Fadeel,** and **Hassanein, 2013.** for the dashboard temperature inside unshaded parked car are compared with the present study was shown in **Fig. 5** The behavior of the two curves is in good agreement but, the average percentage error about 20 % was occurred due to the different measured values of solar radiation.

Since experimental tests for the six cases done during different days, and in order to make comparison between these cases, the reductions in maximum temperature of measuring points (dashboard, steering wheel, seat, and inside air) minus ambient temperature are used. The reductions in maximum temperature of measuring points minus ambient temperature are presented in **Table 2.** and **Fig. 6** The maximum temperature difference is recorded at the dashboard ($T_D - T_a$), which can reach a maximum value of 58^{o}C at noon. At this location, it can be seen that shading application (case # 5 and # 6 in **Table 1.**) are the most effective methods in reducing the dashboard temperature difference from base case by much as 39.2 ^oC and 54.4 ^oC, respectively as shown in **Fig. 7** and **Table 2**. Also there is a reducing in the temperature at the steering wheel by as much as 51^{o}C and 44.2^{o}C. This could be due to the blockage of a large amount of sun radiation entering the car cabin by the cardboard sun shades. On the other hand, the seat temperature change in case #5 experiment have a significant difference from the base case and it reduces by as much as 17.9 ^oC.

The effect of shading and part-down the two side windows by 1 cm on hot days in June was shown in **Fig.8.** It is observed that inside shade (case # 2) had no effect on the inside air temperature due to the greenhouse effect occurs inside car cabin. On other hand, outside shading (case # 4) reduced the inside air temperature by 40 % from the base case. The combination of outside shading and windows part-down by 1 cm (case # 5 and # 6) were observed to be reducing the inside air temperature from the base case by 58 % and 91 % respectively . In short, it can observed from table 2 that the outside shades with part-down by 1 cm the two side windows (case # 5 and # 6) had important effect in reducing the interior temperature. Because they have decreased the interior temperature by 27.2 ^oC and 17.2 ^oC from the base case, respectively.

4. CONCLUSIONS

The following conclusions were recorded from the experimental study:

1- Use the cardboard car shade from outside with part-down windows by 1 cm has achieved an overall good performance in reducing the average maximum temperature at all interior locations of the test car, with higher difference of reduction at dashboard, steering wheel, seat and inside air ambient locations

2- Interior air temperature in unshaded parked car in a hot climate such as Baghdad, reach 70 ^oC and dashboard temperature can approach 100^oC.

3- Use the cardboard car shade behind the car windshield reduced dashboard temperature by 40 % from the base case. While, it does not reduced the air temperature inside parked car.

4- Shelter with part-down side windows by 1 cm made car cabin temperature approximately equal to ambient temperature plus 3^oC in maximum.

5- The obtained results of case #5 enabled to confirm that the suggested car cover designed with part-down side windows is able to keep comfortable conditions in the car cabin. The average temperature values of cabin components (dashboard, steering wheel, seat, and inside air) were reduced by 70 % from the base case.

REFERENCES

- Abd-Fadeel, Waleed. A., and Hassanein, Soubhi. Ali., 2013, *Temperature Variations in a Parked Car Exposed to Direct Sun During Hot and Dry Climates*, International journal of automobile engineering research and development (IJAuERD), vol. 3, Issue I, 75-80.

- Al-Kayiem, Hussain. H., Sidik, M. Firdaus Bin M. and Munusammy, Yuganthira. 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.

- Dadour, I., Almanjahie, I., Fowkes, N., Grant Keady, and Vijayan, K., 2011, *Temperature Variations in a Parked Car*, Forensic science international, vol. I, no. 207, pp. 205-211.

- Jasni, M. A., and Nasir, F. M., 2012, *Experimental Comparison Study of the Passive Methods in Reducing Car Cabin Interior Temperature*, International conference of mechanical automobile and robotics engineering (ICMAR), Penang, Malaysia.

- Saidur, R., Sattar, M. A., and Masjuki, H. H., 2008, *Performance of an Improved Solar Car Ventilator*, International conference on sustainable development: Issues and prospects for the GMS, Kuala Lumpur, Malaysia, pp. 1-6.

NOMENCLATURE

T_a = ambient temperature, ^oC.

T_D = dashboard temperature, ^oC.

T_i = inside air temperature, ^oC.

T_{se} = seat temperature, ^oC.

T_{st} = steering wheel temperature, ^oC.

Table 1. Description of the experimental measurements cases.

Test case	Description
1	Unshaded car and all windows are closed (base case) without any temperature-reducing methods applied.
2	Shaded is placed under the front windshield and all windows are closed
3	Shaded is placed above the front windshield and all windows are closed
4	Shaded is placed above the front windshield and two side windows are part-down by 1 cm
5	Shaded is placed above all windows and two side windows are part-down by 1 cm (novel cap)
6	Shaded is placed above all windshield and all windows are part-down by 1 cm

Table 2. Reduction in maximum temperature of different locations.

Experiment	Reduction in maximum temperature of measuring points minus ambient temperature (°C)			
	Dashboard	Steering wheel	Seat	Inside air
	$T_D - T_a$	$T_{st} - T_a$	$T_{se} - T_a$	$T_i - T_a$
Case # 1	58.0	53.7	27.4	29.9
Case # 2	34.2	28.3	23.4	30.0
Case # 3	19.1	22.1	21.3	24.7
Case # 4	15.8	17.6	16.4	18.1
Case # 5	10.8	9.5	9.5	12.7
Case # 6	3.6	2.7	1.6	2.7

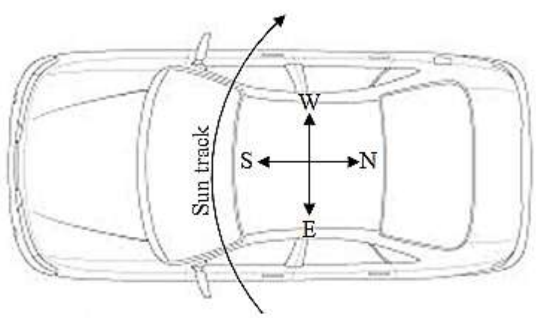

Figure 1. The car orientation during the measurements.

Figure 2. Suggested car cover.

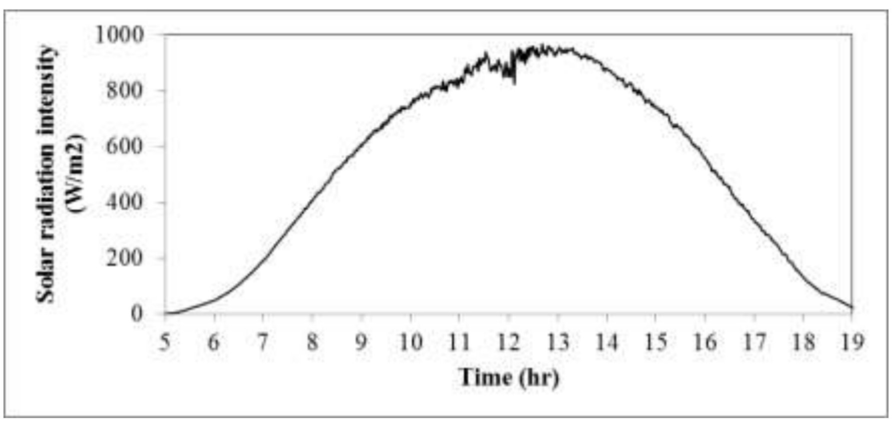

Figure 3. Measured values of solar radiation on the horizontal surface on, 11-6-2014 for clear sky.

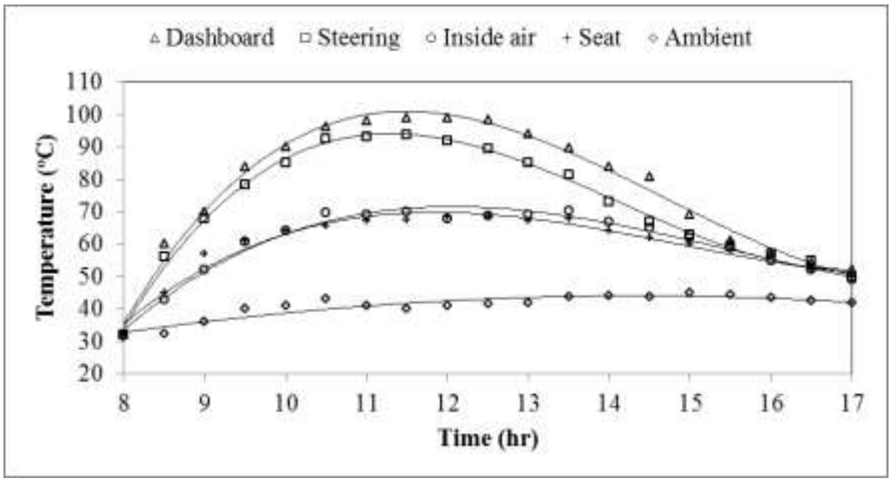

Figure 4. Temperature variations in an unshaded parked car in June.

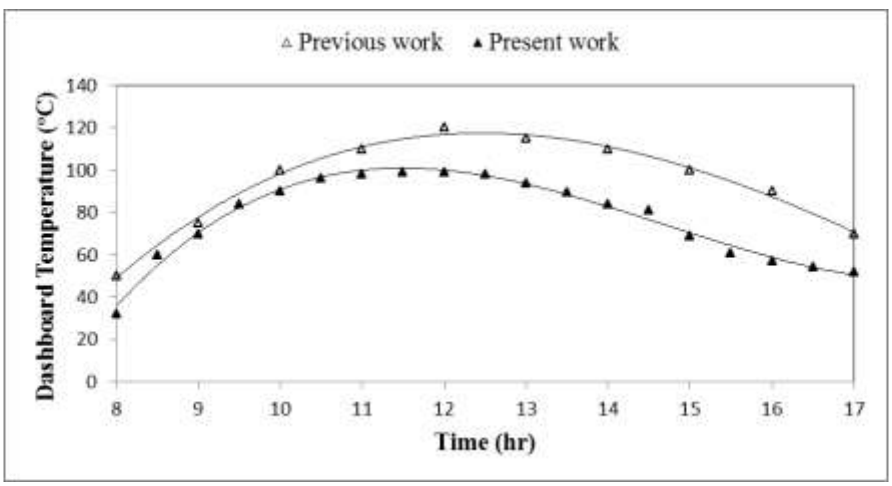

Figure 5. Comparison between present measured dashboard temperature with results measured by ,**Abd-Fadeel,** and **Hassanein, 2013**.

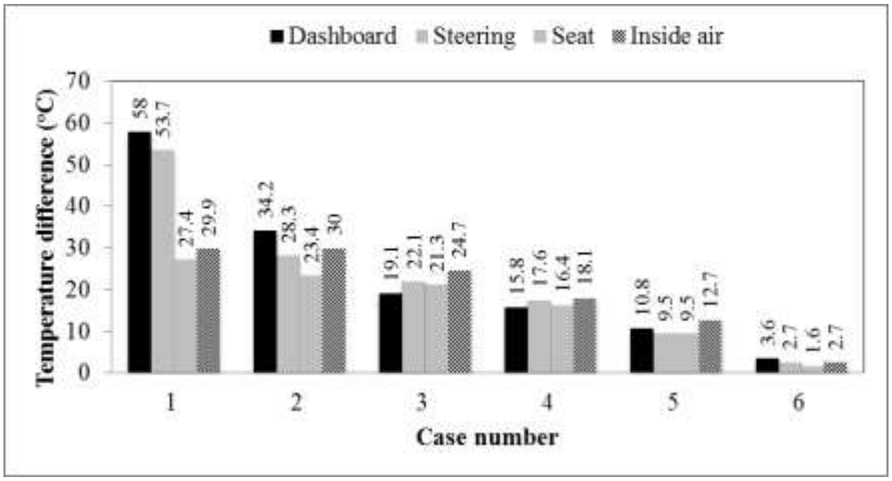

Figure 6. Reduction in maximum temperature of different locations.

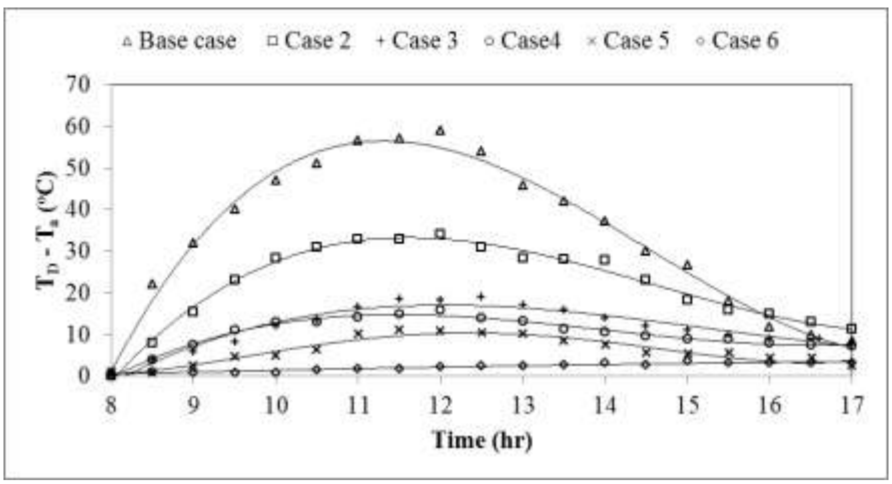

Figure 7. Comparison between temperatures differences for different cases in June.

Formatted: Space After: 0 pt

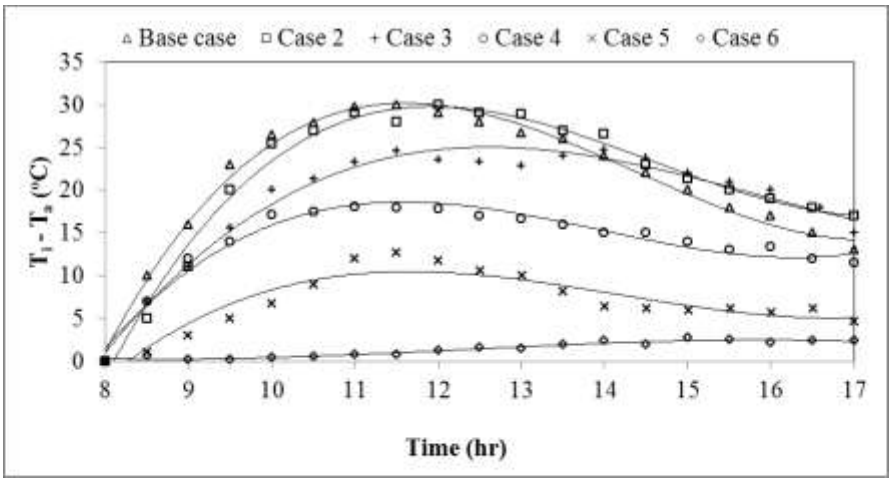

Figure 8. Comparison between temperatures differences for different cases in June.