STUDY OF CABIN TEMPERATURE OF THE CAR PARKED UNDER VARIOUS CONDITION

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This report is submitted
in fulfilment of the requirement for the degree of
Bachelor of Mechanical Engineering (Thermal Fluid)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MAY 2017

DECLARATION

I declare that this project report entitled “Study of Cabin Temperature of The Car Parked Under Various Condition” is the result of my own work expect as cited in the reference.

Signature :……...

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Date :……

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal Fluid).

Signature	:……..
Name of Supervisor	: Dr Suhaimi Bin Misha
Date	:……...

DEDICATION

For my beloved mum and my caring dad.

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my supervisor Dr. Suhaimi Bin Misha for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Secondly, I would like to thank to my housemates who always help me in order to finish this report. Also, I would like to thank laboratory assistant for the kindness in suggesting me the suitable time to use laboratory equipment for his action saved me a lot of time.

I would like to thank my course mates for giving me their support, patience and encouragement. Finally, I would like to thank my family for their support especially to my beloved father and my caring mother.

ABSTRACT

A car parked under direct sunlight for several hours can causes the temperature inside the car cabin increase and heat soak. This due to the closed design of the car cabin and the component made by heat conductor will rapid increasing the temperature. The hot temperature inside the car cabin makes the driver and passenger feel uncomfortable and affecting the degradation interior component besides the heat harmful to human and animals. This project is done to find suitable method to overcome these problem. All car parked under direct sunlight. The conditions are choose for this study; first experiment without use any additional material (Case 1), second experiment using sun shade and close all the windows (Case 2), third experiment using sun shade and open all windows approximately 2 cm (Case 3) and fourth experiment using sun shade, open front window approximately 2 cm and use fan powered by solar (Case4). The main idea of this study is to find suitable method to reduce the heat in shorter time. Temperature different data for each method collected using thermocouples and data logger, then the effective method chosen based on the time to reduce the temperature in car cabin. . For analysis by point, results shows that Case 4 have highest average temperature difference for all point with value of 8.99 °C followed by Case3 and Case 2. For analysis by time, results shows Case 4 can achieve the lowest percentage temperature difference with outside temperature during the experiment carried out for 180 minutes with value of -2.77% followed by Case3 and Case 2

ABSTRAK

Kereta yang diletakkan di bawah cahaya matahari selama beberapa jam akan menyebabkan suhu didalam kereta tersebut akan panas dan menyebabkan haba terkumpul. Ruang dalam kereta yang tertutup serta kompenan dalam kereta yang menjadi conduktor haba akan meningkatkan suhu dalaman kereta dengan cepat. Perkara ini akan menyebabkan penumpang dan pemandu kereta tersebut akan tidak merasa selesa dan boleh memendekkan jangka hayat komponen dalamam serta berbahaya kepada haiwan dan manusia. Penggunaan penghawa dingin mampu untuk mengurangkan haba panas tersebut, namun akan menyebabkan pembaziran bahan bakar jika diguna pada tahap maksimum. Tujuan projek ini adalah untuk mencari cara yang paling sesuai untuk mengurangkan suhu panas didalam kenderaan. Kesemua kereta diletakkan mengadap matahari Empat cara kajian telah dipilih; kereta yang tanpa menggunakan sebarang alat menyejukkanya (Kes 1), kereta yang memasang visor pemantul cahaya dan semua tingkap tertutup (Kes 2), kereta yang memasang visor pemantul cahaya dan tingkap terbuka sebanyak 2 sm (Kes 3) dan kereta yang memasang visor pemantul cahaya dan membuka tingkap hadapan sebanyak 2 sm serta memasang kipas yang dijanakan melalui solar (Kes 4). Idea utama adalah untuk mencari cara paling sesuai untuk merendahkan haba dalam kereta dalam jangka masa yang pendek. Pada akhir projek ini, data perbezaan dan perubahan suhu untuk setiap cara kajian akan dikaji menggunakan peralatan Data logger dan Thermocouple, serta cara paling sesuai akan dipilih berdasarkan masa yang paling singkat untuk mengurangkan haba yang terkumpul. Untuk analisis oleh titik, keputusan menunjukkan bahawa kes 4 mempunyai nilai perbezaan tertinggi. Perbezaan suhu purata untuk semua titik dengan nilai 8.99 °C diikuti oleh Kes 3 dan Kes 2. Untuk analisis oleh masa, keputusan menunjukkan Kes 4 boleh mencapai perbezaan suhu peratusan yang paling rendah dengan suhu di luar semasa eksperimen dijalankan selama 180 minit dengan nilai -2.77% diikuti oleh Kes 3 dan Kes 2.

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VLT	Visible Light Transmission
UVB	Ultra Violet B
UVA	Ultra Violet A
SDLC	System Development Life Cycle
PMV	Predictive Mean Vote
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers

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CHAPTER 1

INTRODUCTION

1.1 Background

Vehicle is important nowadays and it became a necessity for human being to have for many purpose. In the dictionary, vehicle has been translated as a machine, usually with wheels and an engine, used for transporting people or goods on land, especially on roads. Vehicle production has undergone various changes in technology and has achieved a good level from the past to the present. Even though vehicle has always upgrade and update its technologies, there is certain problem happens especially related to car.

One of the problem is the temperature in car cabin. This problem usually will effected to the users who have car in a country with a hot climate for example in Malaysia. This is because when the car is park to direct sunlight in couple hours, the temperature in the cabin car will become hot and will effect human thermal comfort. It happen because solar radiation can penetrate through transparent glass of the car, it because the heat cannot moving out, as the result the heat trapped inside the cabin car.

Thermal comfort is condition when mind express satisfaction with the thermal environment. This term is subjective and can be defined by several of sensational based on factors manipulating the thermal condition experience by the occupant, so the specific definition is difficult to give for this concept. The heat exchange between human body and the ambient environment is become measuring factor for thermal comfort. Human being are different, even in same condition, the thermal sensation can be describe in many way. So it is mean the environmental condition for everyone to feel comfort are not same. (Simion et. al., 2016)

The thermal comfort for occupant become more important because they spent more time inside the car due to increasing their daily mobility. Thermal comfort of occupant in car cabin still get the higher concern because it relate to the safety and health. Day by days, consumers constantly demand for their vehicle, the better understanding about thermal comfort must same with their desire for comfortable journey.

1.2 Problem Statement

Car is the most transportation use from another place to another place. The total number of registered vehicle on Malaysia roads has passed 21.25 million units during 2011. This figure covers all types of vehicle including lorry, buses and motorcycles. Therefore, many people facing problem to find suitable parking and just park the vehicle on open space which does not roof to cover the vehicle as example show in figure 1.4. Malaysia is a country that have average weather and climate throughout a year, but mostly hot in days. This become problem to the car user because if the car park under direct sunlight, the condition in the car cabin will become very hot.

A car that parked under direct sunlight will result the heat trapped inside the car. The heat transfer from the sunlight to the car by radiation and conduction, then the convection process occur inside the car. The passenger cabin being equipped with lot of part (dashboard, steering, center console, seat etc.), usually all this part is made up by plastic and the body part is made up by steel, so the materials has good ability to conduct heat. The convection process occur when the solar radiation is trapped inside the car cabin, the heat cannot go outside, the wind shields of the car will contributing to the greenhouse effect. (Vishweshwara and AL Dhali, 2013)

The parking environment also can affect the temperature inside cabin car. If the car parked under covered place like roof, the temperature will become low. Even when the car is park under direct sunlight but the car window open widely, the temperature inside the car can reduce compare to the car window close, the air circulating in and out of the car. Many variables need to consider to get data clearly.

1.3 Objectives

The objectives of this project are as follow:

1. To investigate the air temperature in car‟s cabin.
2. Propose suitable method to reduce temperature in the car.

1.4 Scope of study

The scopes of this project are:

1. The area that will investigate is inside of the car (car cabin). The car will parked under various condition. Using same car as a constant variable.
2. The measured temperature will be the parameter for choosing the suitable method to reduce the temperature in the car. Choose an alternative and inexpensive method to achieve desirable comfort.

1.5 General Methodology

In this project, the methodology need to be carried out to achieve the objectives are listed below.

1. Literature review
   Collecting data from journal, article or questioning and answering the supervisor regarding the project.

2. Make a hypothesis
   Determine the variable, study the pattern that may exist between two variable; an independent variable: type of car used, and a dependent variable: the car park at various condition, the temperature distribution inside car cabin.

3. Design and conduct a study
   Determine the suitable place to conduct the experiment; such as park at residential area under direct sunlight and park at area covered with roof. Use thermocouple to get the temperature data.

4. Analysis and proposed solution
   Design a suitable method to overcome the problem. Analysis will be presented by data collection during experiment.

5. Report writing
   A report on this study will be written at the end of the project.
   The methodology of this project is summarized in the flow chart as shown below

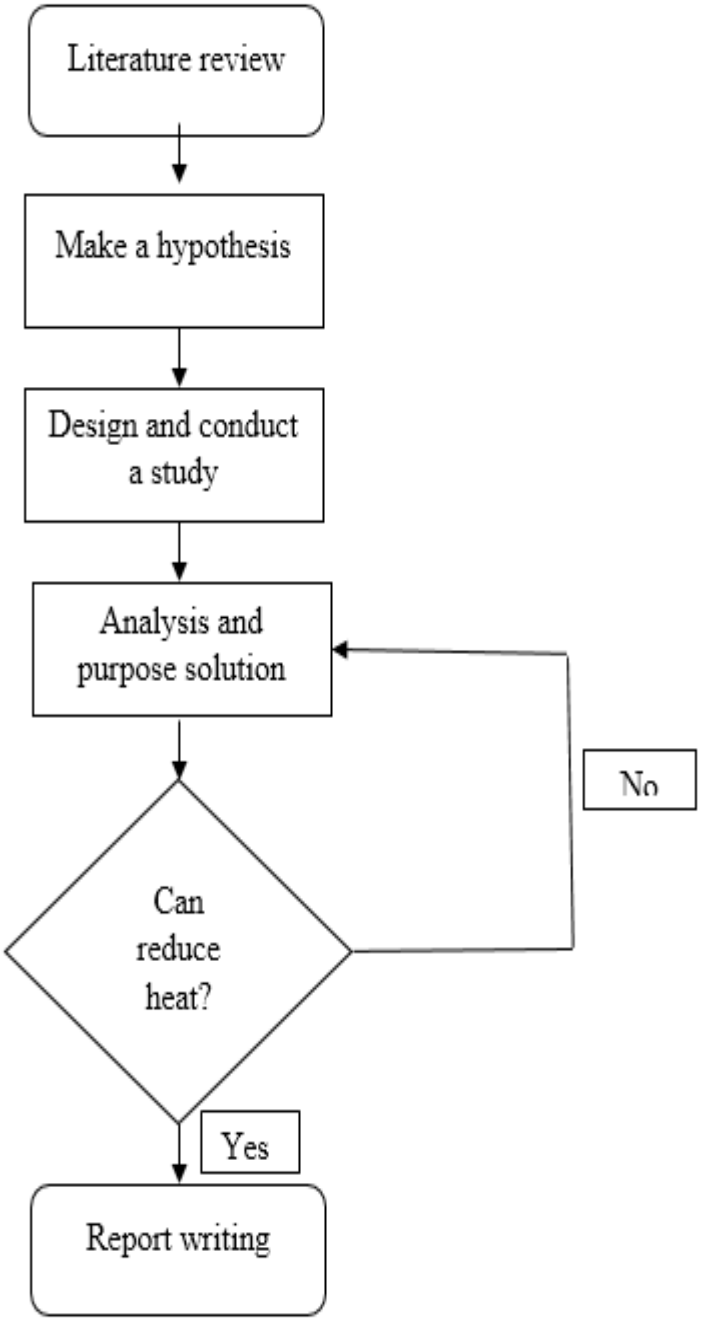

Figure 1.1: Flow chart of methodology

CHAPTER 2

LITERATURE REVIEW

2.1 Thermal Accumulation

The heat produce in car cabin when it park under direct sunlight will increase the interior of the car temperature up to 80 ^{o}C. during the period around 2-5 minutes after entering a car that exposed to heat for a long time will cause the uncomfortable sensation to the driver and passenger due to thermal accumulation. In order to decrease the temperature in the car cabin, the driver have to slightly lowered car window or run the air conditioning at high speed to allow the cabin environment to be like the ambient. To obtain good thermal comfort, by running the air conditioning will decrease the internal temperature compare to cases when the air conditioning is turned off. (Tseng et. al., 2014)

Heat accumulation shows in figure 2.2 occurs when the vehicle is left too long in the hot weather. The heat is trapped in the cabin of the vehicle will cause the temperature to rise. Sunlight that penetrates the windscreen and the transfer of heat from the body of the vehicle. Furthermore, the vehicle body is usually made by metal and parts in vehicles usually made by plastic material, the type of material that a good heat absorber. The higher the accumulation of heat in the cabin of the vehicle, it will increasing the vehicle cabin temperature.

2.2 Air Conditioning System in Car

The main function of car air conditioning system is to make vehicle occupants comfortable. In other words, the air conditioning functions to control of temperature (for cooling or heating), control of humidity (decrease or increase), control of air circulation (amount of air flow and fresh intake vs. partial or full recirculation) and cleaning of the air from odour, pollutants, dust, pollen, etc. before entering the cabin. (Shah, 2006). With the increasing demands by customers and rapid growth of technology, the comfort of the passenger cabin has to be taken into account in vehicle improvement process. It became an important part of vehicle of all categories worldwide, for example, 96% manufacturer car in India had factory-built air conditioning. (Shah, 2006). Even though the previous study shown

that the usage of air conditioning system in car can increase the fuel consumption, but another research shown air conditioning system is one important equipment in automobile (The Global Market for Automotive Heating, Ventilation, Refrigeration and Air Conditioning, Just. Auto, 2004; Lambert and Jones, 2006)

To ensure the air conditioning system in car functioning properly, it is important to take consideration the relationship comfort the variable that effect the comfort in designing of the control system. Thermal comfort become one the most important for satisfaction of customer‟s requirement to enrich the competitive ability in automobile industrial. Automotive industrial such as Toyota have recommended the installation of Solar Powered Ventilation System in car, using electric fan to circulate the air inside the cabin until the inside temperature reach 68 degree Fahrenheit. The cabin temperature will be lowered near to ambient temperature before entering the car and the passengers will feel more contented. (Tseng et. al., 2014)

There are five major component consist in car air conditioning system and all these parts have their own function. All of the component consist of compressor, condenser, evaporator, thermal expansion valve and accumulator.

2.2.1 Working Component of Automotive A/C System

The basic function of compressor is to compress cool gaseous refrigerant from the evaporator outlet with minimum compressor power and deliver maximum pressure and temperature to the condenser. The compressor is the heart of the air conditioning system, it powered by drive belt from the engine and has an electric circuit operate a clutch to turn off or on the A/C system. Next is condenser, it located in front of the radiator. Basically, condenser is crossflow heat exchanger that use air through the fin and the refrigerant through the tube. The condenser cools the high-pressure hot refrigerant gas and convert it to liquid through the use of cool air flow provided by the engine condenser fan.

Then, the refrigerant flow into the accumulator. This component can be seen as a small reservoir placed in in-line with the outlet hose of condenser. Any moisture that has polluted the refrigerant is captured here. It cause blockage if the moisture or other polluted are allowed to circulate and can damage the A/C system.

Next component is thermal expansion valve. After the refrigerant flow into accumulator, the refrigerant flow into this component. The pressure is reduced causing the liquid to return back to a gas which causes rapid cooling of the refrigerant vapour. After that,

the next main component in automotive A/C system is evaporator. This component is rarely seen because it is buried deep under the dashboard of the car and share the space with cabin heating system. Highly cooled refrigerant vapour absorb the heat from the air inside the car by pushing the air from the outside or re-circulating the cool air inside the car cabin.

2.3 Thermal Comfort

Thermal comfort is a very subjective sensation term because we cannot define a significant perfect comfortable ambient temperature for human being based on individual physiological variation. The thermal comfort sensation is depend by factor on heat exchange between human body and ambient environment. The thermal comfort depend on the capability of surrounding for the body to keep the internal temperature close to 37℃. Even though in the same condition, the thermal sensation receive by the people can be different, which means the required for comfort are not exactly to everyone based on environmental conditions.

Increasing human thermal comfort is one of the focused thing in most automotive manufactures, which they provided a suitable and efficient system for their cat to ensure ventilation, heating and cooling air in car cabin. Figure 2.3 shows relative humidity versus temperature that suitable to achieve thermal comfort based on ASHRAE 55. Thermal comfort was highly considered in vehicle and one of the most important factors when vehicular thermal environments were designed. (Ivanescu et. al., 2010). A suitable thermal sensation can contribute many advantages such as more concentrated and motivation in work and increase the life quality because it could bring a good physical state and not only a great feeling. (ZhOU Q., 2013.)

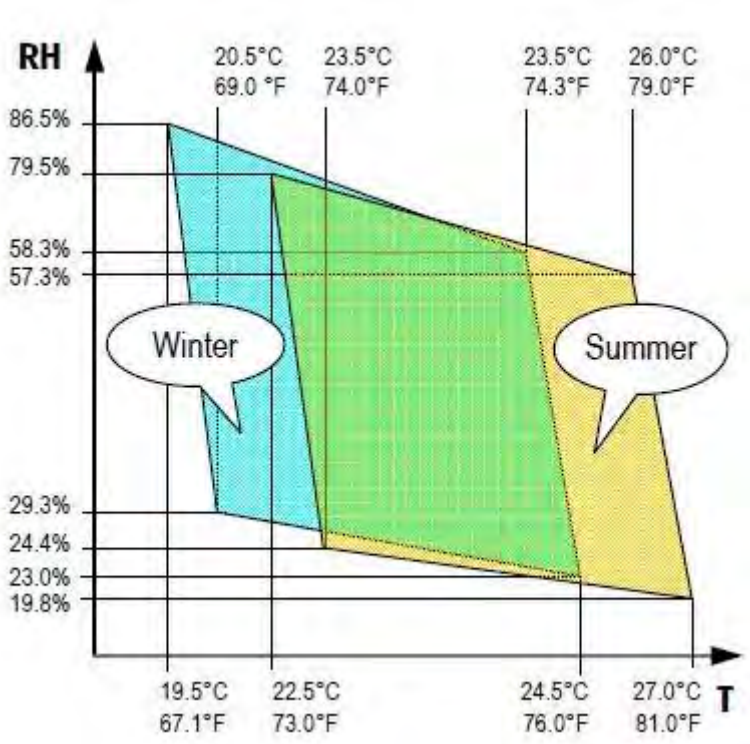

Figure 2.1: Relative humidity (RH)/temperature (T) diagram based on comfort zone according to ASHRAE 55-1992 from the source (Determining Thermal Comfort Using a Humidity and Temperature Sensor)

There are several research concerning the thermal comfort inside the vehicle, but the number of study focus on analysing the factor is just limited, most of the research is focusing on method of estimating the thermal comfort. Mezrhab and Bouzidi (2006) reviewed a numerical model to study the behaviour of thermal comfort inside passenger compartment according to climatic conditions and materials that compose the vehicle. While, according to Ali Alahmer et. al., (2012) investigated the analysis and modelling of vehicular thermal comfort parameter using a set of designed experiments aided by thermography measurements.

There are several factors in defining condition for thermal comfort and these factors can be divide into two categories; measurable factors and personal factors.

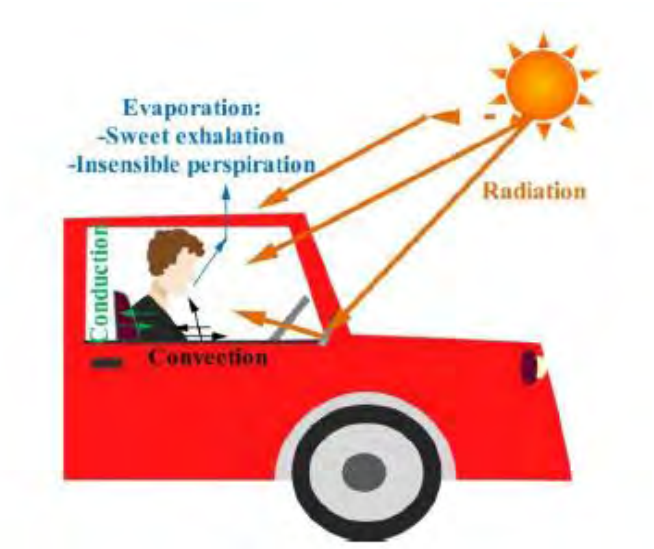

Figure 2.2 : Components contributing to thermal comfort in vehicle from the source (Simion et. al., 2016)

2.3.1 Measureable Factors

Measurable factor is classified as the factor that can be observed or manipulated in an experiment and these factor being measured in controlled experiment. The measureable include; air temperature, air velocity, radiant temperature and relative humidity. Many research was conducted to investigate related to the thermal comfort in cabin car and regulation strategy for a climate controller for car cabin.

2.3.2 Personal Factors

The personal factors are the individual factor that describe their own sensation for thermal comfort and these factors vary from person to person that results in different set of perceptions and may vary in time. The personal factor include; activity level and clothing insulation. One of the recent studied shown that thermal environment in car cabin is complex, continually varies in time and cannot be describe with temperature alone. (Farzaneh and Tootoonchi, 2008)

2.3.3 Predictive Mean Vote (PMV) Index

Using the Fanger model is characterised by the Predicted Mean Vote (PMV) index to predict the thermal comfort, which is created based on the thermoregulation and heat balance theory as shown in figure 2.3. Based on measurable and personal factors, we can calculate

PMV which symbolises to the average thermal sensation sensed by a group of people placed in vehicle and defining the Predicted Percentage of Dissatisfied (PPD) index, which is a group of people at a specific environment sensed the thermal comfort as quantitative measured (Farzaneh and Tootoonchi, 2008).

The provided score for PMV index is correspond to the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) thermal sensation scale and represent the average thermal sensation felt by a large group of peoples. The PMV index did not provide accurate estimataion when applied in non-homogenous conditions such as in car cabin, but it has been suggested and recognised for homogenous condition only.

Fanger‟s PMV gives the expected degree of thermal comfort in relation to experimental factors and personal factors. Fanger‟s PMV is given by Eq. (1)(Fanger, 1972)

$$\begin{aligned} PMV = {} & (0.028 + 0.3033e^{-0.036M}) \times \{(M - W) \\ & -3.05[5.733 - 0.000699\,(M - W) - Pa] - 0.42[(M-W)] \\ & -0.0173M\,(5.867 - Pa) - 0.0014M\,(34 - T_a) - 3.96 \times 10^{-8}) \\ & fcl\,[(T_d + 273)^4 - (T_{mrt} + 273)] - FCL \times h_c\,(T_{cl} - T_a)\} \end{aligned} \quad (2.1)$$

$$\begin{aligned} T_{cl} = {} & 35.7 - 0.028(M - W) - 0.155I_{cl}\,\{3.96 \times 10^{-3}\, fcl\,[(T_{cl} + 273)^4 \\ & - (T_{mrt} + 273)^4 - fcl \times h_c\,(T_{cl} - T_a) \end{aligned} \quad (2.2)$$

$$h_c = \begin{cases} 2.38(T_{cl} - T_a)^{0.25} & 2.38(T_{cl} + T_a) \geq 12.1\sqrt{V_{air}} \\ 12.1\sqrt{V_{air}} & 2.38(T_{cl} + T_a) \geq 12.1\sqrt{V_{air}} \end{cases} \quad (2.3)$$

The parameter are defined as follows:

PMV: predicted mean vote.

M: metabolism (W/m2).

W: external work, equal to zero for most activity (W/m2).

I_{cl}: thermal resistance of clothing (Clo).

f_{cl}: ratio of body‟s surface area when fully clothed to body‟s surface area when nude.

T_a: air temperature (℃).

T_{mrt}: mean radiant temperature (℃).