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Experimental study on the effect of using phase change materials to prevent of increasing the temperature of the interfacial between the hand and the computer mouse

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ABSTRACT

Phase change materials (PCMs) are materials whose most important property is latent heat capacity, which is an effective and important part of energy storage. These materials can provide or improve thermal comfort conditions through a phase change. A computer mouse is one of the pieces of equipment that are dependent on temperature and causes discomfort to the user if the temperature increases. By placing the hand on the mouse and doing the activity, based on the different metabolism of each person's body, it takes some time until the interface between the hand and the mouse gets hot and causes the user to be annoyed. Based on this, an experimental method was used to investigate the effect of using a PCM on the mouse. In this article, two PCMs (Paraffin Wax and Capric Acid) were used inside four capsule models (A: overall capsule, B: capsule parallel to the X-axis, C: capsule parallel to the Y-axis, D: checkered capsule), and the result was that with the addition of the capsule containing Paraffin Wax, the time to reach the maximum temperature was 7.14% compared to the normal state and with the addition of the capsule containing Capric Acid, the time to reach the maximum temperature will increase by 76.4% compared to the normal state. Regarding the comparison of the arrangement of capsules, the best case is to use a general capsule. But because using this type of capsule makes it difficult for the user, therefore, the best layout is the checkerboard type and increases the mouse's performance by 76%.

1. Introduction

The mouse is a device that has been with the computer almost since its inception. This device practically provides all the controls for the user, and every person who turns on the computer, puts his hand on the mouse at the same time, and it can be said that this device has become an inseparable part of the computer. The American Psychological Association has conducted research on stress and the important effects it has on human life, and it can be said that stress has been one of the features of current life in all societies, which increases with time. As a result, controlling and reducing stress is a very important issue [1]. Lazarus and Folkman [2] defined stress as a reactive description of a person's situation and circumstances. Hibbeln et al. [3] conducted the first experimental studies to measure stress through the movement of a computer mouse. Alberdi et al. [4] hypothesized that when a person uses a computer mouse, the stress response is related to psychomotor changes on the mouse. Entwisle et al. [5] conducted a survey of 50 % of employees in an office in Germany and concluded that company employees spend an average of 6 h working with a computer and mouse. Zimmermann et al. [6] conducted an experimental study in which participants' emotions were evoked with the help of a film. They found that there is a significant relationship between the time of emotional arousal and mouse movement. Jenkins et al. [7] evaluated the capacity and level of arousal of the participants' emotions by using the manipulation of

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people's emotions and recording mouse movements and filming and concluded that in these conditions, the amount of mouse movement by users was higher. Iizuka [8] conducted a laboratory study on the mouse and installed a Peltier device on the fingertip and recorded the thermal information of the user by heating and cooling the device. In the experiment, he came to the conclusion that thermal changes in the user's hand can have the same effect on the mouse. Hodes et al. [9] examined the feasibility of using PCMs for thermal management of mobile phones and concluded that even light loads of small PCMs could extend the service life of mobile phones. Ling et al. [10] examined the effective temperature control of four simulated battery packs in combination with PCMs and concluded that PCM blends effectively maintained the working temperature of the battery packs at a steady state and away from the above conditions keep them hot. Arkar et al. [11] examined the thermal reaction of a substrate system under the influence of two modes of specific heat and latent heat and finally concluded that the most appropriate type of PCM should be selected to achieve the best result. Chio et al. [12] examined the microchannels inside a block containing water and concluded that the rate of heat transfer with higher values was higher than in the previous two samples. Mjallal et al. [13] simulated the use of PCMs in heatsinks to cool electronic equipment and compared them with their experimental results; The results show that the use of PCM, even in small quantities, delays the time to reach the maximum temperature in each system by up to 20 min. Zhang et al. [14] investigated the cooling effect of a newly designed system combined with PCM under 10 W, 20 W, 30 W, and 40 W fluxes, and after experimental comparison and simulation of the system, concluded that the porosity in the packaging and its wall thickness has a great effect on the phase change process and the amount of heat transfer of the system depends on both the internal design of the box cells and its external structure. Chen et al. [15] performed various cooling methods on all computer equipment and concluded that in addition to cooling, freezing of the PCMs could have a positive effect on restarting the system and they also examined the effect of nano-PCMs.

Alizade et al. [16] by experimentally investigating the effect of using two boxes and two different phase change materials simultaneously in different heat fluxes, came to the conclusion that in order to use the most suitable phase change material, the temperature of the heat produced by the system should be matched with the melting temperature of the PCM under checked. Also, by adding forced air flow, the efficiency of the system can be increased up to 3 %. Siyabi et al. [17] studied the effect of the simultaneous use of two-PCMs inside a set and compared them to a box that has only one type of PCM. This simulation was performed to arrange the PCM and was investigated under fluxes of 1 W, 1.5 W, and 2 W until complete melting. Abdulateef et al. [18] examined various variables in the design and models of vanes along with a variety of PCMs to increase the thermal energy storage of the assemblies.

In previous research, no method was proposed to increase the heating and sweating time of the palm that is on the mouse with the help of PCM and an aluminum capsule. But in this research, with the help of the PCM and also the capsules containing this substance, an attempt was made to make the temperature of the palm that is on the mouse warm up later, and as a result, the sweating time is delayed.

2. Experimental setup

The experiment was performed using a special sample of a computer mouse with specific dimensions and size and using PCMs. The experiment was examined under laboratory conditions in three modes of palm heating: hot, normal and cold. Also, this design was tested with different arrangements of capsules containing PCM and also with different volume percentages of PCM, in laboratory conditions and with specified measurement accuracy.

2.1. Test sample

For the experimental investigation, in the use of PCM, four models of capsules with different volume percentages (capsules in general and capsules parallel to the X-axis and capsules parallel to the Y-axis and capsules in a checkered pattern) have been used. Also, all the above conditions were examined in the condition that the capsules were filled with liquid PCM. The capsules used in this experiment were all made of 0.015 mm thick aluminum, which was cut and assembled with scissors to specific and desired dimensions. Table 1 shows the general dimensions of the mouse and the capsules used. It should also be said that this mouse is made by DELL company.

As shown in Table 1, the general capsule used is 75 mm long and 125 mm wide, and one capsule was used for this test; Also, in the case that parallel to the X axis has been examined, 6 capsules have been used, 4 of which include the length and width of 11 and 73 mm, respectively, and 2 capsules including the length of 11 mm and the width of 15 mm. In the next case, which was examined parallel to the Y axis, 3 capsules were used, 2 of which are 11 mm long and 123 mm wide, and one of them is 11 mm long and 73 mm wide. In the last stage, checkered capsules were examined, and 10 capsules with length and width of 11 and 15 mm were used. In this experiment, the person who placed his hand on the mouse was an adult, and therefore the size of his hand is equal to the size of an adult's hand, and regarding the position of the hand on the mouse, it should be said that like any person who puts his hand on the mouse, this test was also done in a way that the person put his hand on the mouse normally. The capsules under study are made of aluminum, which has thermophysical properties such as melting point, specific heat, thermal conductivity and density. The mentioned properties can also be seen in Table 2.

Regarding the division and separation of the different parts of the experiment, it can be said that this experiment is divided into three parts: measuring the data and recording them on the computer and the part under test. Also, these three sections will be examined separately, which can be seen in Fig. 1.

You can see the images, designs and assembly principles in Fig. 2. As can be seen in Fig. 2-a, the mouse design used. As shown in the picture, the length, width and height of the mouse are indicated by L, W and H, respectively. Fig. 2-b shows the capsules used in this experiment. As can be seen from the image, Fig. 2-b-1 shows a large, general capsule that is located on the mouse as a whole. Fig. 2-b-2 shows the capsule shape, which is located parallel to the X-axis on the mouse. Also shown in Fig. 2-b-3 is a capsule that is placed parallel to the Y-axis on the mouse, and the checkered capsules placed on the mouse are shown in Fig. 2-b-4. In all capsules, length and width are introduced with L and W, respectively, and the dimensions of the capsules are given in Table 1. Capsule 1, shown in Fig. 2-b-1, is cut and assembled to cover the entire surface of the mouse. This capsule covers the entire contact surface between the hand and the mouse and there is no space between the hand and the mouse. This capsule is cut from an aluminum sheet with dimensions $153 \times 250\ \text{mm}^2$. Capsule 2, shown in Fig. 2-b-2, is cut and assembled into dimensions and sizes that are arranged parallel to the X-axis and spaced one in between on the mouse, and the length of these capsules is different because they are arranged differently on the mouse. This capsule is cut from an aluminum sheet with dimensions $22 \times 146\ \text{mm}^2$. Capsule 3, shown in Fig. 2-b-3, is positioned on the mouse parallel to the Y-axis. In this type of capsule, due to the type of arrangement as well as the distance and curvature of the mouse, the length is different but its width is constant. This capsule is cut from an aluminum sheet with dimensions $22 \times 246\ \text{mm}^2$. Capsule No. 4, which is checkered, can be seen in Fig. 2-b-4. The initial dimensions for this design were $22 \times 30\ \text{mm}^2$ on the aluminum screen, and its arrangement on the mouse is one in between. The initial dimensions for each capsule are measured with a ruler on an aluminum plate and cut with scissors. Sealing glue has also been used to assemble and glue the folded edges of the aluminum

Table 1
Dimensions and number of used items.

Equipment	Mouse		General capsule		Capsule parallel to X-axis			Capsule parallel to Y-axis			Checkered capsule		
Amount used	1		1		6			3			10		
Dimension (mm)	x	60	x	75	No 4	x	11	No 2	x	11	No 10	x	11
	y	130				y	73		y	123			
	z	40	y	125	No 2	x	11	No 1	x	11		y	15
						y	15		y	73			

Table 2
Thermophysical properties of aluminum.

Parameter	Melting point (°C)	Specific heat capacity $C_p(kJ/kgK)$	Thermal conductivity $k\ (W/mK)$	Density $\rho(kg/m^3)$
Aluminum	1199	963	180	2730

sheet. After folding the plate, a thin layer of sealing glue is poured on the side edge and then the two edges are pressed together to finally stick and seal. A thin layer of silicone paste is also used to reduce the thermal resistance between the hands and the capsules. The function of silicone paste is to eliminate the space between the surface of the hand and the capsules, and with this paste, there will be no air between the two surfaces, and as a result, any heat generated by the surface of the hand is transferred directly to the capsules. It should be noted that the air is heat insulating and should be completely removed from the joint contact surface with the help of silicone paste.

The surface of the skin of the hand was used as the heat source in this experiment, and the heat applied to the capsules from the hand was examined in three ways. In this test of the hand surface, in a situation where the person is completely normal and has not done any physical activity and only the hand is on the mouse, temperature changes were recorded on the mouse. In the next step, the person performs normal activities and unexciting activities and the data related to each sensor is recorded again. In the last step, the person performs exciting computer activities, such as computer games, and the information is recorded. Also, since the test conditions should be completely isolated and heat transfer from the system to the environment and vice versa should not be done, so, the studied system was placed in a wooden box with a length, width and height of 120, 200 and 100 mm, respectively. The wooden box is 10 mm thick and only a space as size of a wrist movement is installed inside it, so that the wrist can be easily moved inside the box. Also, to control the lack of heat transfer around the wooden box, it was covered with a layer of rock wool with a thickness of 10 mm, and again only the wrist movement area is opened. The adhesive has been used to fix each capsule in their place. The joint between the surface of the capsule and the upper surface of the mouse is covered with a layer of adhesive to prevent it from moving while is dries.

2.2. Properties of PCM

PCM is a type of heat absorber that takes heat from a hot source and retains heat inside due to its latent heat capacity. In the experiment, two PCMs, Paraffin Wax, and Capric Acid, were used as heat absorbers. Regarding Paraffin Wax, it should be said that the melting temperature of this PCM is about 56$^{\circ}C$ and this material is produced by the brand of Ishtar Company LLC. Also, the maximum amount of Paraffin Wax used in this experiment is given in Table 3. Also, in the case of Capric Acid, it can be said that the melting temperature of this substance is about 32°C and the consumption of this substance in the test can be seen in Table 3. Also, this substance (Capric Acid) was prepared from Merck company. It should also be noted that the change in volume of the PCM during and after the phase change should not be neglected, and for this purpose to fill the capsules of these PCMs, are first liquefied and then transferred. In general, the amount of PCM consumed in this test as well as its volume in the liquid state is shown in Table 3.

Regarding the thermophysical properties, it should be said that these properties, include specific heat capacity, thermal conductivity, melting point, latent heat, and density. The properties of each materials are unique and can be seen in Table 4 for two materials, Paraffin Wax and Capric Acid.

2.3. Experimental testing

To study the heat dissipated from the surface of the hand to the mouse, a thermocouple is used, where each thermocouple is located in a specific position from the mouse surface, the position of each thermocouple is shown in Fig. 3.

In the other research, one of the sensors that can be used in tests is the K-type thermocouple. For this reason, in this experiment, 6 thermocouples were used, all of each are K type, and the accuracy of measuring these thermocouples based on laboratory results is ±0.1°C. For the calibration of all thermocouples, the thermocouples were tested at 100 °C boiling water temperature and 0 °C water temperature, and the result was that the measurement error was equal to 0.2 %. If the center of the mouse is assumed to be the origin of the coordinates, as shown in Fig. 3, sensor 1 is located in the upper left position and on the left click, also at the outermost point of the left click. Regarding sensor number 2, it should be said that this sensor is located in the upper and right position of the mouse and on the right click and at the outermost point of it. Sensor No. 3 is also located on the left click and slightly lower than sensor No. 1 and, of course, slightly further inward than sensor No. 1 and toward the center of the mouse (All the explanes are shown in Fig. 3). Also, sensor number 4 is located on the north and right side and is a little lower than sensor number 2. This sensor is also a little further in

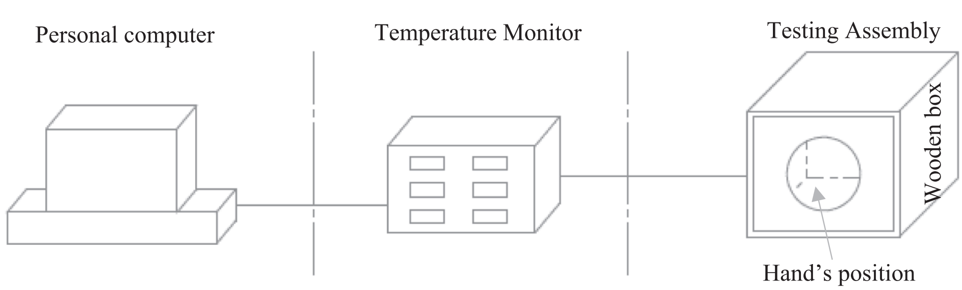

Fig. 1. Schematic diagram of experimental set.

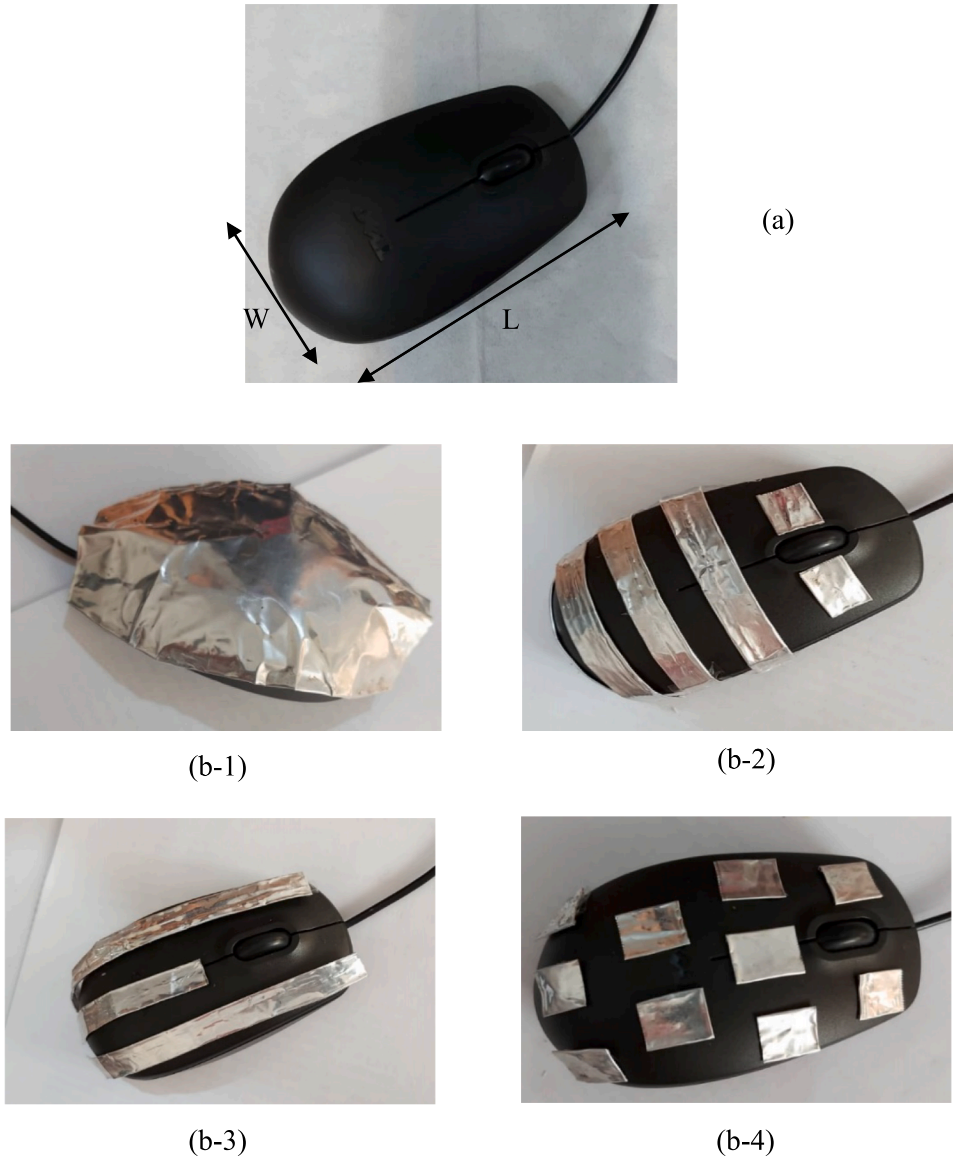

Fig. 2. An overview of the experimentally study set.

Table 3
Amount of PCM used in each step.

PCM	State			
	General	Parallel to the X-axis	Parallel to the Y-axis	Checkered
Paraffin Wax in liquid mood	29.1 gr	5.6 gr	6.3 gr	2 gr
Capric Acid in liquid mood	26.2 gr	5.14 gr	5.8 gr	1.7 gr

than the number 2 sensor and is located towards the center of the mouse. The position of sensor 5 is exactly in the direction of the center of the mouse and slightly lower than the center of the mouse. Regarding the placement of the sensors in one direction, it should be said that because all the heat received from the palm can be recorded, none of the thermocouples are in the same direction and have different angles. It should also be noted that sensor number 1 is responsible for measuring the temperature of the index finger and sensor number 2 is responsible for measuring the temperature of the middle finger. Also, sensors 3 and 4 are again responsible for controlling the temperature of the same fingers, but in a new location, as well as sensor number 5, which is located below the center of the mouse, is responsible for controlling the temperature of the palm. Regarding the connection of temperature sensors

Table 4
Thermophysical properties of Capric Acid and Paraffin Wax.

Material	Melting point T_m(°C)	Latent heat $\Delta H(kJ/kg)$	Specific heat capacity $C_p(kJ/kg.K)$		Thermal conductivity $k(W/m.K)$		Density $\rho(kg/m^3)$	
			Solid	Liquid	Solid	Liquid	Solid	Liquid
Capric Acid	32	153	1.95	1.72	–	0.153	1004	878
Paraffin Wax	56–58	173.4	1.92	3.26	0.212	0.167	880	790

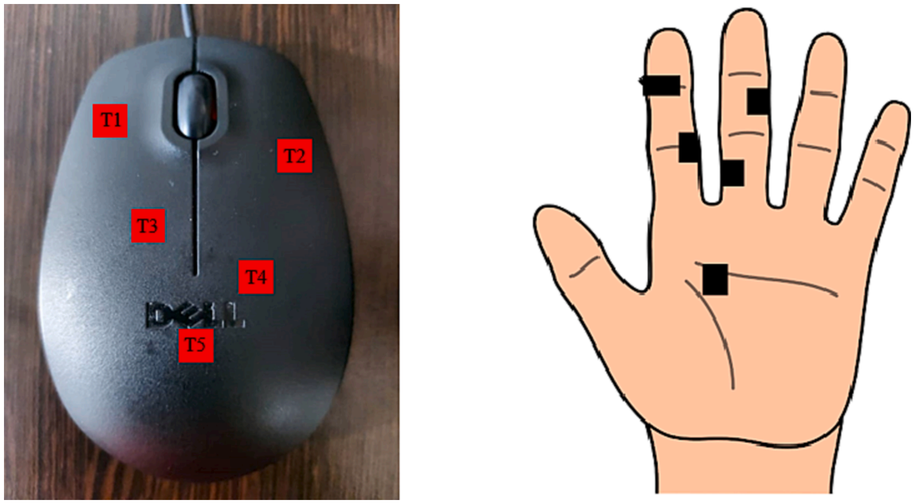

Fig. 3. Situation of each thermocouple on mouse and hand.

to the mouse, it should be said that each of the sensors is glued directly to the mouse. Therefore, they report all the received data, but in cases where the capsules and the sensors collide with each other, the sensors are glued to the capsule and in the other words, the gap between the capsule and the hand is filled. In this experiment, the source of heat production is the human hand. The temperature changes that occurred in this test are caused by the psychological changes of the user. For example, it can be said that a person is playing with the computer or doing daily tasks or is completely still, all of which can change the heat generated. All tests of this test were performed at an ambient temperature of $27 \pm 0.2\,^{\circ}C$ and because this test was a completely new design, to validate this test, its reproducibility was evaluated in three steps.

2.4. Test campaign methodology

Before starting the test, it must connect the power supply to the city 220 V power and wait until the sensors reach a steady state. In the present experiment, three modes have been investigated and each of these modes was also tested with the introduced PCMs. The first person is completely normal and is engaged in daily activities by computer. In the second case, the person is playing an exciting computer game, and in the third case, the person simply puts his hand on the mouse and doesn't do anything. It should be noted that in all cases, two types of PCMs, Paraffin Wax and Capric Acid, are filled into the capsules and evaluated. In the first case, when the test was normal, the person placed his hand on the different positions of the capsule that filled by Paraffin Wax, and the temperatures were recorded every 10 s until recorded temperatures reached about $40^{\circ}C$. Also, in this case, the person puts his hand on the capsules that filled by Capric Acid again and the data is recorded for 10 s until it reached a temperature of about $40^{\circ}C$. In the second case, which was an emotional experiment and placed the user in a very exciting space such as a computer game, the person placed his hand on the capsules that filled by Paraffin Wax and reached a temperature of about $40^{\circ}C$ in 10 s. The data is recorded and in the next part, this time the person puts his hand on the capsules that are already filled by Capric Acid PCM. Again, at this step, the data were recorded until the temperature reached about $40^{\circ}C$ with a step of 10 s. In the third and last case, the person simply puts his hand on the mouse and does not do any activity, and only the hand contact with the mouse is tested. This time, the test was performed with capsules that filled by Paraffin Wax. The data were recorded until the temperature reached about $40^{\circ}C$ and a time interval of 10 s with a step of 10 s. In the final test, the capsules were filled by Capric Acid and the test was repeated until the temperature reached about $40^{\circ}C$ with step of 10 s. In each case of the above tests, it should be said that four models of capsules used in this test, the first model is such that the capsule is completely and uniformly covered on the surface of the mouse, and in the second model, the capsules are spaced parallel to the X-axis, and in the third model the capsules are spaced parallel to the y-axis, and in the fourth model, the capsules are arranged in a checkered pattern with one in between. While studying the effect of using PCM, the arrangement of this material should also be evaluated. After performing each test to reach stable and constant conditions and reach the ambient temperature, time should be spent and after the system reaches the ambient temperature, the test should be performed again.

2.5. Assumptions

Given that in this experiment the area around the system is covered by a layer of rock wool and a layer of wood, so it can be assumed that the ambient temperature was constant and also the transfer of heat from the system to the environment and vice versa was neglected and exactly after performing the test to cool down and reach ambient temperature, a pause has been made. Also, due to the use of silicone paste, the heat generated by the palm has been directly transferred to the mouse and sensors.

2.6. Validation

In this research, because the presented plan is a completely novel and new idea, it is not possible to use other people's experiments to validate the experiment. For this reason, to refer to these tests, the repeatability method has been used, and each test has been performed 4 times under the same conditions, and the results show that the percentage error of the test and measurement is less than 0.4 %.

Measurement error is the difference between the approximate value and the actual value of the object/quantity. Relative error can be calculated as a percentage using the relative error formula. The error of measuring equipment is caused by the inevitable error of measuring equipment and the limits of human eyes. Errors come in different sizes, and you may need to determine if the error is so large that the measurements are meaningless. The smaller the error, the closer it is to the actual value. There are three main types of measurement error:

- Total error

Absolute error is the difference between the measured value and the actual value. The formula for absolute error is:

$$E_{absolute} = |X_{measured} - X_{accepted}|$$

- Relative error

It expresses the ratio of the absolute error of the measurement to the acceptable measurement. Relative error can be expressed as:

$$\text{Relative Error} = \frac{|measured\ value - actual\ value|}{actual\ value}$$

- Percentage Error

Percentage error is similar to relative error besides that the error here is converted to a percent value. The expression for percent error is:

$$Percent\ of\ Error = \frac{|measured\ value - actual\ value|}{actual\ value \times 100\%}$$

3. Result and discussion

3.1. Using a mouse without any PCM

The first part was tested in a state where the person put his hand on the mouse and is done his normal activity. All tests were performed until the sensors have no increases. Fig. 4 shows the temperature displayed for each sensor in 10 s. In this curve, the X-axis represents the time from 0 to 800 s with a step of 20 s and the Y-axis represents the temperature from 27 °C to 37 °C with a step of 1 °C. In Fig. 4, the temperature changes of the sensors are visible and it shows that the T5 sensor, which is in the center of the mouse and where the palm is located, has received more heat. After that, sensors T4, T3, T1, and T2 receive the most heat from the hand respectively. In this case, because the hand is in direct contact with the mouse, the heat is transferred directly and its temperature has increased.

3.2. Comparison of the arrangement of different capsules containing Paraffin Wax in a normal state

At this step, the capsules were filled with Paraffin Wax and arranged on the mouse in order and examined in a normal step. The results of the test at this stage are shown in Fig. 5. The X-axis in the graphs reported in

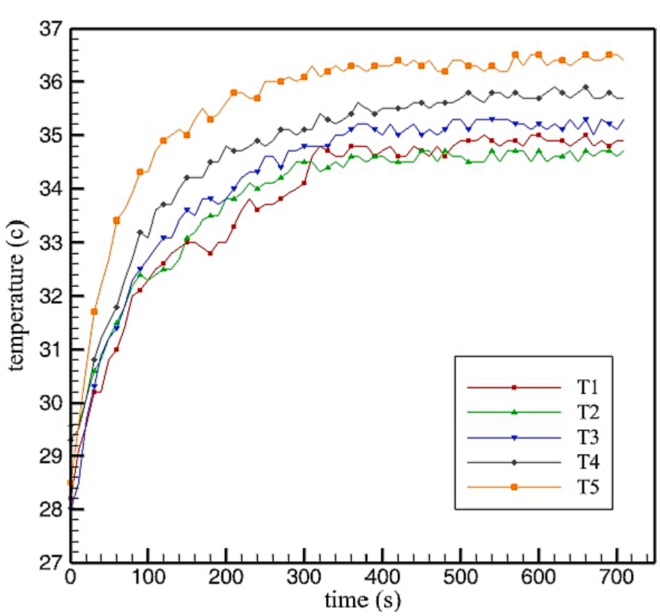

Fig. 4. Temperature changes of sensors in the case without capsule.

Fig. 5 represents the time from 0 to 800 s with a step of 30 s and the Y-axis represents the temperature from 27 °C to 38 °C with a step of 1 °C. Fig. 5-a shows the step where the general capsule of Paraffin Wax was placed on the mouse and the data was recorded. In this curve, all the sensors installed on the surface of the mouse are in contact with the aluminum capsule and as a result, are affected by the behavior of PCM. In this chart, all temperature changes are upward and will never decrease, which is the reason for the temperature changes on the skin surface. Fig. 5-b shows the case where the capsules are arranged parallel to the X-axis on the mouse. In this case, T2 and T4 sensors are not in contact with the capsules, but the rest of the sensors are in direct contact with the capsules, because the melting temperature of Paraffin Wax is higher than the temperature produced by hand, therefore it is not possible to observe temperature changes and behavioral changes that are specific to this PCM. Fig. 5-c shows the case where the capsules are arranged parallel to the Y-axis. In this graph, the T1 sensor takes a longer time (about 580 s) to reach a steady state because it is in direct contact with the aluminum capsule. In T2 and T5 graphs, there is an upward trend exactly according to the T1 sensor and it takes about 580 sec to reach a linear and almost constant trend. But in T3 and T4 curves, according to the arrangement of the cells on the mouse, it takes about 490 s to reach a constant trend. Fig. 5-d shows the state where the capsules are placed on the mouse in a checkered pattern. At this step, the T5 sensor is not in contact with the capsule and only shows the temperature of the hand's skin.

In Fig. 5, because the operating temperature of the system, which is the palm here was lower than the melting temperature of paraffin wax, Therefore, the behavioral changes of this phase changing material are not visible because the heat produced was not enough to melt the paraffin wax.

3.3. Comparison of the arrangement of different capsules containing Capric Acid in a normal state

At this step, different arrangements of capsules containing Capric Acid on the mouse and in normal conditions were examined. Fig. 6 shows the behavior of the capsules when they are placed on the mouse. In this figure, the X-axis represents the time from 0 to 1200 s with a step of 200 s and the Y-axis represents temperature from 27 to 37 °C with a step of 1 °C. Fig. 6-a shows the general capsule behavior. In this diagram, with time of 1130 s, the system has reached a stable state, and in other words, there will be no increase in temperature from now on, which is more than the amount consumed due to the lack of heat production. In this graph, from 0 to 60 s, the growth rate of the curve is about 60 °C, and from 60 to about 240 s, this growth occurs in this process with an angle of approximately 45 °C, and after that, the movement process is almost linear and constant (until time 1000 s) and after that, the growth of the graph occurs with an angle of 50 °C. Fig. 6-b represents the case where the capsules are arranged parallel to the X-axis. In this diagram, T2 and T4 sensors are not on the capsule and they show normal behavior, but in T1, T3 and T5 sensors, the trend of temperature changes is upward, and the behavior changes of the Capric Acid PCM can be seen in this form. Fig. 6-c shows the temperature changes of the sensors in a state where the capsules are arranged parallel to the Y-axis. In this curve, the T3 and T4 sensors were not in contact with the capsules and reached the maximum recorded temperature after about 500 s. Meanwhile, in the rest of the sensors, considering that the time has passed around 1100 s, the temperature changes have not reached their maximum value. Also, from 200 to 1000 s, the graph is linear, which shows that in this period, the PCM is melting and this melting is caused by the absorption of heat from the hand by the phase change material. Fig. 6-d shows when the capsules are placed on the mouse in a checkered pattern. At this point, the T5 sensor has nothing to do with the capsules and only shows the temperature changes in the palm, while the other sensors clearly show that the temperature is changing upwards. It had a steeper slope until about 240 s and then lost its slope graph at about 1000 s, in other words,

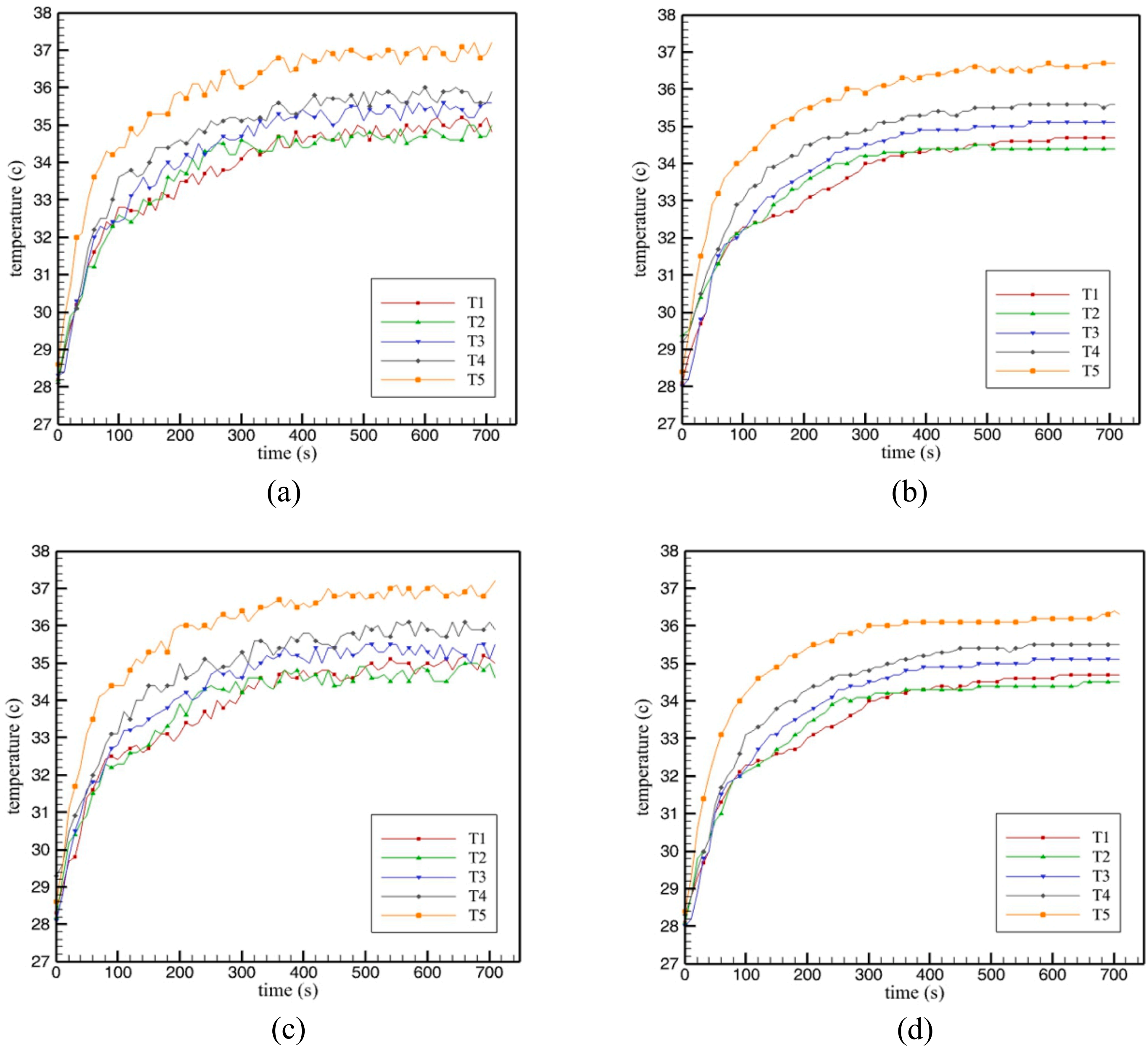

Fig. 5. Temperature changes of sensors along with Paraffin Wax capsule in normal mode.

it became stable and linear, but after the complete melting of the PCM, the upward trend moves upward again with a steep slope. Because the latent heat capacity of the phase change material to absorb heat during the phase change has reached its maximum and it has no ability to absorb heat.

3.4. *Comparison of the arrangement of different capsules containing Paraffin Wax in emotional and stress states*

At this step, according to part 3.2, the arrangement was the same, but this time the person performed the test in a state that was stressful and exciting (such as a stressful computer game). At this stage, the X-axis in Fig. 7 represents the time from 0 to 210 s with a step of 50 s and the Y-axis represents the temperature from 27 °C to 40 °C with a step of 1 °C. Fig. 7-a shows the state where the entire Paraffin Wax capsule is placed on the mouse. At this stage, the T5 sensor is still at the highest level of heat due to its location. Also, with time of about 220 s, the temperature recorded by the sensors reached 39 °C and after that, the trend has been constant or decreased because this temperature is in not suitable for the skin and internal conditions of human hands. Fig. 7-b shows the state where the capsules are arranged parallel to the X-axis on the mouse. The data recorded in this curve is shown in such a way that the trend of temperature changes is upward and is fixed after 220 s and continues linearly. The reason why temperature changes are not visible for the PCM used in this graph is that the temperature is so low that it has not even reached the melting point of Paraffin Wax, so the presence of this type of PCM is completely useless. Fig. 7-c shows the state where the capsules are arranged parallel to the Y-axis on the mouse. In this curve, due to heat production by human hands, the T5 sensor has recorded a higher temperature (about 39 °C). The lowest temperature recorded in this graph was related to the T1 sensor, which records the temperature of the finger and shows a temperature of about 36 °C, and the rest of the sensors report between these two numbers. Fig. 7-d shows the state where the capsules are placed on the mouse in a checkered pattern. The important point that can be seen in this diagram is that due to excitement and stress, the time to reach the maximum temperature has

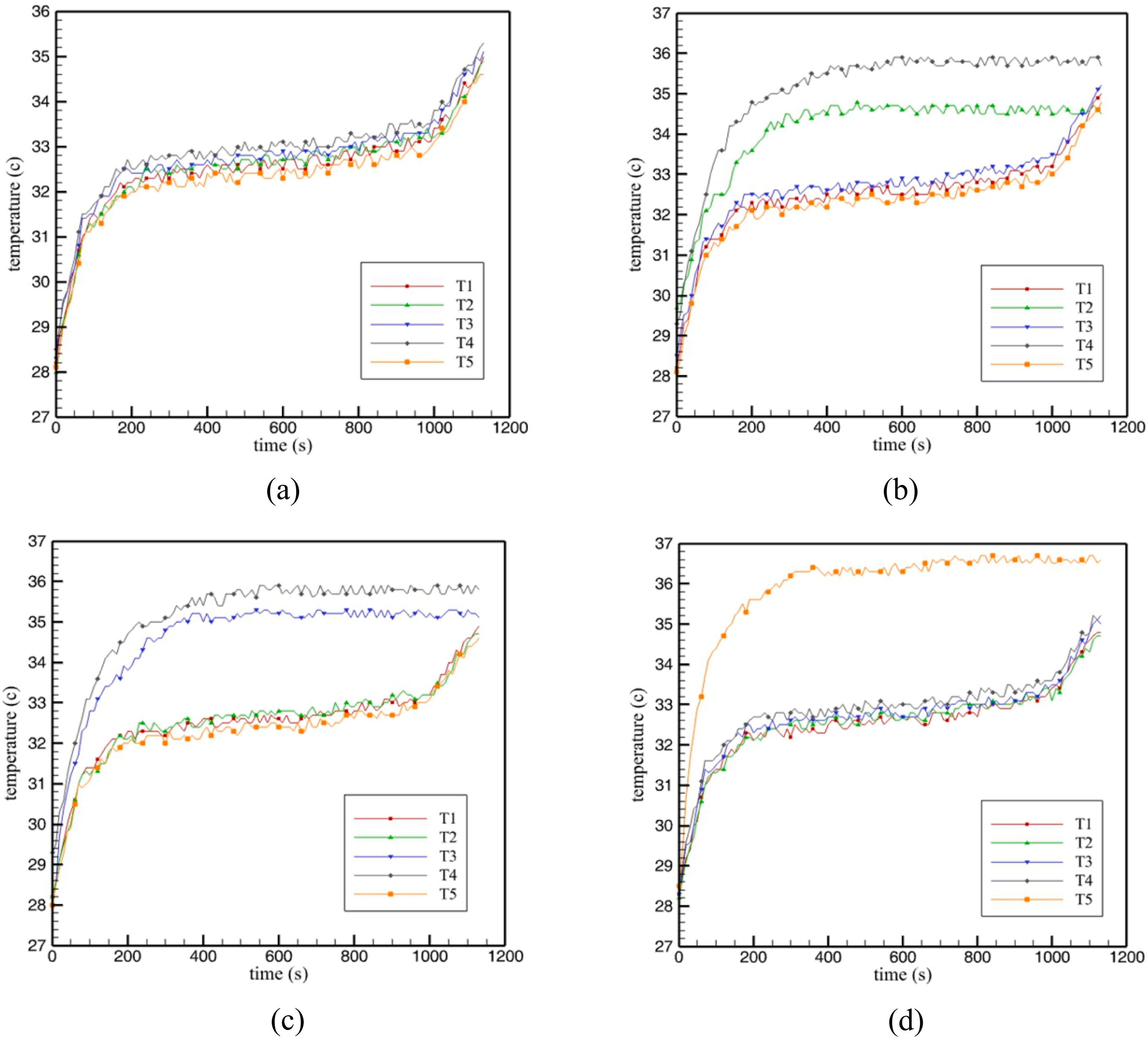

Fig. 6. Temperature changes of sensors along with capric acid capsule in normal mode.

decreased to 290 s, and on the other hand, the increase in temperature has also increased due to the conditions mentioned.

3.5. Comparison of the arrangement of different capsules containing Capric Acid in emotional and stress states

At this stage, the arrangement of the capsules was according to the previous stages, but this time the person who experimented with the help of it was excited and stressed, and the capsules were filled with Capric Acid. Fig. 8 shows the behavior of the sensors. In this figure, the X-axis represents the time from 0 to 350 s with a step of 50 s and the Y-axis represents the temperature from 27 °C to 39 °C with a step of 1 °C. Fig. 8-a shows the state in which the general capsule of Capric Acid is located on the mouse. In the above diagram, after a time of about 340 s, the system has reached its maximum temperature, and in other words, there will be no increase in temperature, which is more than the amount released due to the lack of heat generation. In the chart above, all the curves have an ascending trend, in other words, from 0 to 30 s, the slope of the chart is about 60 °C, and from 30 to about 260 s, this growth trend occurs at an angle of approximately 45 °C and then the upward trend is up to 350 s. In the diagram above, the change in the behavior of this PCM is easily seen due to the correlation of the temperature generated by the hand with the melting temperature of the phase change. Fig. 8-b represents the state where the capsules are arranged parallel to the X-axis. In sensors T1, T3, and T5, the process of temperature changes due to exposure to Capric Acid capsules, shows a behavior similar to the melting process of PCM. At intervals of 0 to 20 s, the graphs grow steeply, and then for sensors that are in contact with the capsules, a linear trend occurs at 33 °C, and for sensors that are not in contact with the capsules, a linear trend occurs at about 35 °C. After that, the growth process increases again with a steep slope to the maximum temperature. Fig. 8-c represents the state where the capsules are arranged parallel to the Y-axis. In this diagram, the T1 curve, because the sensor is in direct contact with Capric Acid, at a lower temperature range than in the case where it lacks PCM (about 3 °C). The T2 and T5 diagrams are exactly according to the T1 sensor, the upward trend and grow at a steeper slope for about 30 s, then becomes almost linear, and then at about 260 s again increases the slope. However, in the T3 and T4 curves, due to the

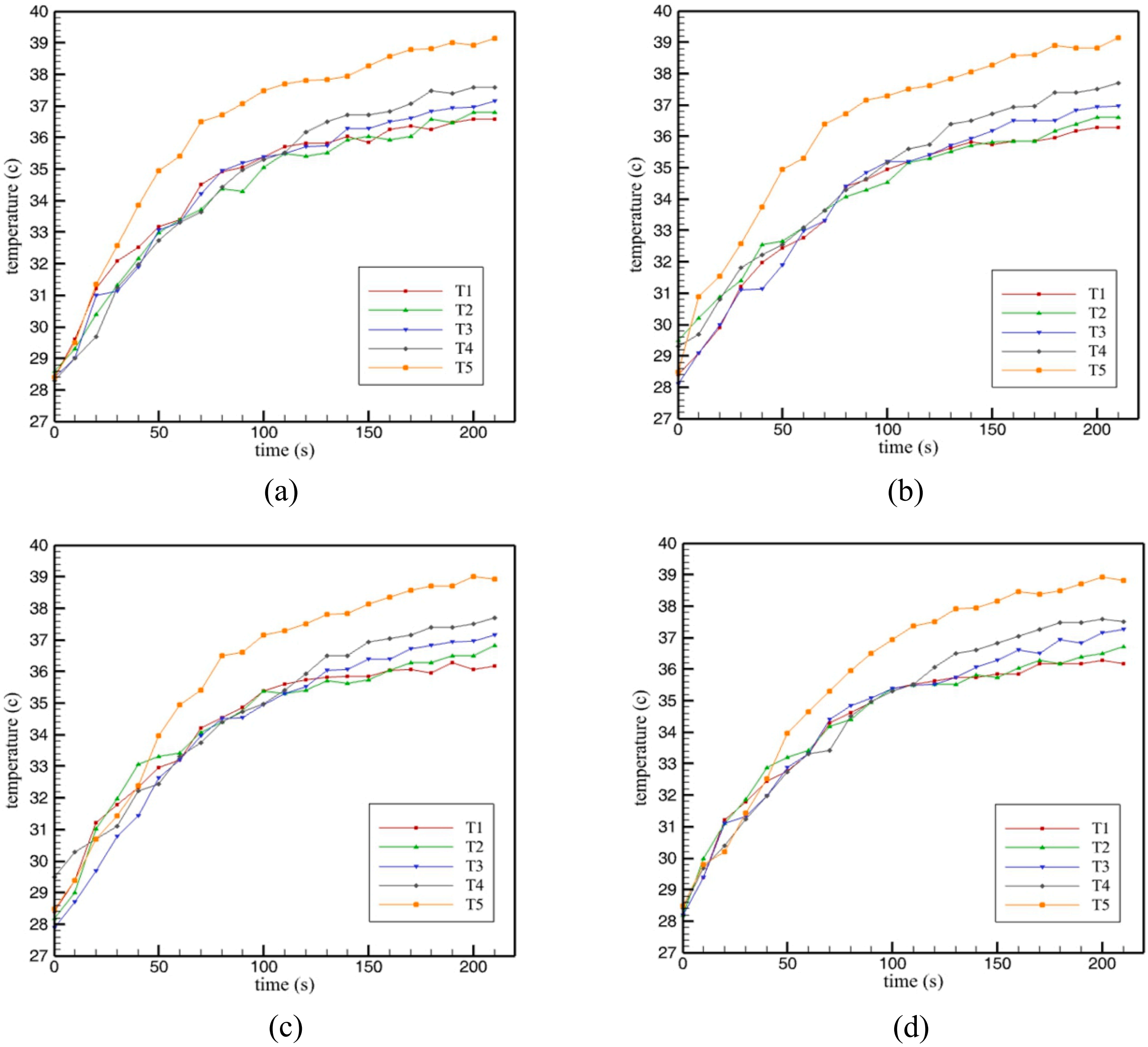

Fig. 7. Temperature changes of sensors along with Paraffin Wax capsule in exciting mode.

arrangement of cells on the mouse and the fact that they are not in contact with PCM, they undergo their linearization process at a temperature of 36 °C. Fig. 8d shows the state where the capsules are placed on the mouse in a checkered pattern. In this curve, after about 30 s, the T5 sensor reached a temperature of 35 °C, while in the other sensors, it reached a temperature of about 33 °C in the same amount of time, and it remained constant at a temperature of about 33 °C for 240 s, and then the upward trend and will grow to reach the maximum possible temperature. To summarize and similarity in the phase change process of Paraffin Wax PCM, temperature changes in a completely relaxed state were done only for Capric Acid and the experiment with Paraffin Wax was omitted.

3.6. Comparison of the arrangement of different capsules containing Capric Acid in a completely relaxed state

At this step, the arrangement of the capsules is as before and they are filled with Capric Acid, and the person simply puts his hand on the mouse and does not perform any activity. In Fig. 9, the X-axis represents the time from 0 to 1500 s with a step of 200 s and the Y-axis represents the temperature from 27 °C to 38 °C with a step of 1 °C. Fig. 9-a shows the state where the overall capsule is on the mouse. As it is clear in the figure, the system changes its movement direction and becomes almost linear after reaching the melting point of capric acid at a certain time. Fig. 9-b shows the state where the capsule is parallel to the X-axis on the mouse All the explanations for this mode are the same as the previous modes and the sensors on the capsules show the temperature changes perfectly. Fig. 9-c shows the state where the capsule is parallel to the Y-axis on the mouse All the explanations are the same as the explanations of part 9-b. Fig. 9-d shows the state where the capsule is located on the mouse in a checkered pattern. Regarding Fig. 9, it should be said that the behavior and explanations related to it are the same as those in Fig. 8, and the difference is only at the end of the test time.

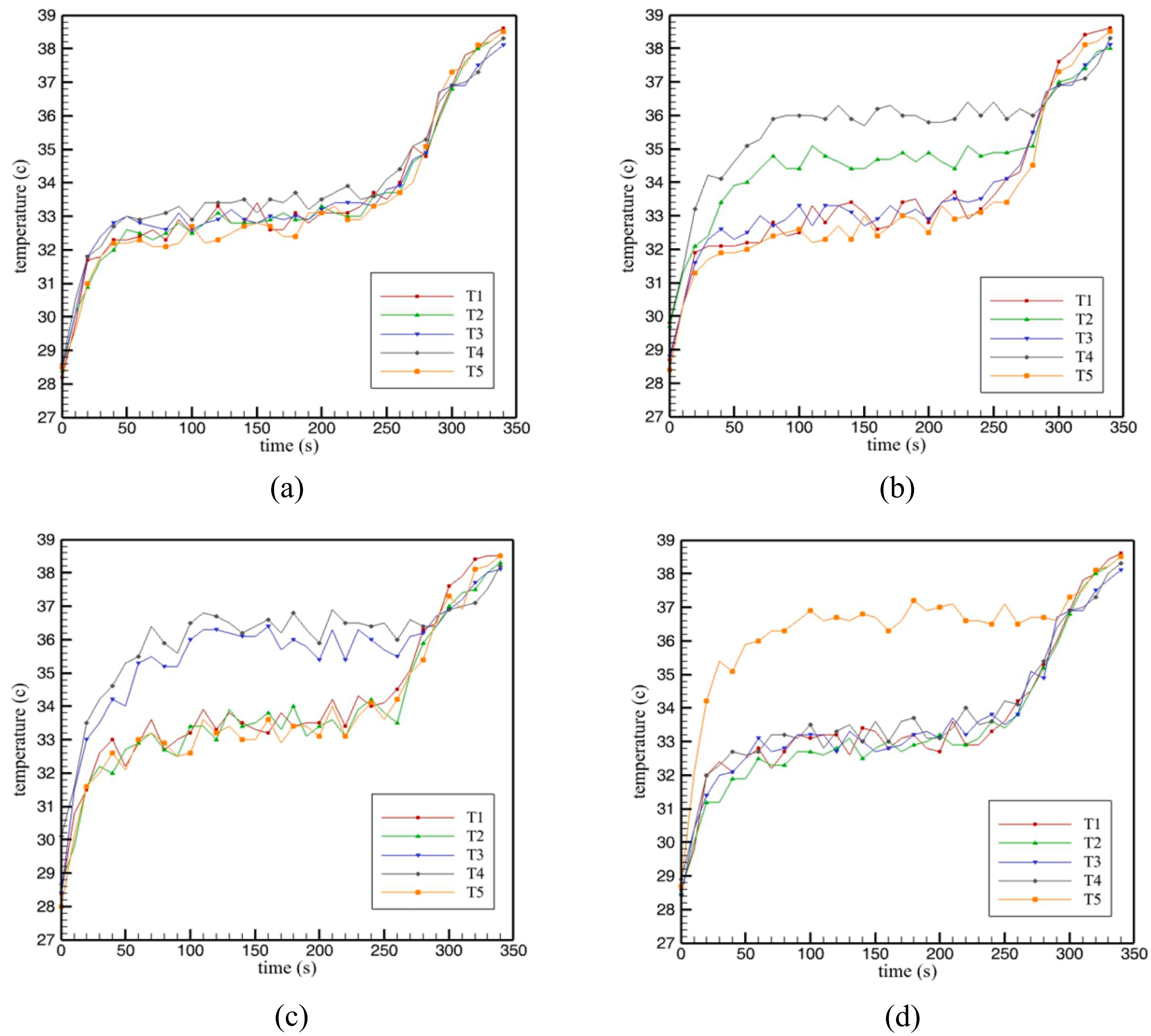

Fig. 8. Temperature changes of sensors along with capric acid capsule in exciting mode.

4. Application of the proposed design in computer mice

Different layouts on the mouse were investigated and as stated in the conclusion section, the most suitable layout is the checkered capsule. On the other hand, considering that a special type of mouse is available in the market to prevent hand overheating and sweating, it can be combined with a checkered design. As mentioned, the mouse available in the market, which is selected here and can be seen in Fig. 10, is the GM 602 RGB model. This mouse model is of gaming type and is made by Green company [19]. As it is known, some parts of it are hollowed out in order to cool the hands and prevent sweating; Therefore, with the combination of this mouse and the presented design, which can be seen in Fig. 10-b, it can be said that the places where the hand is in contact with the mouse are filled by Capric Acid capsules. The combination of these two designs causes a part of the heat of the hand to be absorbed by Capric Acid.

5. Conclusion

In this article, the surface temperature of the mouse was investigated in four different arrangements (A: overall capsule, B: capsule parallel to the X-axis, C: capsule parallel to the Y-axis, D: checkered capsule). Also, two types of PCM, Paraffin Wax and Capric Acid, were used inside the capsules, and these two types of materials were examined in the following three states:

- The user performs an exciting activity with the mouse.
- The user performs normal activities with the mouse.
- The user just puts his hand on the mouse.

The results obtained from the experimental test are as follows:

If no PCM is used in the system, the time to reach the maximum temperature will be about 260 s. However, with the addition of Paraffin Wax, this time reaches 280 s, and if Capric Acid is used in the system, the time to reach the maximum temperature will increase to 1100 s. Of course, the reason for this is that the temperature of the surface of the human hand does not exceed a certain range. Therefore, the use of Paraffin Wax with a higher melting temperature is practically unnecessary and we will not have time growth. However, if Capric Acid is

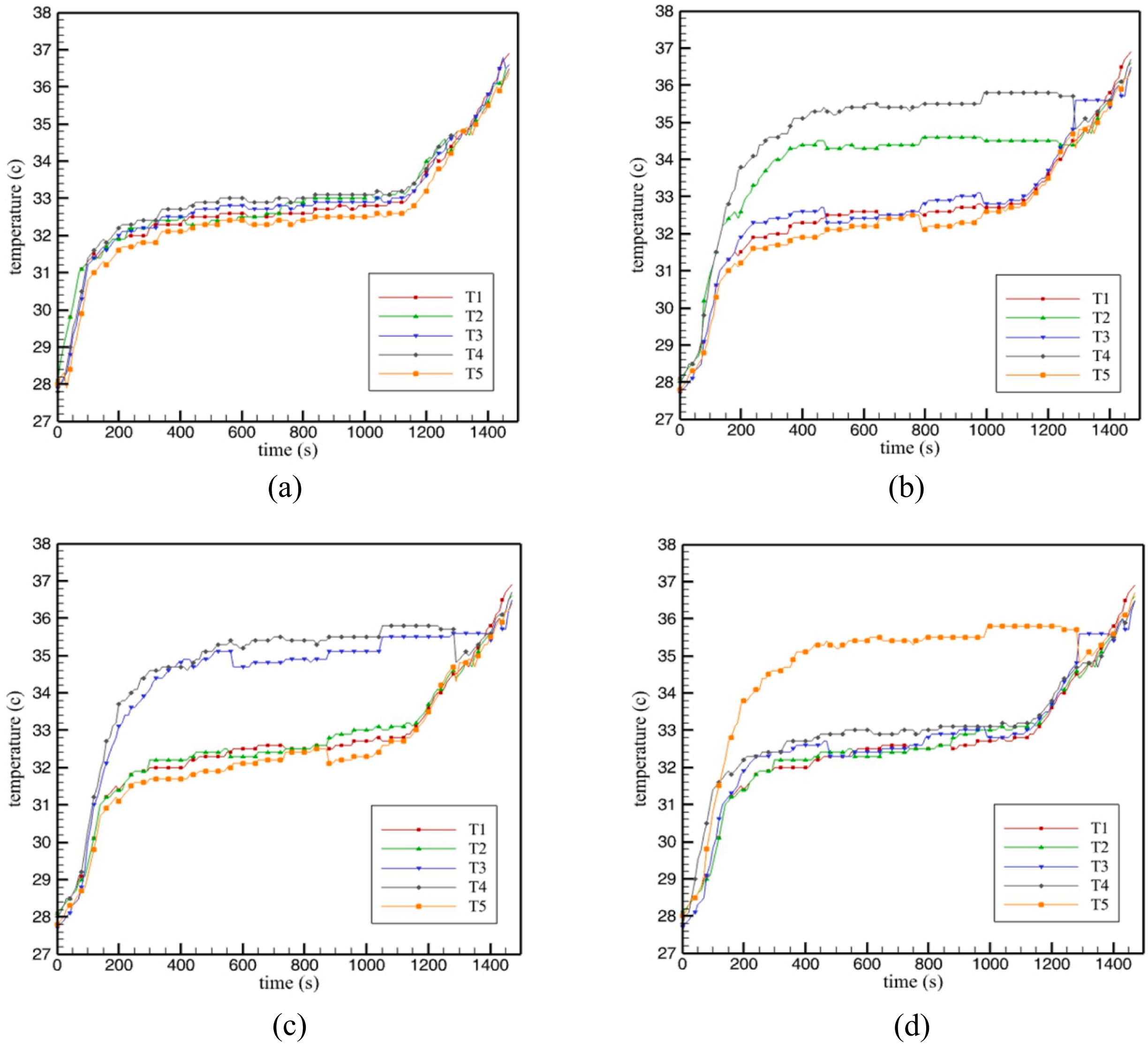

Fig. 9. Temperature changes of sensors along with capric acid capsule in relaxing mode.

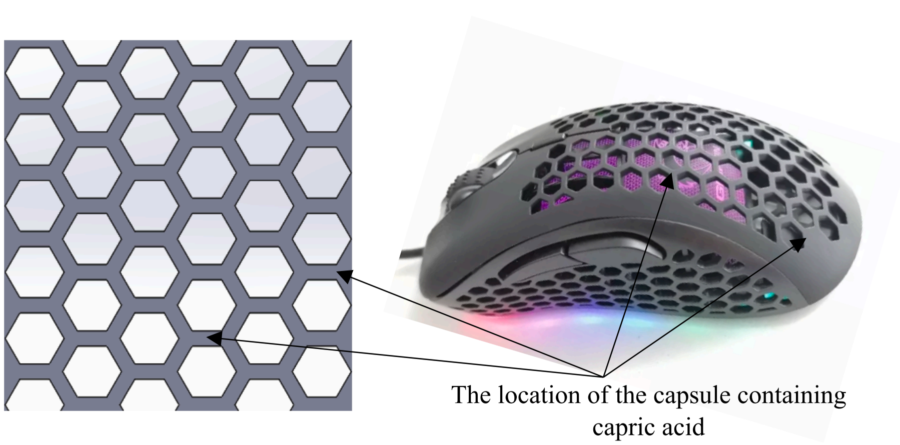

Fig. 10. The combination of gaming mouse with the design presented.

used, the growth rate will be approximately 76 %. The reason why using Capric Acid is more appropriate than Paraffin Wax is that the melting range of Paraffin Wax is 57 °C and the melting range of Capric Acid is 32 °C. On the other hand, the temperature of the hand skin will reach 39 °C in the highest state, so using Capric Acid phase change material is a good option. On the other hand, regarding the arrangement proposed in this research, it should be stated that in general, with the use of the Y-axis parallel arrangement compared to the general capsule, the time to reach the maximum temperature happens almost 7 % earlier, and it is practically not recommended to use this type of arrangement. Also, if the arrangement is parallel to the X-axis, the time to reach the maximum temperature happens 21 % earlier, and this type of arrangement is also not recommended. Regarding the comparison between the checkered arrangement and the general capsule, it can be admitted that in the checkered mode, the system reaches the maximum temperature 3 % earlier than in the overall mode. But it should be kept in mind that using the overall capsule makes the work more difficult for the user, and for this reason, it's strongly recommended to use the checkered layout model.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors listed on the manuscript are not employed by a government agency that has a primary function other than research and/or education. Also, the authors declare they are not belong to an official representative or on behalf of the government.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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