Temperature Distribution Control for Baby Incubator System Using Arduino AT Mega 2560

by Wayan Widhiada

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Temperature Distribution Control for Baby Incubator System Using Arduino AT Mega 2560

W. Widhiada, D. N. K. P. Negara, P. A. Suryawan

***Abstract*—**The technological advances in the field of health is very important, especially for the safety of the baby. A lot of death cases of premature babies are mainly caused by poorly managed health facilities. Mostly the deaths of premature babies are caused by bacteria since the temperature around the baby is not normal. Related to this, the incubator of the premature babies needs to be very well equipped, especially in how to control the correct temperature inside the incubator. The On / Off controls is used to regulate the temperature distribution inside the incubator so that the desired temperature of 36 ^{0}C can be achieved to maintain a stable and normal condition for the baby inside the incubator. The authors have been observing and analyzing the data to determine the correct temperature distribution in the incubator using the program of MATLAB / Simulink. The output temperature distributionis obtained at 36 ^{0} C in 400 seconds using an Arduino AT 2560. This incubator is able to maintain an ambient temperature and maintain the baby's body temperature within normal limits and keep the air moisturized corresponding with the limit values that is required within the baby's/infant incubator.

***Keywords*—**On/Off Control, Distribution Temperature, ArduinoAT 2560, Baby Incubator.

I. Introduction

PREMATURE infant deaths are mainly caused by poorly managed health facilities. Babies born prematurely have a high degree of sensitivity to the environment and are very vulnerable to disease, Mostly the deaths of premature babies are caused by bacteria since the temperature around the baby is not normal. Related to this, the incubator of the premature babies needs to be very well equipped, especially in how to control the correct temperature inside the incubator. Incubator is a tool that helps to normalize the temperature and humidity around the baby's body. Babies who are born prematurely needs intensive care and the correct level of warmth to keep them in a normal condition because babies cannot adapt to temperatures outside the mother's womb yet. There are disadvantages of the local incubators, one of which is negligence in maintaining the stability of the temperature so that the baby in the incubator does not feel comfortable, this will endager the baby's health condition. To manage the incubator's temperature automatically, Singlaet(2015) have developed and designed the microcontroller to control the distribution of temperature and humidity controller for an infant incubator which are very critical for the normal growth of the premature babies [1].This research proposed a microcontroller which is a tool that is used to control the temperature and humidity in the infant incubator,it is programmed to heat the baby's incubator towards the temperature between 35^{0}C to 37^{0}C. The Baby Incubator research-based Computational Fluid Dynamics (CFD) is proposedby RuriWahyuono A. (2014). This research aims to analyze the influence of the type of walls and the addition of overhead screen on the distribution of temperature and heat loss in infants [2] at the physical measurement data Amecare incubator in the Central Security facility health Surabaya.

Rayzah NurIlmiyati (2012), has been monitoring the temperature and humidity of the incubator using DHT11 sensor (Digital Humidity Temperature Sensor) which is coupled with Arduino to monitor the temperature and humidity of the incubator. In this case, the output data from an arduino processed by visual basic is used by the operator as its output data will appear on the computer [3].

The design of the baby's incubator has been manufactured and used in Ghana. This incubator has used a control system to control the temperature inside the incubator. The proses of developing the baby's incubator caused some problems because it was quite hard to find the materials and electronics components for the incubator. But fortunately all the problems can be solved [4]. According to Guler, the PIC microcontroller is used to control humidity inbaby's incubator using an ultrasonic sensor. The research has been developed to achieve the high performance and high speed to control the actual response [5].

In this research, the modeling of incubator tool is using ArduinoAT Mega 2560 as the microcontroller. The general purpose is to correct the deficiency which was found in the previous incubators. The research has developed by using a simulation and experiment. Simulink toolbox is one of the parts of MATLAB (Matrix Laboratory) which is used for technical calculation, control design, etc. Simulink Toolbox provides a graphical interface to several MATLAB functions, enabling designing of models and dynamically controlling systems dynamically [6].

The program of the distribution temperature and humidity is transferred from a computer to an Arduino AT Mega 2560 when the prototype of the incubator is ready. The Arduino AT Mega 2560 microcontroller has arranged the temperature inside the incubator to be stable in the range 36 ^{0}C. The research was tested using the formula of heat transfer and flow rate in the form of linear algebraic equations which is completed by calculation to show convergent value.

The process of the simulations have calculated and analyzed the responses of temperatures inside the infant incubators. The application of Simulink/support package Arduino toolbox is programmed in Arduino AT Mega 2560 as a microcontroller which can regulate the stability of temperature control system inside the infant incubators

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towards the stable temperature of 36 ^{0}C.

II. Methology Research

2.1. Research Description

The design of this incubator consists of two main parts namely the top of the box and the bottom of the incubator box. In the lower part of the box consists of Arduino AT Mega 2560 board, heater, and fan while the upper part consists of a temperature sensor. The Size of the Incubator is :

- Length = 85 cm
- width = 40 cm
- height = 55 cm.

The following picture is the shape and dimensions of the baby's incubator (shown in Figure 1).

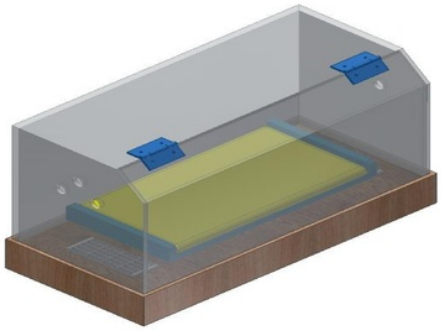

Fig.1 Baby Incubator Design

2.2. Temperature Control System

Figure 2.Shows the diagram block of an incubator control system. The temperature adjustment is done by regulating the amount of heat generated by the heater on the plant through the provision of AC voltage. The temperature range as the output is measured by the temperature sensor and is used as a feedback input for the controller. The input of the sensor is then compared by the controller to the input set-point (temperature desired). Furthermore, both variables are processed by microcontroller. The result of the process is used as input on the voltage control block to determine the timing of the heater's ignition.

In general, the design block diagram of the temperature setting system is shown as in Figure 2.

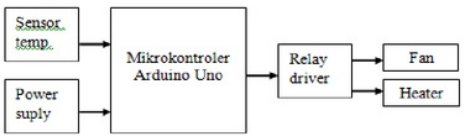

Fig. 2 Block diagram of the incubator system control

The following diagram shows a flow chart of the temperature control system in the incubator chamber:

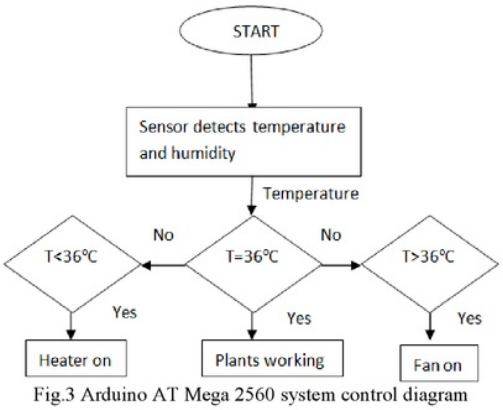

Fig.3 Arduino AT Mega 2560 system control diagram

The temperature sensors such as DHT11 and LM35 detect the distribution of temperature and humidity inside the incubator space and display in LCD installed. When the temperature is less than 36^{0}C then automatically the heater will be turned on until the temperature of 36^{0}C is achieved. When the temperature is over 36^{0}C then automatically the fan will be turned on.

III. Result and Analysis

3.1. Data Research Results

This research was conducted by placing the DHT11 sensor inside the incubator chamber to measure the temperature of the incubator plant. To justify the temperature value out of the sensor is accurate; the sensor needs to be calibrated by comparing the temperature output value using a thermometer. The research of this incubator was firstly performed with a baby who has the weight of 2.0 kg and secondly was performed with no baby/infant. The Data retrieval is done for 3000 seconds.

The table 1 and 2 shows the data of the baby's incubator temperature with the baby/infant and without the baby/ infant. The surroundingtemperature outside the incubator is 32^{0}C. In this incubator chamber, it has installed five temperature sensors such as 4 sensors of LM35 and a sensor of DHT11. The distribution of temperature data is recorded until 3000 seconds. The desired temperature at 36^{0}C is achieved at 300 seconds.

Fig.4Incubator Testing with 2 kg of baby weight

TABLE I
THE DATA OF INCUBATOR BABY WITHOUT INFANT

Time second)	Outside Thermo-meter (T_{d1}(°C)	Sensor DHT11 (°C)	Sensor 4 LM35 (T_4(°C)	Sensor 1 LM35 (T_1(°C)	Sensor 2 LM35 (T_2(°C)	Sensor 3 LM35 (T_3(°C)	Rata-rata Suhu Ruangan (Tf)	Inside Therm ometer (T_{d2}(°C)
0	32	32	32	32	32	32	32	32
100	32	32	33.3	31.5	33.4	34.3	33.1	32
200	32	33	34.5	32.8	33.7	34.1	33.8	33
300	32	34	35.4	34.3	34.2	35.8	34.9	34
400	32	35	36.1	35.4	35.8	36.5	36.0	34
500	32	35	36.3	35.6	36.4	36.3	36.2	35
600	32	35	36.2	35.5	36.3	36.5	36.1	35
700	32	35	35.8	35.6	35.9	36.3	35.9	35
800	32	35	35.7	35.5	36.1	36.2	35.9	35
900	32	35	35.9	35.6	36.3	35.8	36.1	35
1000	32	35	36.2	36.1	36.3	36.3	36.1	35
1100	32	35	36.3	36.3	36.4	36.3	36.3	35
1200	32	35	36.1	35.8	36.6	36.1	36.3	35
1300	32	35	36.3	36.3	36.2	36.4	36.3	35
1400	32	35	36.1	36.2	36.5	36.2	36.3	35
1500	32	35	36.3	36.3	36.4	36.3	36.2	35
1600	32	35	36.5	36.4	36.2	36.2	36.3	35
1700	32	35	36.4	35.7	36.3	36.4	36.2	35
1800	32	35	36.3	35.8	35.9	36.3	36.1	35
1900	32	35	36.2	35.7	35.9	36.1	36.0	35
2000	32	35	36.5	35.4	35.9	36.2	36.0	35
2100	32	35	36.3	35.5	36.2	36.3	36.3	35
2200	32	35	36.4	35.4	35.9	36.4	36.3	35
2300	32	35	36.3	35.8	36.1	36.4	36.3	35
2400	32	35	36.3	35.7	36.2	36.3	36.2	35
2500	32	35	36.5	35.7	36.3	36.3	36.2	35
2600	32	35	36.5	35.8	36.2	36.3	36.2	35
2700	32	35	36.2	36.2	36.1	36.4	36.3	35
2800	32	35	36.3	36.3	36.4	36.2	36.4	35
2900	32	36	36.3	35.4	36.2	36.3	36.3	35.5
3000	32	36	36.4	35.6	36.3	36.4	36.3	35.5

TABLE II
THE DATA OF INCUBATOR BABY WITH 2 kg of WEIGHT

Waktu (detik)	Thermometer luar (T_{d1}(°C)	Sensor DHT11 (°C)	Sensor 0 LM35 (T_0(°C)	Sensor 1 LM35 (T_1(°C)	Sensor 2 LM35 (T_2(°C)	Sensor 3 LM35 (T_3(°C)	Rata-rata Suhu Ruangan (Tf)	Therm ter dal (°C)
0	32	32	32	32	32	32	32	32
100	32	32	33.4	32.2	32.4	33.2	33.4	32
200	32	34	35.2	33.8	34.9	36.1	35	32.5
300	32	35	36.3	35.3	36.2	36.2	36.1	34
400	32	35	36.1	36.4	36.3	36.3	36.3	34
500	32	35	36.4	35.2	36.3	36.2	36.3	35
600	32	35	36.2	36.3	36.3	36.5	36.3	35
700	32	35	36.2	36.4	36.1	36.3	36.3	35
800	32	35	36.3	35.7	36.2	36.2	36.2	35
900	32	35	36.5	35.8	36.2	36.2	36.2	35
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1400	32	35	36.4	36.1	36.2	36.3	36.3	35
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1600	32	35	36.5	36.4	36.3	35.9	36.3	35
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2300	32	36	36.2	35.5	36.2	36.5	36.1	35
2400	32	36	36.3	35.7	36.3	36.1	36.2	35
2500	32	36	36.4	35.8	36.3	36.3	36.3	35
2600	32	36	36.5	35.7	36.2	36.4	36.2	35
2700	32	36	36.4	36.3	36.4	36.4	36.3	35
2800	32	36	36.3	36.3	36.2	36.2	36.3	35
2900	32	36	36.5	35.4	36.4	35.9	36.3	35.5
3000	32	36	36.3	35.5	36.3	35.9	36.3	35.5

3.2.Analysis of Temperature using MATLAB/Simulink

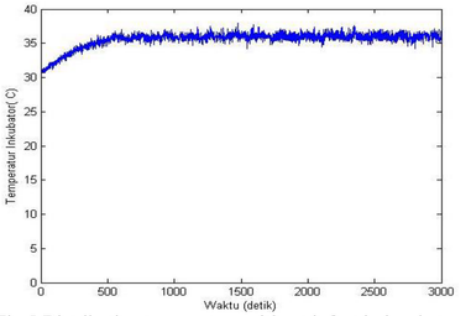

Fig.5 Distribution temperature without infant in incubator.

Figure 5. It appears that the incubator can reach the temperature of 36^{0}C after 500 seconds. The heat continues to spread until the temperature's stability is maintained until testing it at 3000 sec. From the comparison of the graphic above, there is a connection of temperature stability at the required time which is influenced by the fluid flow velocity. The air flows down the top of the box and begins to increase the density due to the cooling of the upper wall. As a result of increasing density, the fluid flows downward faster, so that the temperature distribution in the incubator space is in accordance with the temperature required by the baby/infant.

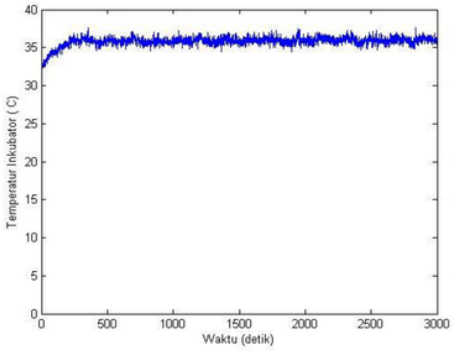

Fig.6Temperature Distributionin incubators with 2 kg of weight

Figure 6. It can be seen that the temperature changes or oscillates continuously to achieve stability and starts to stabilize from 400 to 3000 seconds. Thus the system in general has produced a fairly good controlling action.

IV. CONCLUSION

By adjusting the incubator heating by using the MATLAB / Simulink program , the temperature in the baby's incubator can be stabilized at the normal temperature of . The stabilized temperature of 36 ^{0}C inside the baby's incubator is very important because it maintains the baby's temperature within normal limits and keep the air humidity in accordance with the required value limit In the baby's incubator. The design of the on / off control system with the help of MATLAB/Simulink program is very accurate to compute the result as desired.

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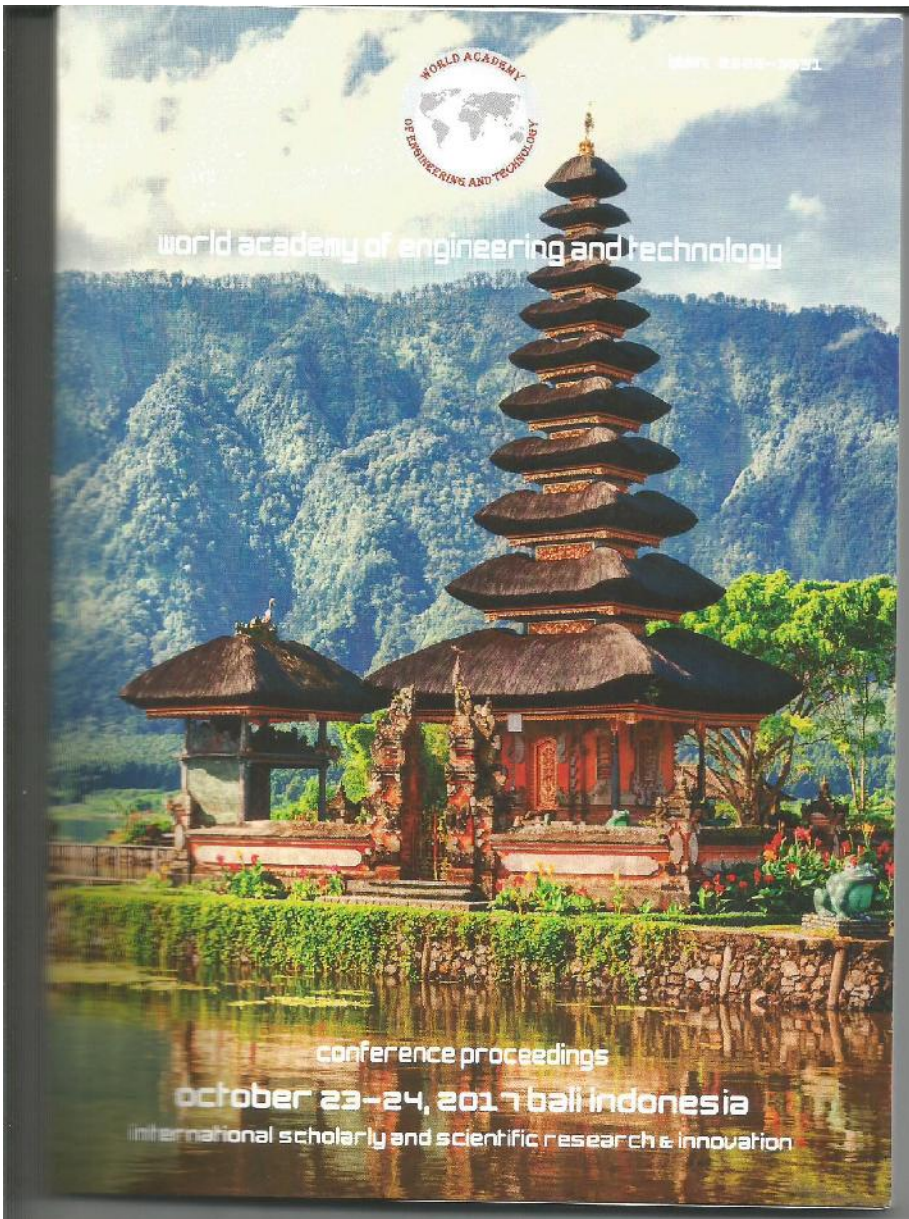
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The process of the simulations have calculated and analyzed the responses of temperatures inside the infant incubators. The application of Simulink/support package Arduino toolbox is programmed in Arduino AT Mega 2560 as a microcontroller which can regulate the stability of temperature control system inside the infant incubators

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towards the stable temperature of 36 ^{0}C.

II. Methology Research

2.1. Research Description

The design of this incubator consists of two main parts namely the top of the box and the bottom of the incubator box. In the lower part of the box consists of Arduino AT Mega 2560 board, heater, and fan while the upper part consists of a temperature sensor. The Size of the Incubator is :

- Length = 85 cm
- width = 40 cm
- height = 55 cm.

The following picture is the shape and dimensions of the baby's incubator (shown in Figure 1).

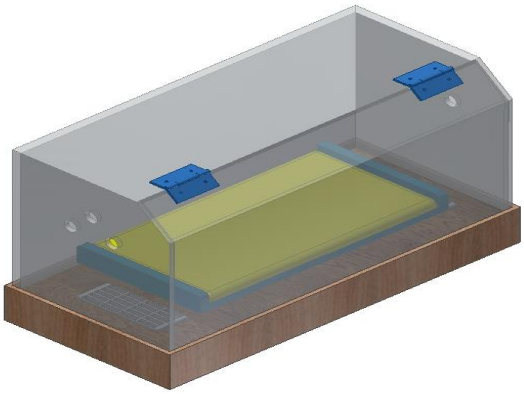

Fig.1 Baby Incubator Design

2.2. Temperature Control System

Figure 2.Shows the diagram block of an incubator control system. The temperature adjustment is done by regulating the amount of heat generated by the heater on the plant through the provision of AC voltage. The temperature range as the output is measured by the temperature sensor and is used as a feedback input for the controller. The input of the sensor is then compared by the controller to the input set-point (temperature desired). Furthermore, both variables are processed by microcontroller. The result of the process is used as input on the voltage control block to determine the timing of the heater's ignition.

In general, the design block diagram of the temperature setting system is shown as in Figure 2.

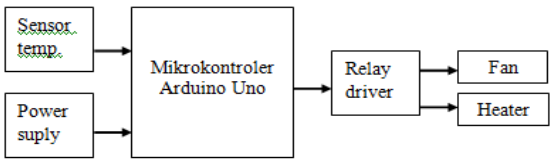

Fig. 2 Block diagram of the incubator system control

The following diagram shows a flow chart of the temperature control system in the incubator chamber:

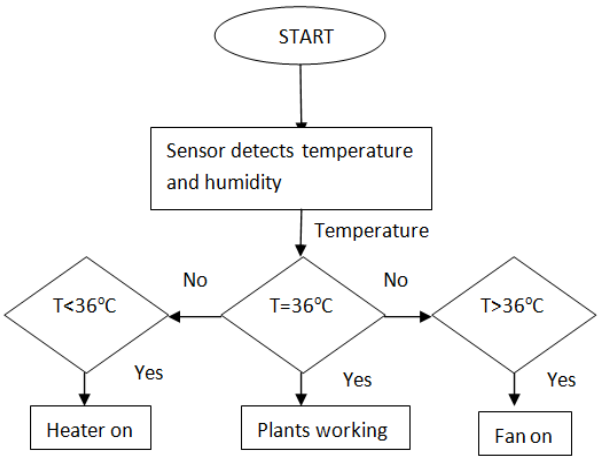

Fig.3 Arduino AT Mega 2560 system control diagram

The temperature sensors such as DHT11 and LM35 detect the distribution of temperature and humidity inside the incubator space and display in LCD installed. When the temperature is less than 36^{0}C then automatically the heater will be turned on until the temperature of 36^{0}C is achieved. When the temperature is over 36^{0}C then automatically the fan will be turned on.

III. Result and Analysis

3.1. Data Research Results

This research was conducted by placing the DHT11 sensor inside the incubator chamber to measure the temperature of the incubator plant. To justify the temperature value out of the sensor is accurate; the sensor needs to be calibrated by comparing the temperature output value using a thermometer. The research of this incubator was firstly performed with a baby who has the weight of 2.0 kg and secondly was performed with no baby/infant. The Data retrieval is done for 3000 seconds.

The table 1 and 2 shows the data of the baby's incubator temperature with the baby/infant and without the baby/ infant. The surroundingtemperature outside the incubator is 32^{0}C. In this incubator chamber, it has installed five temperature sensors such as 4 sensors of LM35 and a sensor of DHT11. The distribution of temperature data is recorded until 3000 seconds. The desired temperature at 36^{0}C is achieved at 300 seconds.

Fig.4Incubator Testing with 2 kg of baby weight

TABLE I
THE DATA OF INCUBATOR BABY WITHOUT INFANT

Time second)	Outside Thermo-meter (T_{d1}(°C)	Sensor DHT11 (°C)	Sensor 4 LM35 (T_0(°C)	Sensor 1 LM35 (T_1(°C)	Sensor 2 LM35 (T_2(°C)	Sensor 3 LM35 (T_3(°C)	Rata-rata Suhu Ruangan (Tf)	Inside Therm ometer (T_{d2}(°C)
0	32	32	32	32	32	32	32	32
100	32	32	33.3	31.5	33.4	34.3	33.1	32
200	32	33	34.5	32.8	33.7	34.1	33.8	33
300	32	34	35.4	34.3	34.2	35.8	34.9	34
400	32	35	36.1	35.4	35.8	36.5	36.0	34
500	32	35	36.3	35.6	36.4	36.3	36.2	35
600	32	35	36.2	35.5	36.3	36.5	36.1	35
700	32	35	35.8	35.6	35.9	36.3	35.9	35
800	32	35	35.7	35.5	36.1	36.2	35.9	35
900	32	35	35.9	35.6	36.3	35.8	36.1	35
1000	32	35	36.2	36.1	36.3	36.3	36.1	35
1100	32	35	36.3	36.3	36.4	36.3	36.3	35
1200	32	35	36.1	35.8	36.6	36.1	36.3	35
1300	32	35	36.3	36.3	36.2	36.4	36.3	35
1400	32	35	36.1	36.2	36.5	36.2	36.3	35
1500	32	35	36.3	36.3	36.4	36.3	36.2	35
1600	32	35	36.5	36.4	36.2	36.2	36.3	35
1700	32	35	36.4	35.7	36.3	36.4	36.2	35
1800	32	35	36.3	35.8	35.9	36.3	36.1	35
1900	32	35	36.2	35.7	35.9	36.1	36.0	35
2000	32	35	36.5	35.4	35.9	36.2	36.0	35
2100	32	35	36.3	35.5	36.2	36.3	36.3	35
2200	32	35	36.4	35.4	35.9	36.4	36.3	35
2300	32	35	36.3	35.8	36.1	36.4	36.3	35
2400	32	35	36.3	35.7	36.2	36.3	36.2	35
2500	32	35	36.5	35.7	36.3	36.3	36.2	35
2600	32	35	36.5	35.8	36.2	36.3	36.2	35
2700	32	35	36.2	36.2	36.1	36.4	36.3	35
2800	32	35	36.3	36.3	36.4	36.2	36.4	35
2900	32	36	36.3	35.4	36.2	36.3	36.3	35.5
3000	32	36	36.4	35.6	36.3	36.4	36.3	35.5

TABLE II
THE DATA OF INCUBATOR BABY WITH 2 kg of WEIGHT

Waktu (detik)	Thermometer luar (T_{d1}(°C)	Sensor DHT11 (°C)	Sensor 0 LM35 (T_0(°C)	Sensor 1 LM35 (T_1(°C)	Sensor 2 LM35 (T_2(°C)	Sensor 3 LM35 (T_3(°C)	Rata-rata Suhu Ruangan (Tf)	Thermo ter dal (°C)
0	32	32	32	32	32	32	32	32
100	32	32	33.4	32.2	32.4	33.2	33.4	32
200	32	34	35.2	33.8	34.9	36.1	35	32.5
300	32	35	36.3	35.3	36.2	36.2	36.1	34
400	32	35	36.1	36.4	36.3	36.3	36.3	34
500	32	35	36.4	35.2	36.3	36.2	36.3	35
600	32	35	36.2	36.3	36.3	36.5	36.3	35
700	32	35	36.2	36.4	36.1	36.3	36.3	35
800	32	35	36.3	35.7	36.2	36.2	36.2	35
900	32	35	36.5	35.8	36.2	36.2	36.2	35
1000	32	35	36.2	36.1	36.2	36.3	36.2	35
1100	32	35	36.3	35.7	36.5	36.2	36.1	35
1200	32	35	36.1	35.6	36.2	36.3	36.3	35
1300	32	35	36.3	35.8	36.2	36.2	36.2	35
1400	32	35	36.4	36.1	36.2	36.3	36.3	35
1500	32	35	36.6	36.4	36.3	36.3	36.2	35
1600	32	35	36.5	36.4	36.3	35.9	36.3	35
1700	32	35	36.4	35.7	36.3	36.3	36.3	35
1800	32	35	35.8	35.8	36.4	36.3	36.1	35
1900	32	35	35.7	35.7	36.2	36.2	36.0	35
2000	32	36	36.5	35.5	35.8	36.2	36.0	35
2100	32	36	36.3	35.6	36.2	35.8	36.3	35
2200	32	36	36.4	35.4	35.9	36.4	36.3	35
2300	32	36	36.2	35.5	36.2	36.5	36.1	35
2400	32	36	36.3	35.7	36.3	36.1	36.2	35
2500	32	36	36.4	35.8	36.3	36.3	36.3	35
2600	32	36	36.5	35.7	36.2	36.4	36.2	35
2700	32	36	36.4	36.3	36.4	36.4	36.3	35
2800	32	36	36.3	36.3	36.2	36.2	36.3	35
2900	32	36	36.5	35.4	36.4	35.9	36.3	35.5
3000	32	36	36.3	35.5	36.3	35.9	36.3	35.5

3.2.Analysis of Temperature using MATLAB/Simulink

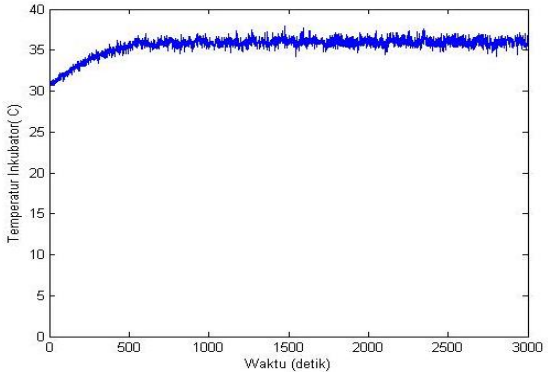

Fig.5 Distribution temperature without infant in incubator.

Figure 5. It appears that the incubator can reach the temperature of 36^{0}C after 500 seconds. The heat continues to spread until the temperature's stability is maintained until testing it at 3000 sec. From the comparison of the graphic above, there is a connection of temperature stability at the required time which is influenced by the fluid flow velocity. The air flows down the top of the box and begins to increase the density due to the cooling of the upper wall. As a result of increasing density, the fluid flows downward faster, so that the temperature distribution in the incubator space is in accordance with the temperature required by the baby/infant.

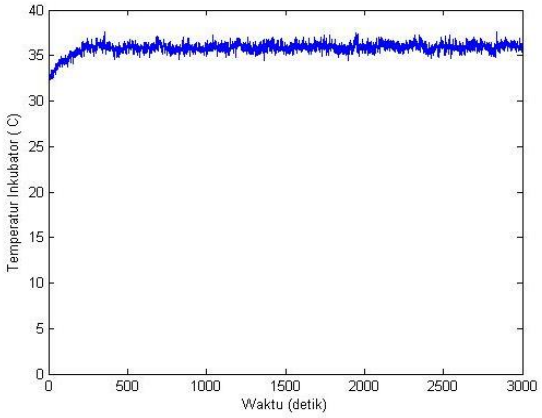

Fig.6Temperature Distributionin incubators with 2 kg of weight

Figure 6. It can be seen that the temperature changes or oscillates continuously to achieve stability and starts to stabilize from 400 to 3000 seconds. Thus the system in general has produced a fairly good controlling action.

IV. CONCLUSION

By adjusting the incubator heating by using the MATLAB / Simulink program , the temperature in the baby's incubator can be stabilized at the normal temperature of . The stabilized temperature of 36 ^{0}C inside the baby's incubator is very important because it maintains the baby's temperature within normal limits and keep the air humidity in accordance with the required value limit In the baby's incubator. The design of the on / off control system with the help of MATLAB/Simulink program is very accurate to compute the result as desired.

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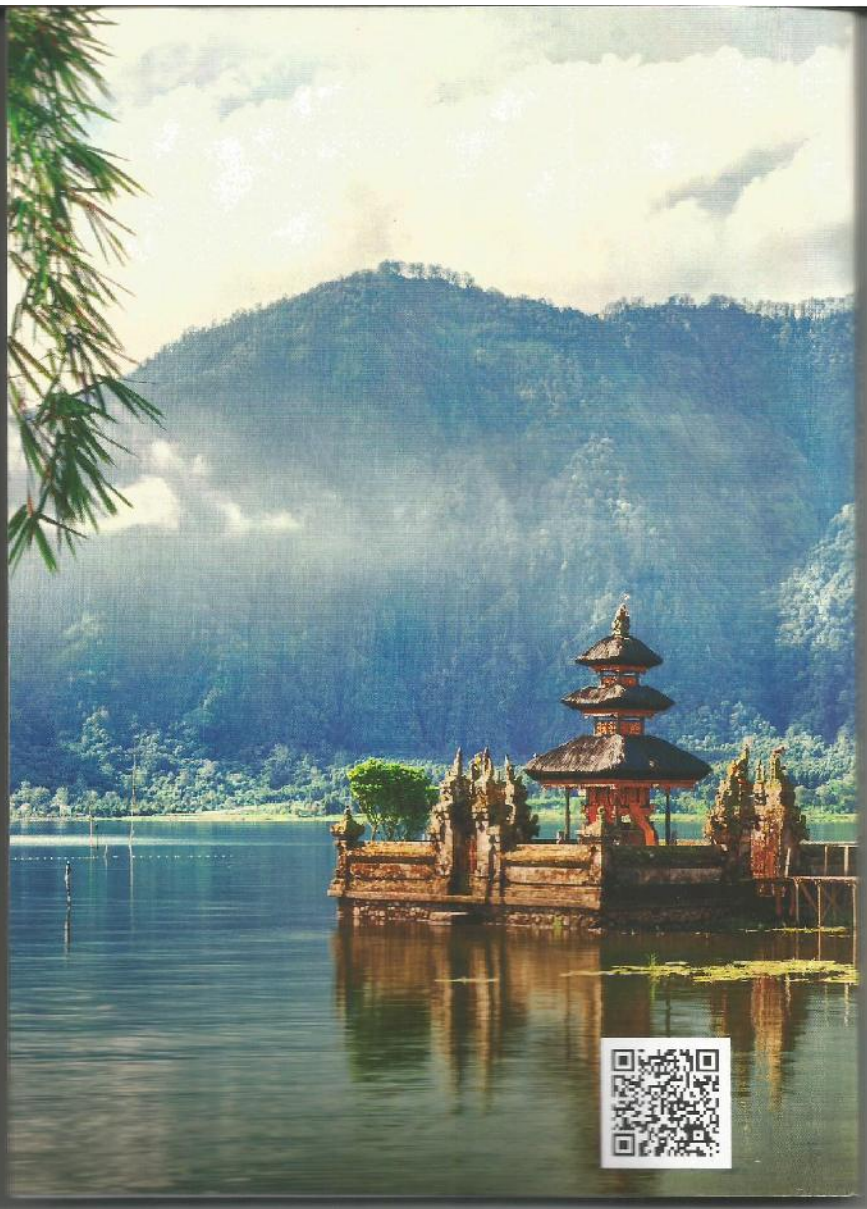

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