Numerical Analysis for Temperature Profile of the Closed House Using Computational Fluid Dynamics

by - Munadi

Numerical Analysis for Temperature Profile of the Closed House Using Computational Fluid Dynamics

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Abstract. This study aims to analyze the air temperature distribution in the closed house system for broiler using ABAQUS CFD Model. The obtained data is used for placing the temperature sensor before making the control system for the closed house. The dimesion of the experimental house was 30 m x 12 m x 2 m (length x width x height) which could be occupied by 7.500 broiler. The wall was made from expose mercy brick and curtain, ventilation system used 7 exhaust fan with diameter 1 m and 2 cooling unit, the roof was made from wood, and system used 45 of 7 watt lamp. The results of the analysis show that temperature distribution occurs on temperature 21-33.5^{0}C and still relatively comfortable for broiler at the age of 1-21days. The air temperature distribution near the cooling unit is lower and increases to near the exhaust fan. In addition, the air temperature in the area near the roof is more high than others.

INTRODUCTION

Indonesia is a very fertile agrarian country. The majority of the population lives from the agricultural sector and work as farmers, plantation, farms and fishermen. One of the farms that live in Indonesia is the broiler farming. For the broiler farming, it needs better and continuous maintenance to produce the broiler that has a good quality. The climate change that currently occurs, directly or indirectly the temperature and humidity of the cage to be changed drastically. This is not handled properly can lead to high mortality rates and decreased production broiler[1]. In such us production process the response of the animal to its environment is the most important part. However this information is not measured during the production process nor taken into account for climate control purpose in animal production house[2]. Increased consumption of the broiler meat required broiler breeders are able to maintain the broilers well. One of the decisive factors to produce the good broilers is the closed house system. A good a system requires proper air conditioning management, because broiler require different room temperatures at each growth period[3].

The thermal environment condition (temperature, relative humidity, wind speed and solar radiation) is very important to animal production, because it can affect broiler homeothermy responsible for guaranteeing the welfare and productive responses[4], So, the temperature is the main climatic parameter, the overall climate indoors is determined by the dynamics of the sensible and latent heat present in the building. Consequently, the water vapour released from various sources such as the broilers, the rearing system, the heaters and the degree of natural ventilation should all be included when calculating heat and mass balances. Also gases derived from the dynamics of heat and water vapour generation such as CO_2 should be incorporated since they impact on the environment and animal welfare[5].

The closed house system is recently used for the broiler production. The place where broiler are kept in order to providea healthy environment and to enhance optimum feeding efficiency for the broiler. To get the most productivity in poultry production, it is essential that the thermal environment presents appropriate comfort levels. When thermal environment becomes uncomfortable, the body of the broiler will begin to require some physiological adjustments in order to maintain their homoeothermic conditions making them to either retain or dissipate heat[6]. The air temperature and relative humidity of this housing can be controlled by mechanical ventilation and wind tunnel which are equipped

Engineering International Conference (EIC2017)
AIP Conf. Proc. 1941, 020032-1–020032-7; https://doi.org/10.1063/1.5028090
Published by AIP Publishing. 978-0-7354-1633-8/$30.00

with a cooling pad. The ventilation system in the closed house can reduce environmental head load produced by the metabolic heat of the broiler, cage material which exposed to solar radiation, the heat from brooder and heat of litter fermentation[7]. The closed house system is an enclosure system that must be able to remove excess heat, excess moisture, harmful gases such as CO, CO_2, and NH_3 in the enclosure.

To maintain the air temperature and humidity inside the poultry house at the desirable level in ahot, humid climate in a country, such as Thailand or Indonesia, ventilation fans, evaporative cooling systems, and electronic controllers are essential components. Moreover, many recently developed devices and technologies have been applied to the poultry house environment control related works[8]. The control of environmental conditions is crucial for the success and safety of livestock. To keep the broiler healthy and productive, the environment needs to be maintained, air quality, food, and water[9]. In a conventional the broiler farming monitoring system, feeding and water supply, environmental parameters such as temperature and humidity are done manually. To provide the appropriate environment, we have to manually operate different devices such as air conditioners, blowers, exhaust and others that are complicated for humans and the mechanism is outdated. It is possible to control the conditions (temperature and relative humidity) in the enclosure to fit the broiler conditions thereby minimizing brolier death and increasing production.

The broiler breathe by inhaling oxygen and releasing carbon dioxide gas and water, if too low oxygen levels in the enclosure this condition relates to the temperature and humidity of the cage, it will have an impact on broiler production and health. The broiler poison contains toxic gases of ammonia (NH_3), hydrogen sulfide (H_2S), carbon dioxide (CO_2) and methane. Among the gases that cause the most problems for the health and productivity of livestock and settlements are ammonia[10].

Maintenance of the broiler in the tropics as in Indonesia requires careful attention and accurate in order to obtain optimal results. High temperatures and humidity in the tropics allow easy stress broiler that lead to easy broiler disease, growth disorders, increased feed conversion and increased broiler mortality. The factors of temperature and humidity in the maintenance of the broiler especially in the tropics is one factor that is very important in the success of broiler farms. Therefore, an early handling of optimal temperature requirements in the broiler phases and the consequences that can occur when maintenance temperature is not considered and how to handle it.

There are many parameters such as a temperature, relative humidity and air movement that are needed to be monitored in poultry house. As the thermal environment becomes increasingly stressful, the animal body perceives the risk to life and ceases to prioritize production and reproduction but focus only on their survival[11]. Next, tropical environmental conditions required by farm technology in the form of control system to optimize environmental management of broiler closed house gives the result of cultivation of livestock which has economic characteristic with characteristic characteristic such as fast growth, as producer of meat with low food conversion and ready to cut at relatively young age.

One of the factors that lead to decreased productivity. The broiler in closed house systems are uneven airflow rates around housing. The non-uniform distribution of air flows in the housing system resulted in uneven distribution of air temperature and relative humidity among places in the housing. This condition ca reduce animal performance and increased animal mortality. The problem of air flow distribution in the housing can be analyzed quickly and simulytaneously by using computational fluid dynamics[12].

To produce the quality of the broiler, reduce mortality, and increased production of the broiler required good environmental conditions that is the temperature in accordance with the needs of broiler. So, we need to design the cage and control or control system of temperature and relative humidity in enclosure closed house for broiler production increasing. Simulation is done to predict the distribution of enclosure closed house broiler. The input temperature of 1-7and 8-14 days of data collection is the temperature of the cage.

CFD MODEL AND METHOD

The simulation was done at Robotic, Automation, amd Computation Laboratory Department of Mechanical Engineering, Faculty of Engineering, Universitas Diponegoro. The experimental design dimension (closed house designed for the broiler) is 30 m x 12 mx 2m (length x width x height) which can be occupied by 7,500 broiler. The floor is made of concrete cement, the roof is tin, the walls are made of bricks and tarps. Ventilation system using 7 exhaust fan installed to lower the temperature on the cage. The geometry of the enclosure can be seen in Fig. 1.

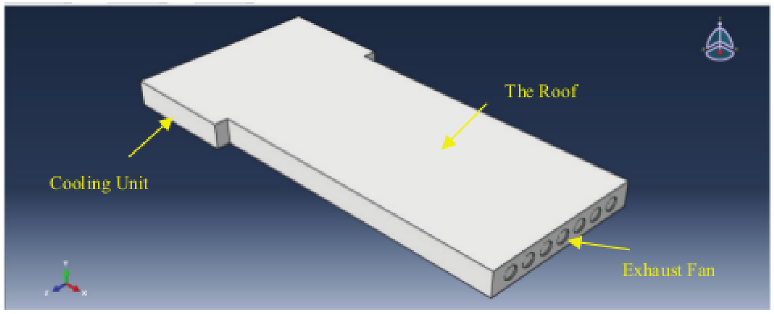

FIGURE 1. Geometry of closed house

The assumptions used in the analysis of air temperature distribution in enclosed enclosures using CFDs are: (a) home air is considered a compressed fluid, (b) constant fan motion during simulation, (c) specific heat, conductivity and air viscosity constan. The computation in solver of CFD based on mass, momentum, and energy. The equations are described as equations[13] 1 to 3.

$$\frac{\partial \rho}{\partial t} = \frac{\partial \rho}{\partial x_i}\left(\rho u_i\right) = S_m \tag{1}$$

Where x_i = component of length (m) , u_i = component of velocity (m s^{-1}), ρ = fluid density (kg m^{-3}), and Sm = mass source (kg m^{-3} s^{-1}).

$$\frac{\partial}{\partial t}\left(\rho u_i\right) + \frac{\partial}{\partial x_i}\left(\rho u_i u_i\right) = -\frac{\partial \rho}{\partial x_i}\frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i + F_i \tag{2}$$

Where p = pressure (Pa), τ_{ij} = stress tensor (Pa), gi (gravitational acceleration) (ms^2), Fi = external force vector (Nm^{-3}) and t = time (s)

$$\frac{\partial}{\partial t}(\rho h) + \frac{\partial}{\partial x_i}(\rho u_i h) = \frac{\partial}{\partial x_i}\left(K\frac{\partial T}{\partial x_i}\right) - \frac{\partial}{\partial x_i}\sum_j h_j J_j + \frac{\partial p}{\partial x_i} + u_i\frac{\partial p}{\partial x_i} + \tau_{ij}\frac{\partial u_i}{\partial x_j} + S_h \tag{3}$$

Where J_j = component of diffusion flux (kg m^{-2} s^{1}) h = spesifik enthalpy (J kg^{-1}), K = thermal conductivity (W m^{-1} ${}^{0}K^{-1}$), Sh = total entropy (J $^{o}K^{-1}$) and T = temperature (^{o}K).

RESULTS AND DISCUSSION

Simulation of air velocity and temperature distribution at 1-21 days, in simulation there is no initialization broiler heat that affect the temperature of the cage. Simulation is a steady state simulation because it uses daytime data to represent the optimum temperature due to solar radiation. Temperature measurements were made at 12.00 using the Big Dutchman data logger with bright weather conditions. Input of boundary condition for computation of analysis air velocity and temperature in closed house system for broiler using ABAQUS CFD Model are describe at Table 1.

TABLE 1. Boundary Condition

Input Boundary Condition	Age 1-7 days	Age 8-14 days	Age 15-21 days
	12.00	**12.00**	**12.00**
Roof temperature (°C)	33.5	33	33
Right curtain temperature (°C)	33	33	33
Left curtain temperature (°C)	33	33	33
Right cooling Unit temperature (°C)	26	26	26
Left cooling Unit temperature (°C)	26	26	26
Litter temperature (°C)	34	34.45	35.45
Atmospheric pressure (Pa)	101325	101325	101325
No of activated exhaust fan	3	5	7
Meshing	150	150	150

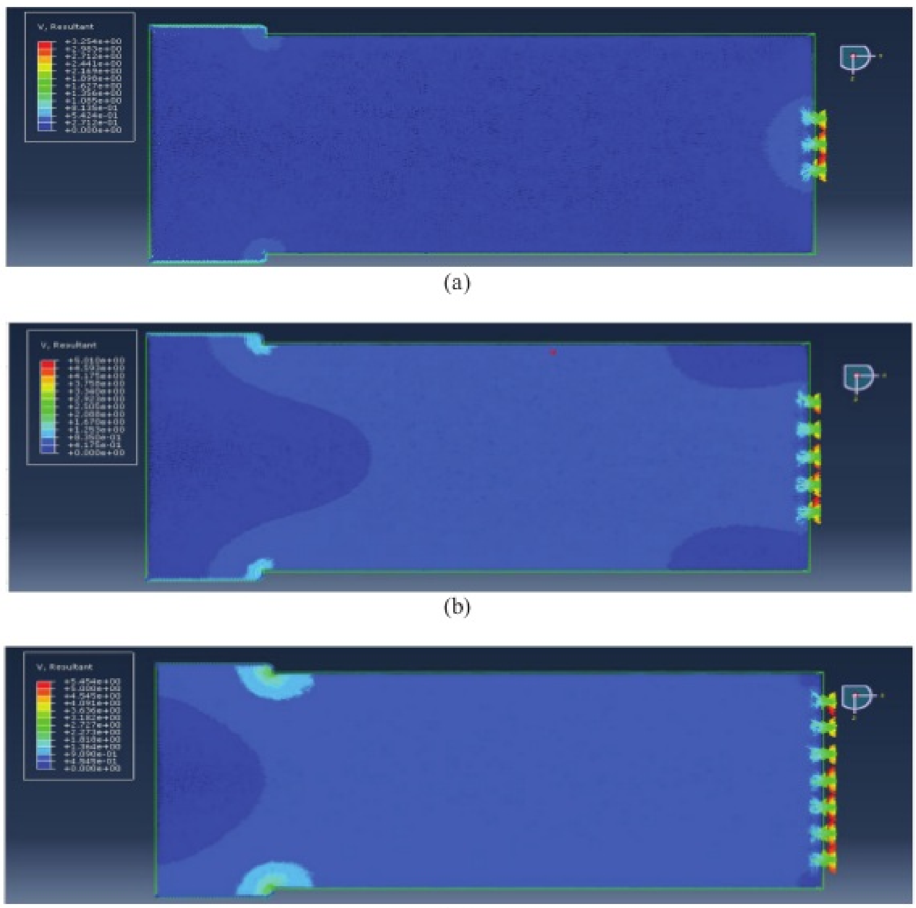

FIGURE 2. The profile of the air velocity at the closed house:(a) 1-7 days (b) 8-14 days, (c) 15-21 days

The geometry of the closed house coop is assumed to be a thin flat plate that does not affect the flow in the simulation. Two air inlet areas located in front of cooling system are defined as the environment pressure, the exhaust fan is assumed to be the velocity outlet. The mesh selection uses a value of 150 on the meshing process via mesh control test, with the number 1159357 element, number of nodes is 213722, iteration limit of mass equation linear solver is 250 (default), iteration limit of momentum equation linear solver is 50 (default), and iteration limit of energy transport equation linear solver is 50 (default)

The simulation results are shown in the form of contour and vector. The simulated image graph is shown in Fig. 2 to show the profile at air velocity. Figure 2 illustrates the incoming air from the cooling edge due to the suction of the exhaust fan. The presence of air pressure at the cooling end so that the force of the fluid urges the direction of the fluid flow. Based on Fig. 2, more and more fans are active, the flow of air velocity inside the closed house is more evenly distributed.

(a)

(b)

(c)

FIGURE 3. Temperature profile at closed house on side view:(a) 1-7 days; (b) 8-14 days; (c) 15-21 days

Figure 3 shows the temperature near the cooling unit was lower than at the other locations because this location was first area that crossed through by cold air from cooling unit. At age 1-7 the air temperature is higher because the broiler need heat to survive. That has because the input temperature distribution of the cage should be controlled in accordance with the needs of the broiler. The temperature of the closed house at the age of 15-21days is lower because the broiler get bigger, and the heat released by the broiler is also higher.

FIGURE 4. Temperature profile at closed house on top view:(a) 1-7 days; (b) 8-14 days; (c) 15-21 days

Figure 4 shows the difference in temperature between 1-7 days, 8-14 days, and 15-21 days. The temperature distribution at 1-7 days ranges from 29°C-33.9°C, at ages 8-14 ranging from 26.5°C-33°C, and at ages 15-21 ranging from 21°C-33°C. It is still relatively comfortable temperature for broiler at the age of 1-21 days. The roof tended to be higher than other measurement, because the roof while cooling unit is 2 m of high. The roof had higher temperature due to the heat released from the roof and the lamp attached on roof.

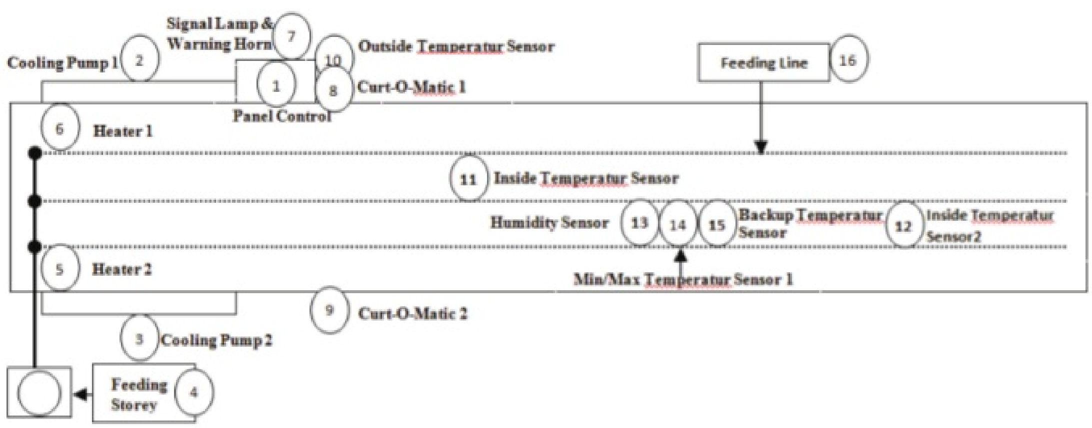

FIGURE 5. Layout Design of the Closed House

Figure 5 shows the layout design of the closed house. The layout data taken from Jatisari Farm in Purwodadi, Central Java, Indonesia.The dimesion of the closed house was 90 m x 12 m x 2.2 m (length x width x height) which could be occupied by 15.000 broiler. Based on the cage layout we can know that the temperature sensor is placed at number 11, 12, 14 and 15.

CONCLUSION

We had ABAQUS CFD Model is used to analyze the distribution of air temperature in the closedhousefor the broiler. The simulation results show that the temperature near the cooling unit is lower and increases towards the exhaust fan. Predicted average temperature distribution of 21^0C-33.5^0C in the closed house for broiler. This condition is still relatively comfortable for broiler at the age of 1-21 days. Based on the analysis of the spread of temperature near the roof is evenly distributed. So, we can placed the temperature sensor based on fig. 5 observation data.

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