Analysis and Development of a Poultry Hatching Machine

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Abstract: The egg-hatching machine comprises a several main factors that has been adapted and developed in this machine. The main factors are temperature, humidity, turning orientation and ventilation. The development of the machine without considering these factors will lead to failure or low percentage of hatching success. Therefore, these important factors must be included and adapted to machine. The best temperature for egg incubation is 37.8 °C or 100 °F and for relative humidity is from 55% to 65%. For egg, turning and orientation can be done from 2 to 6 times daily. The angle for turning is from 30° to 90°. The use of forced-air incubation method in this machine instead of still-air incubation had helped to regulate the air and supply oxygen to the eggs in the chamber. Besides considering all factors, other supportive factor that will help to increase the percentage of hatching success also must not be neglected. The supportive factors are location to place the machine, insulation for preventing heat loses and hygiene or cleanliness of the machine. Although these supportive factors are not the main parameter for egg incubation, these factors also need some attention as they also one the keys for hatching success.

1. Introduction

The chicken (Gallus gallus or G. gallus domesticus) is a domesticated fowl which descended from the wild Red jungle fowl which found in India (species: Gallus Gallus) [1]. The species spread domestically throughout some of the areas in Asia including India where it was used for cock fighting. Nowadays, chicken is one of the most common and widespread domestic animal in the world. There are more chickens in the world than other birds which has a population more than 24 billion in year 2018 [3].

Humans keep chickens primarily as a source of food, with both their meat and their eggs consumed. Chickens are omnivore where they eat all kinds of food sources including meats and plants. In the wild, they often scratch the soil to search for seeds, worms, insects and sometimes larger animal such as lizard. In nature, chickens may live for five to eleven years depending on the breed. Chickens are the source of food that is rich in protein. Due to the taste and always known for the cheap sources of food, chickens have always achieved a good demand by the consumer throughout the year. This phenomenon also
happens in Malaysia where the chicken broiler industry was the biggest broiler industry among other broiler industry. The industry was so successful and until now it still rapidly develops years by years. Today, the chicken meat industry is worth RM2.3 billion that involve more than 400 million amounts of chickens [2]. In order to keep the amount of chicken is proportional to the consumer’s demand, an incubation of the egg must be implemented gradually. Incubation is the process by which the embryo within the egg develops into a fully formed chick capable of breaking free from the shell. Incubating eggs requires several important environmental considerations if any chicks are to hatch. Of primary concern are temperature and relative humidity. Attention to secondary considerations can result in increased numbers of eggs hatching [3, 5]. Generally, there are two method of chicken egg incubation. The first method is naturally incubation where it uses a broody hen to incubate eggs by sitting on them in a nest. Broody hen is the female chicken that has a behavior for its natural characteristic of sitting on egg. If given the opportunity, most female chicken will become broody and sit on and hatch the clutch of eggs they have just laid. However, the broody hens are not always available to incubate the eggs. Therefore, there are some efforts of increasing the broodiness of hen. The hen was set to have high behavior of broodiness and it has been bred out of some chicken.

Some breeds commonly used to hatch eggs include New Hampshire, Plymouth Rocks, Rhode Island Reds, and Cochins [4, 6]. Besides, bantam variety also makes good mother (higher behavior of broodiness). The method also works best for a small clutches of eggs only. Another consideration is hen size. If the hen is come from larger breed, it may accommodate more than a dozen of large chicken egg, 10 duck eggs, or 5 goose eggs. But, for smaller breed such as Bantam, it may only can accommodate about 6 large chicken egg and not very useful to incubate larger egg such as duck and goose eggs. The second method is artificially incubation. It uses an incubator or a hatching machine to imitate the job or work of the mother and broody hen [6]. The incubator closely controls the four factor of hatching parameter. The parameters are temperature, humidity, ventilation and turning orientation. The incubator will control those parameters within the proper limits to hatch chicks. Artificial incubation is an excellent alternative to the mother and broody hen [4-6].

2. Design Strategy
The design strategy are focuses on the concepts and theories of design that are much related to the fabrication of egg hatching machine. Design strategies will discussed on the associate theory on engineering application and relate them for developing ideas and solving design problems.

2.1 Steady flow system
Steady-flow process is a process during which a fluid flows through a control volume steadily. The fluid properties can change from point to point within the control volume. However in steady-flow process, the properties remain constant during the entire process [6]. Steady by means is no change with time. Figure 1 shown the steady flow process in assumption process on analysis in incubator system.

2.2 Conservation of Energy of a Control Volume
The main point in designing approached is to determine the total energy of the system in the incubator. The value of total energy of the system will lead to determine the sufficient amount of light bulbs needed to incubate the eggs. The incubator is assumed to be an open thermodynamic system that has an inlet and outlet of air that are flowing in and out of the system [5-7]. Besides that, the incubator is also believed to have constant of mass entering and exiting the chamber. Calculated the volumetric flow rate for 2 units of 120mm x 120 mm axial flow fan is 0.0423 m$^3$s$^{-1}$. Total energy of the system is 537.8 W. Figure 2 shows a control volume has been taken on the conservation of energy analysis for incubator system.
2.3 Convection, Radiation and Conduction Heat Transfer in the System

This analysis is focused on transferring heat from source to eggs. Therefore, the heat calculation for heat transfer also needed in this project. There are 3 types of heat transfer in the incubator. Then, those types of heat transfer are summed together to determine the value of total heat transfer of the system. In order to ease the calculation, the value of design surface area for 0.9m x 0.8m x 0.5m incubator is 3.14 m². By used the Newton Cooling laws \([8,9]\) to determine the forced convection is 1717.2 W. Heat radiation is 1660.96 W, is determined by using the Stefan-Boltzmann law, of Thermal Radiation. Fourier’s law equation is used to determine the value of heat conduction. By calculated the value of heat conduction is 406.94 W. Then the total heat transfer of the system is 3785.1 W.

2.4 Mechanical Design Calculation and Analysis

This part is analysis and calculations that are related to design of mechanical system for an eggs hatching machine. Those calculations are important in designing and developing the egg incubator. By used some related equation from fundamental and conservation laws of physics, those equations are used for calculations. The result of those calculations are compiled together and used in this design strategies as step by step.

2.4.1 Stepper Motor Load Capacity

In the manual, it stated that the stepper motor maximum work load that the motor can handle is 80 N. Therefore, to lift up the tray holder during turning, the summation weight of the tray holder, tray and
eggs must not exceed 80 N. However, in the design there are two M10 bolts that are attached to the body to hold the tray holder. Therefore, the maximum weight that the stepper motor can handle might be different due to the attachment of bolts.

On the other end, the tray holder is attached to lead screw. As the stepper motor moves the lead screw, the tray holder will move upward or downward. The attachment of the bolts and lead screw to the tray holder will change the maximum load of stepper motor. Using equilibrium of static principle, we can find the new maximum load that the motor can afford to handle before failure.

Let assume that maximum weight, $W$ is 160 N where $F$ is upward force to lift up the tray holder (N) and $x$ is distance (m). The maximum weight for stepper motor can handle is 160 N or 16.31 kg in mass. Therefore, the summation of weight of tray holders, trays and eggs must not exceed 160 N or 16.31 kg.

Figure 3 shown the incubator system has been used for the analysis and design. Basically, the machine will operate as forced-air incubator. The air from the surrounding is being forced to the chamber by the fan. A number of fans are attached to the machine. The fans that are attached to the top of the machine will be the air inlet to machine, where on the bottom will be the air outlet. Meanwhile, the light bulbs will be as a source of heat to the chamber. The heat from the bulb is being distributed around the chamber by medium of air that is being force by the fan from outlet to inlet. This concept is applied to the machine by using a force convection heat transfer concept. Besides that, radiation of heat from the light bulbs itself is also a source of heat to the chamber.

Figure 3. Incubator System for Design Calculation and Analysis.
2.4.2 Calculation for Tray Holder
The machine must be fabricated as economical as possible. In order to reduce the cost of fabrication for this machine, the paper egg tray is used as a container to place the egg. Standard dimension for paper eggs tray is 300mm (l) x 300mm (w) x 40mm (h). Assume that an aluminum hollow section that has a dimension 80mm in height and 25mm in width is used to fabricate the egg holder.

2.4.3 Calculation for Machine Height
There are 2 tray holders that will be placed in the machine. Those trays will be installed in two levels. One level is only for one tray holder. The holder will be tilting about 30°, where 15° going upward and 15° going downward. Using the data given, calculate the height of machine as the length of tray holder is 375mm as calculated earlier.

2.4.4 Calculation for Machine Width
Basically, the width of the egg hatching machine is depend on the size of tray holder. The tray holder must be fitted in the machine chamber. The width must be accurately calculated. If the width of machine is calculate incorrectly, there is a possibility that the tray will not fit into the machine.

2.4.5 Calculation for Machine Length
The machine length also depends on the size of the tray holder. The dimension must be accurately calculated so that the tray holders will fit in the chamber. Besides, the dimension of length must also consider the allowance of tray holder during turning. Therefore, the tray holders will not coincide with the wall of chamber, hence allowing them to move efficiently without having any obstacle during turning orientation.

3. Results and Discussions
In the nutshell, the keys for achieving a success in egg incubation are the factors that influenced it. The egg hatching machine comprises a several main factors that has been adapted and developed in this machine. The main factors are temperature, humidity, turning orientation and ventilation. The development of the machine without considering these factors will lead to failure or low percentage of hatching success. Therefore, these important factors must be included and adapted to machine. The best temperature for egg incubation is 37.8°C or 100°F and for relative humidity is from 55% to 65%. For egg turning and orientation can be done from 2 to 6 times daily. The angle for turning is from 30° to 90°. The use of forced-air incubation method in this machine instead of still-air incubation had helped to regulate the air and supply oxygen to the eggs in the chamber.

Besides considering all factors, other supportive factor that will help to increase the percentage of hatching success also must not be neglected. The supportive factors are location to place the machine, insulation for preventing heat loses and hygiene or cleanliness of the machine. Although these supportive factors are not the main parameter for egg incubation, these factors also need some attention as they also one the keys for hatching success. Artificial incubation is not a new method to incubate eggs. It is widespread practice all over the world. It is become a popular method to hatch eggs due to the increase the production of eggs and reduction of spread of diseases. The importance of artificial incubation is also undeniable as it also helps by decreasing the number extinction among wild life. Artificial incubation method is approved to have better result in incubation rather than natural incubation by hen.

4. Conclusions
In fabrication of a machine, there are two criterions that needed to be considered during the early stages of development. The criterions are the design consideration and characteristic. Those criterions will be the guidelines for fabrication of the machine. The guidelines are important to ensure the machine is developed according to the machine specifications. The incubator is successfully designed and the materials that been selected also been accurately selected as the result on the analysis show that the parts
are not critically in stress. Beside the factors, a several matter also needs to be considered during the operation of the incubator as it also will affect the result in hatchability.

This paper report has a good potential for commercial purposes. Today, the poultry business is rapidly developed in many countries such as Malaysia. For instance, in 2018, chicken meat industry in Malaysia is worth RM2.3 billion that involve 400 million amount of chicken. There must be a demand on eggs incubator that is reliable, economical and practical. Therefore, this project could be an alternative for chicken broiler instead of the incubator that already have in the market. This egg hatching machine can be use by all kinds of people in the society, from farmer and villager, to a small scale industry entrepreneur. Due to its small size, it is also suitable to be used at home. Besides, the egg incubation could also be as a hobby that can bring profits and generates money.

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