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POULTRY FARM VENTILATION SYSTEMS USING DIRECT EVAPORATIVE COOLING AND CFD ANALYSIS

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Abstract

Submersible motors are critical components in agriculture, water management, and industrial applications, yet they suffer frequent failures due to harsh operating conditions and inadequate maintenance. This paper presents the design and implementation of an intelligent preventive maintenance kit utilizing Internet of Things (IoT) sensors, edge computing, and cloud analytics for real-time condition monitoring and predictive maintenance of submersible motors. The proposed system employs a NodeMCU ESP8266 microcontroller integrated with multiple sensors to continuously monitor motor health parameters including temperature (DS18B20), vibration (MEMS accelerometer), voltage, flow rate, and RPM. Data is wirelessly transmitted to a cloud platform where machine learning algorithms analyse patterns and detect anomalies. Experimental results demonstrate the system's capability to identify early signs of insulation degradation, bearing wear, cavitation, and electrical imbalances, thereby reducing unplanned downtime by up to 40% and extending motor lifespan. The kit is low-cost, user-friendly, and deployable in remote areas, making it a practical solution for farmers and small-scale industries. This work contributes to the growing field of IoT-based predictive maintenance and provides a feasible model for enhancing the reliability and efficiency of submersible motor systems.

1. Introduction

Ventilation is crucial for poultry houses as it helps control the indoor climate and air quality. Factors such as relative humidity, air quality, and air temperature are important thermal

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conditions that significantly affect the health and productivity of poultry. Over the years, poultry ventilation practices have evolved, driven by advancements in farming methods and technology. Initially, natural ventilation systems relied on open structures and coops to enable airflow. As the commercial poultry sector advanced, mechanical airflow systems, such as fans, were introduced to better control humidity and temperature.

Recent developments have further enhanced ventilation with sensors and automated systems that allow real-time monitoring of conditions. Prioritizing animal well-being, adequate airflow is essential for reducing discomfort and preventing the spread of diseases. Modern poultry house ventilation focuses on sustainable practices and energy efficiency. The adoption of energy-saving systems not only improves air quality but also plays a critical role in maintaining the health of poultry.

The poultry industry relies heavily on creating and maintaining an optimal environment for breeding and productivity, as environmental conditions directly impact the health, growth, and overall performance of poultry animals. Ventilation plays a critical role in poultry housing by regulating temperature, humidity, and air quality, ensuring that poultry animals remain comfortable and free from stress. Proper ventilation systems help remove harmful gases such as ammonia and carbon dioxide, control excess moisture, and reduce the risk of respiratory diseases and heat stress. Additionally, maintaining a well-ventilated environment contributes to better feed conversion, improved egg production, and healthier livestock. This experimental analysis focuses on evaluating various ventilation systems and their efficiency in maintaining suitable environmental conditions for poultry. By monitoring factors such as airflow, temperature, and humidity, and analysing their effect on animal performance and productivity, this study aims to optimize ventilation practices, enhance breeding outcomes, and promote sustainability within the poultry industry

2. Literature Review

Predictive maintenance of submersible motors has attracted significant research attention, with various condition monitoring techniques and preventive strategies being explored. This section examines relevant contributions in the field, highlighting technological advancements and gaps that motivate the current work.

The tunnel ventilation systems are primarily used in China for poultry houses, with most research focusing on summer conditions and limited attention given to winter seasons. Exhaust fans are essential for improving the indoor thermal environment. For adult chickens, the thermal neutral zone ranges from 291 K to 296.9 K. During winter, climatic changes expose chickens to cold stress, leading to weight loss and reduced feed intake, which negatively affects egg quality, including egg weight and yolk index. Proper ventilation is also crucial for reducing contaminants, odors, and volatile organic compounds, making tunnel ventilation systems indispensable. Computational Fluid Dynamics (CFD) methods were utilized to optimize exhaust fan layouts and improve the indoor thermal environment. The thermal performance of the system was evaluated using the nonuniformity coefficient and the Temperature-Humidity-Velocity Index (THVI). The study found that the indoor velocity distribution had a nonuniformity coefficient of 0.74 and a maximum velocity difference of 0.62 m/s, while the

indoor air temperature distribution had a nonuniformity coefficient of 0.16 and a maximum temperature difference of 285.9 K. Only 61.4% of the space was within the thermal comfort zone, but by placing exhaust fans symmetrically at the front and end walls and optimizing their sizes, uniform air velocity and temperature improved by 22% and 88.33%, respectively [1].

The focus in this paper on investigating localized HVAC systems for broiler chicken brooding to ensure the thermal environment is optimal and air quality is maintained. The aim is to design a system that reduces energy consumption while meeting ASHRAE and European Gas Standards. The method used in this paper is CFD modeling, where the system's performance is analyzed. A comparison is made between two systems: a localized heating system with side ventilation and a fully mixed heating and ventilation system. It ensured that CO₂ and ammonia concentrations remained within acceptable limits. The results show that the localized system saves 74% of energy compared to the conventional mixed system, and the solar system covers 84% of the load required for six weeks of winter. Factors contributing to the 74% energy savings in the solar-assisted localized system include heating efficiency, which helps provide heat to the chickens, and the sustainability maintained by the solar-assisted system, among others [2].

Studied how to maintain a healthy environment in broiler houses, with a focus on the microclimate, which is important for productivity. A mathematical model was developed that correlates the weight and age of broilers with their specific needs in hot climates, to regulate pressure and air velocity inside a mechanically ventilated poultry house. Both mathematical simulations and experimental calculations were conducted. The parameters considered included indoor air temperature, humidity, air velocity, and differential pressure, with relative errors and mean square errors calculated for air velocity and differential pressure. The results showed that the differential pressure ranged from -5 to 39 Pa, while the air velocity varied from 0.09 to 1.641 m/s, depending on the ventilation mode used (tunnel, natural, or powered) [3].

Poultry farms often experience poor environmental control due to inefficient ventilation systems. Uneven airflow distribution, excessive heat gain, and inadequate removal of contaminants result in reduced productivity, increased mortality rates, and higher operational costs. There is a need for a scientifically designed ventilation system capable of maintaining uniform temperature and airflow while minimizing energy consumption. The scope of this work includes heat load estimation for a poultry cell, design of a ventilation system using direct evaporative cooling, and CFD-based analysis of airflow and temperature distribution. The study focuses on summer operating conditions and evaluates the effectiveness of the proposed system in maintaining thermal comfort for poultry where L is the failure threshold, $D(t)$ is current degradation level, and dD/dt is degradation rate.

3. Methodology

A. Poultry House Description

The poultry house considered in this study has overall dimensions of 80 m × 30 m × 4 m with a total floor area of 2400 m². The structure is divided into eight identical cells, each measuring 20 m × 13 m × 4 m and housing 125 hens. Industrial exhaust fans and honeycomb cooling pads are installed to facilitate airflow and cooling.

B. Heat Load Calculation

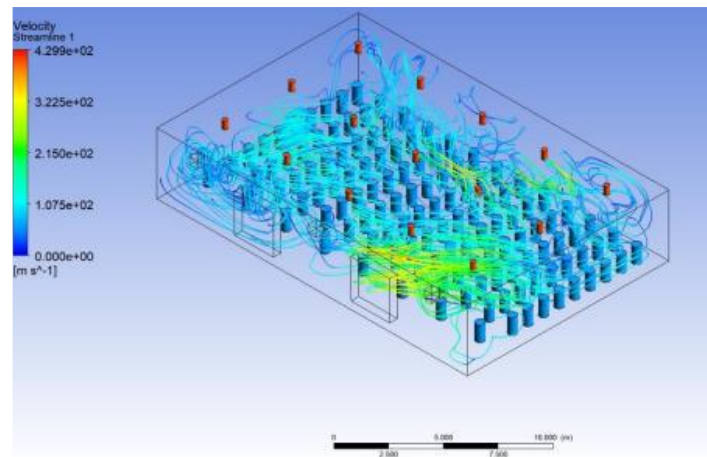
The total cooling load is calculated by considering sensible and latent heat gains from hens, heat transfer through walls, roof, floor, doors, windows, and internal heat sources such as lighting. Each hen produces approximately 7.51 W of sensible heat and 3.3 W of latent heat. The total room sensible heat load is estimated as 53.33 kW, while the total latent heat load is 18.329 kW.

C. CFD Modeling

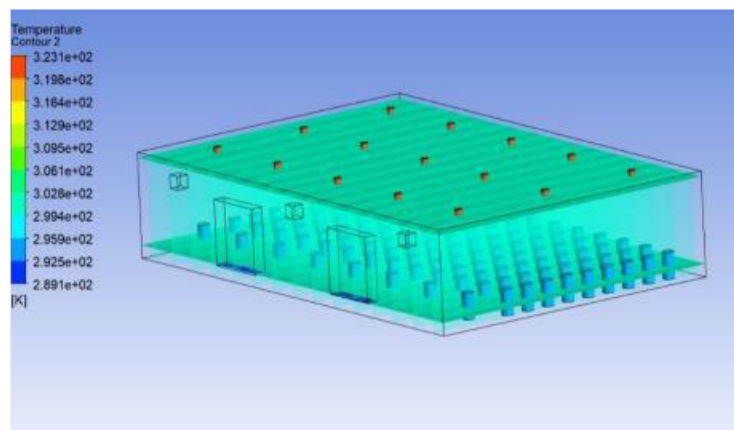
A three-dimensional CAD model of the poultry cell was developed using CATIA and imported into ANSYS Fluent for simulation. Boundary conditions include an outdoor temperature of 305–307 K and an inlet air temperature of 289 K supplied through evaporative cooling pads. The inlet air velocity was set to approximately 10.3 m/s based on cooling load requirements. A fine mesh was generated near critical regions such as air inlets, hens, lights, and walls to accurately capture airflow and heat transfer phenomena.

4. Results and Discussion

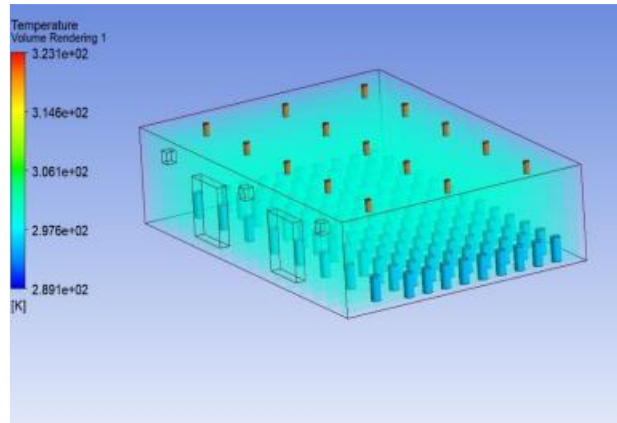
CFD simulation results indicate that the airflow distribution within the poultry cell is uniform, ensuring effective mixing of cooled air. Velocity contours show sufficient air movement reaching all regions of the cell, including corners. Temperature distribution analysis reveals that the average indoor temperature is maintained around 297 K, while the temperature near the hens remains close to 295 K. Higher temperatures observed near lighting fixtures (up to 323 K) have minimal impact on overall indoor conditions due to efficient air circulation. The results confirm that the proposed ventilation system effectively reduces heat stress and maintains a stable thermal environment conducive to poultry health and productivity.



Ventilation is crucial for poultry houses as it controls the indoor climate and air quality. Relative humidity, air quality, and air temperature are thermal factors that affect the health and productivity of poultry. This study aimed to analyze the airflow throughout the cell to determine whether it is sufficient, assess the temperature difference at the inlet and outlet, and evaluate the overall cooling efficiency. The streamlines that occur in the poultry cell show the distribution of cooled air throughout the poultry.



The cell is enough for hens and also sufficient to maintain the temperature in the regions where the temperature is high. Considering streamlined flow the flow at the inlet is higher and at the same velocity, the flow reaches the critical corners of the cell. There was an observation that the temperature at the hen's wall is about 295K, and the temperature around the lights wall is 323K. Overall and according to streamline flow in the critical areas the overall temperature of the cell is maintained at 297 K (Fig.8). So according to the results the system which is implemented for the poultry is efficient and has higher efficiency.



The cooling performance of the system is very efficient compared to others. From the (Fig.9) the temperature distribution over the cell is presented and this temperature goes about 297K which desired temperature in the cell. The temperature of lights is about 323K but it is not affecting on the overall temperature, where the temperature for the hens is 293K.

5. Conclusions

This study focuses on the ventilation system for maintaining a cooling effect with ideal temperature and humidity levels using the direct evaporative cooling method. This will help the hens achieve enhanced breeding and productivity, and due to proper air supply, the spread of diseases will be prevented. CFD simulations are performed to optimize airflow and maintain temperature. The air inlets installed on the side wall ensure proper air regulation in the indoor climate. The calculation for the heat generated i.e. total room sensible heat 53.33Kw for this out input conditions are sufficient to reduce this heat load. The inlet temperature is considerably lower than the outlet temperature, which matches the theoretically calculated temperatures of 297 K at the inlet and 305 K at the outlet. Importantly, the temperature of the hens' bodies is also maintained at 295 K. The effects of the lights are minimized due to the constant room temperature. The results of this research may eventually be used for designing an efficient and effective ventilation system to reduce heat stress and temperature differences in hot climates. Additionally, any advanced ideas or materials that can replace the honeycomb structure could lead to further research into a cheaper and relatively simple design. Improved ventilation systems will help keep fresh air flowing. They will control temperature and reduce harmful gases in such an environment the chickens will be healthy and free of diseases. A comfortable environment neither too hot nor too cold helps eggs to be laid more comfortably and grow faster. Meaning, more food production. The future of farm control is going to rely on smart sensors and automated systems in terms of air,

temperature, and humidity and all of these operations will be done automatically instead of the farmer having to do everything himself. New ventilation systems will consume less electricity, save money for farmers, and minimize environmental effects. Cleaner air and better waste management will decrease pollution and make farms more environmentally friendly. Therefore, healthy chickens, more eggs, and lower costs will help farmers earn more money while working less.

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