

DESIGN AND IMPLEMENTATION OF A HUMIDITY-BASED CORROSION RISK MONITORING SYSTEM FOR AIRCRAFT STRUCTURES

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ABSTRACT

Corrosion is a critical issue in aircraft structures as it directly affects structural integrity, safety, and service life. Aircraft operate in varying environmental conditions such as high humidity, temperature variations, and exposure to saline atmosphere, which accelerate corrosion in metallic components. If not detected and controlled at an early stage, corrosion can lead to structural weakening and increased maintenance costs. The main objective of this project is to study corrosion in aircraft structures and to develop a simple humidity-based corrosion risk detection model to demonstrate preventive monitoring. In this project, a detailed study of different types of aircraft corrosion such as uniform corrosion, galvanic corrosion, pitting corrosion, and stress corrosion cracking was carried out. A prototype model was developed using a humidity sensor and microcontroller to monitor environmental moisture levels. The sensed humidity data is continuously compared with a predefined threshold value. When the humidity exceeds the critical limit, visual and audio alerts are activated to indicate a high corrosion risk condition. The results show that increased humidity levels significantly raise the probability of corrosion formation. The working model successfully demonstrates early-stage environmental monitoring as a preventive approach. This project highlights the importance of condition-based monitoring in aviation maintenance. The proposed system can be further enhanced with advanced sensors and integrated monitoring systems for real-time aircraft health management.

I. INTRODUCTION

Corrosion is one of the most critical challenges affecting the safety, reliability, and longevity of aircraft structures. It is a natural process that results in the gradual deterioration of metals due to chemical and electrochemical reactions with the surrounding environment. In aircraft, structural materials such as aluminum alloys, steel, and other metals are continuously exposed to varying atmospheric conditions, making them highly susceptible to corrosion. Aircraft operate in diverse environments, ranging from high-altitude regions with low temperatures to coastal and humid areas where moisture and salt content are significantly high. These environmental conditions, especially humidity, temperature fluctuations, oxygen, and pollutants, accelerate the corrosion process. Among these factors, humidity plays a major role, as the presence of moisture facilitates electrochemical reactions on metal surfaces, leading to the formation of rust and other forms of degradation. Corrosion in aircraft structures can occur in various forms such as pitting corrosion, galvanic corrosion, crevice corrosion, and stress corrosion cracking. These types of corrosion can affect critical structural components like the fuselage, wings, joints, fasteners, and internal structures. If not detected and controlled at an early stage, corrosion can lead to weakening of structural integrity, reduced load-carrying capacity, increased risk of component failure, and ultimately compromise aircraft safety. In the aviation industry, corrosion-related issues result in significant economic impact due to increased maintenance, repair, and inspection costs. Traditional corrosion detection methods mainly involve periodic inspections, visual checks, and non-destructive testing techniques. Although these methods are effective, they are time-consuming and may not always provide real-time information about environmental conditions that contribute to corrosion formation. To overcome these limitations, there is a growing need for simple, cost-effective, and real-time monitoring systems that can detect corrosion-prone environmental conditions before actual damage occurs. Monitoring key parameters such as humidity can provide valuable insights into the likelihood of corrosion and enable preventive maintenance strategies. This project focuses on the development of a humidity-based corrosion risk detection system using an Arduino microcontroller and a DHT11 humidity sensor. The system continuously monitors the surrounding humidity levels and compares them with a predefined threshold value. When the humidity exceeds the threshold, the system activates visual and audio alerts using LEDs and a buzzer, indicating a potential corrosion risk. The proposed system is designed as a simple prototype to demonstrate the concept of environmental monitoring for corrosion prevention. It highlights the importance of early detection and preventive measures in maintaining aircraft structural integrity.

II. PROBLEM DESCRIPTION

Corrosion in aircraft structures is mainly caused by environmental factors such as humidity, moisture, oxygen, and temperature changes. These factors accelerate the deterioration of metal components, leading to reduced strength, increased maintenance costs, and potential safety risks. Traditional inspection methods are periodic and may not provide real-time detection of corrosion-prone conditions. As a result, early-stage corrosion risks may go unnoticed. Therefore, there is a need for a simple system that can continuously monitor environmental conditions, especially humidity, and provide early warning to prevent corrosion and improve aircraft safety.

III. DATA ANALYSIS

The data analysis is based on the humidity values recorded using the sensor at different time intervals. The collected data shows how humidity levels vary throughout the day, week, and month, and how it affects corrosion risk. From the observed data, it is clear that when the humidity level is below the threshold value of 70%, the system indicates a safe condition through the green LED. As the humidity level approaches the threshold, the system remains in a normal state but indicates that conditions are becoming favorable for corrosion. When the humidity exceeds the threshold level, the system immediately responds by activating the red LED and buzzer. This indicates a high corrosion risk environment. The graphical representation shows a clear transition from safe to risk conditions once the threshold is crossed. The analysis also shows a gradual increase in humidity over time in certain conditions, which increases the probability of corrosion. This proves that humidity is a key factor influencing corrosion in aircraft structures.

Overall, the system successfully monitors environmental conditions and provides timely alerts, demonstrating its effectiveness as a simple corrosion risk detection system.

Table .1 Daily , Weekly and Monthly Analysis

Day	Humidity (%)	Week	Avg Humidity (%)	Month	Avg Humidity (%)
D-1	55%	W-1	60%	Month-1	62%
D-2	60%	W-2	65%	Month-2	68%
D-3	65%	W-3	70%	Month-3	72%
D-4	72%	W-4	75%	Month-4	78%
D-5	75%	W-5	78%	Month-5	80%
D-6	80%	W-6	82%	Month-6	85%

DAILY ANALYSIS

The daily analysis represents the variation of humidity levels at different times of the day. From the data, it is observed that humidity gradually increases from morning to evening. When the humidity remains below the threshold level (70%), the system indicates a safe condition. As the humidity increases beyond the threshold, the system activates alerts using the red LED and buzzer. This shows that corrosion risk can change within a single day based on environmental conditions.

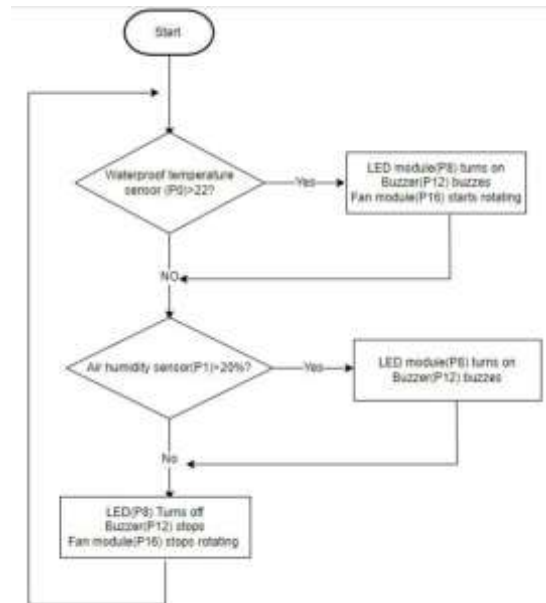
WEEKLY ANALYSIS

The weekly analysis shows the average humidity values over different days of the week. It helps in understanding short-term trends in environmental conditions. From the data, it is clear that humidity levels gradually increase over the week. Initially, the system remains in a safe condition, but towards the later days, the humidity crosses the threshold, indicating higher corrosion risk. This analysis helps in identifying patterns and predicting corrosion-prone periods within a week.

MONTHLY ANALYSIS

The monthly analysis represents long-term changes in humidity levels over several weeks. It shows a clear trend of increasing humidity over time, which directly increases the risk of corrosion. In the initial months, the system indicates normal conditions, but in later months, continuous high humidity leads to frequent alerts. This analysis highlights the importance of long-term monitoring for effective corrosion prevention and maintenance planning.

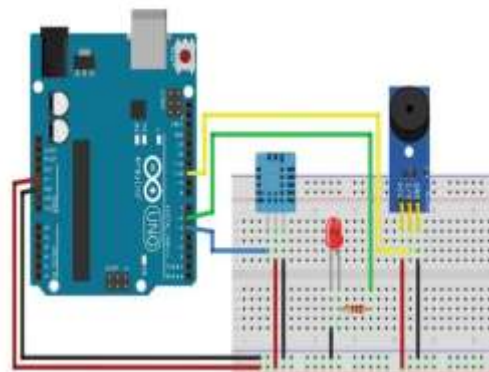
IV. FLOW CHART



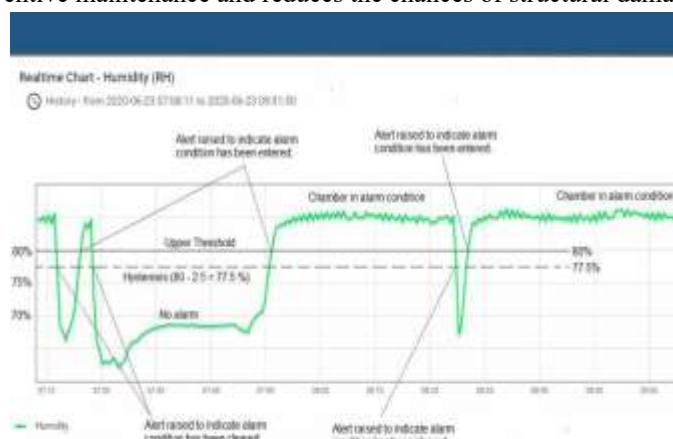
V. RESULTS AND DISCUSSIONS

The humidity-based corrosion risk detection system was successfully designed and implemented using an Arduino microcontroller and a DHT11 sensor. The system was tested under different environmental conditions to observe its performance in detecting corrosion-prone situations.

The results show that when the humidity level is below the predefined threshold value of 70%, the system indicates a safe condition by turning ON the green LED. As the humidity level increases and crosses the threshold, the system immediately responds by activating the red LED and buzzer, indicating a high corrosion risk environment. This demonstrates that the system is capable of accurately detecting changes in humidity and providing real-time alerts.



From the data analysis, it is observed that humidity levels tend to increase over time under certain conditions, which directly increases the risk of corrosion. The graphical and tabular representations clearly show a transition from safe to risk conditions once the threshold is exceeded. The discussion highlights that humidity is a key environmental factor influencing corrosion in aircraft structures. By continuously monitoring humidity, the system helps in identifying corrosion-prone conditions at an early stage. This supports preventive maintenance and reduces the chances of structural damage.



However, the system has certain limitations, as it only considers humidity and does not directly measure corrosion on metal surfaces. Future

improvements can include additional sensors such as temperature and corrosion sensors to enhance accuracy. Overall, the project successfully demonstrates a simple, cost-effective, and reliable method for detecting corrosion risk based on environmental conditions.

VI. CONCLUSION

The project successfully presents the development of a humidity-based corrosion risk detection system using an Arduino microcontroller and a DHT11 sensor. The system continuously monitors environmental conditions and accurately detects variations in humidity levels, which are a major factor contributing to corrosion in aircraft structures. By comparing the sensed humidity with a predefined threshold value, the system effectively differentiates between safe and corrosion-prone conditions. When the humidity level exceeds the threshold, the system immediately activates visual and audio alerts, ensuring quick identification of potential risk. The experimental results and data analysis clearly demonstrate that as humidity increases, the probability of corrosion also increases. This validates the effectiveness of the system in providing early warning signals, which is essential for preventive maintenance in the aviation industry. The implementation of such a system can help reduce unexpected structural damage, improve operational safety, and minimize maintenance costs by enabling timely action before severe corrosion occurs. In addition, the project highlights the importance of real-time environmental monitoring compared to traditional periodic inspection methods. While conventional techniques may fail to detect early-stage corrosion conditions, this system provides continuous monitoring and immediate response, making it more efficient and reliable. Although the current model focuses only on humidity-based detection, it establishes a strong foundation for future improvements. Further enhancements can include the integration of additional sensors such as temperature and corrosion-specific sensors, as well as advanced technologies like Internet of Things (IoT) and Artificial Neural Networks (ANN) for intelligent prediction and remote monitoring. These advancements can transform the system into a fully automated and smart corrosion monitoring solution suitable for real-world aircraft applications. Overall, the project successfully demonstrates a simple, cost-effective, and efficient approach to detecting corrosion risk at an early stage. It emphasizes the significance of preventive maintenance and showcases how embedded systems can be effectively used to improve the safety, reliability, and lifespan of aircraft structures.

VII. REFERENCES

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