SMART LUBRICATION SYSTEM

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ABSTRACT

In most industries, big machines operate for long periods, and over time, this continuous operation between their moving parts generates friction. If the friction becomes too great, it can result in overheating, damage, or even serious accidents if left unmanaged. To avoid such issues, the Smart Lubrication System constantly monitors machinery condition and detects early signs of friction. Automatically, when necessary, it applies the right amount of lubricant to keep the machine running smoothly and safely. In doing so, the system reduces the likelihood of failure, improves performance, and maintains the equipment without complete reliance on manual checks. It consists of an Arduino UNO as the main microcontroller, which keeps track of and regulates the lubrication in machinery. The system is interfaced with an LM35 temperature sensor and a corrosion sensor fabricated using two metallic nails. Both sensors continuously monitor the rise in temperature and corrosion, respectively. When the corrosion sensor detects increased conductivity due to rust or inadequately lubricated joints, the Arduino triggers a 5V DC pump via a relay module. The pump automatically supplies grease or oil at the required site to maintain smooth operation without mechanical wear and tear. The proposed system effectively detects early signs of wear, reduces friction, and maintains machinery in proper working condition.

Keywords: *Smart Lubrication System, Corrosion, Arduino UNO, Lubrication, Machinery, Corrosion Sensor, Temperature Sensor*

INTRODUCTION

Industrial machinery fulfills a very important role in manufacturing, production, and heavy-duty operations, where equipment often operates unceasingly under very strenuous conditions. With every passing period, continued usage increases friction between mechanical parts, causing heat, wear, corrosion, and efficiency losses. If not attended on time, these may lead to unexpected failures, delays in production, or hazardous disasters. Traditional lubrication methods rely on manual inspection and periodic maintenance that do not always mirror the real-time condition of machinery. As a result, machines may get delayed or extra amounts of lubrication, both of which have negative impacts on performance and safety. To overcome these challenges, intelligent sensor-based systems are being adopted in industries to ensure timely, precise lubrication.

This Smart Lubrication System developed in the project is an efficient and automated method of detecting machinery conditions and performing lubrication without manual effort. The general controller used in this work is an Arduino UNO, which was interfaced with an LM35 temperature sensor and a corrosion sensor fabricated using two metallic nails. Both sensors continuously monitor temperature changes and corrosion levels as main indicators of friction and mechanical deterioration. When corrosion exceeds a threshold set in the algorithm, the Arduino turns on the 5V DC pump via a relay to pump grease or any other viscous lubricating oil. This prevents friction and overheating, thus prolonging the life of machines.

Overall, the Smart Lubrication System increases efficiency, reduces downtime, and enables safer industrial operation by providing an affordable, scalable design suitable for a modern automated maintenance environment.

LITERATURE REVIEW

Recent industrial automation research has emphasized intelligent lubrication and condition-monitoring systems for machinery reliability. In the conventional type of lubrication, much dependence is placed on periodic manual inspections that often fail to identify early signs of friction, overheating, and corrosion, which lead to unexpected breakdowns and inefficiencies in maintenance. It has been reported in studies that one of the main reasons for mechanical failure is inadequate lubrication, hence requiring continuous monitoring. Sensors like LM35 are widely used in different studies due to their high accuracy and stability and for detecting abnormal temperature rise caused by friction. Similarly, corrosion detection using metallic electrodes has been investigated as one of the cost-effective means of identifying oxidation and deterioration of lubricants in real time. The literature related to embedded systems establishes that microcontrollers such as Arduino UNO offer a flexible platform for integrating several sensors and running automated decision-making maintenance activities. Past research significantly justifies the integration of sensing technologies and automated lubrication mechanisms to improve machinery performance. These studies collectively validate the reviewed works on the development of a Smart Lubrication System that will be able to monitor in real time, automatically lubricate, and improve machine health through preventive maintenance.

EXISTING SYSTEM

Most industrial environments still use conventional manual methods of lubrication. Operators periodically inspect equipment for signs of friction, overheating, or corrosion and then apply grease or oil based on their observations or fixed schedules for maintenance. These inspections are manual, inconsistent, and cannot detect wear or corrosion at an early stage in continuously running machines or under severe conditions. Without real-time monitoring, lubrication is often applied too late, causing damage and unnecessary friction, or too early, which results in the wastage of lubricants and increases maintenance costs. Manual lubrication also depends heavily on operator experience and therefore suffers from human error, oversight, and irregular intervals. Traditional systems also lack data logging and analytical capabilities, which inhibit industries from finding patterns over the long term or predicting failures. Without automated control or monitoring based on the IoT, the current lubrication practices have limited accuracy, lower reliability, and a higher risk of unexpected breakdowns in modern industrial operations.

PROPOSED SYSTEM

The Smart Lubrication System proposed herein integrates an embedded, sensor-based lubrication control architecture for monitoring, in real-time, the conditions of lubrication and automating the lubrication of industrial machinery. This system uses the ATmega328P-based Arduino UNO as its central processing and control unit. Two major sensing modules have been integrated into the system: first, a precision analog temperature sensor, LM35, supplying a linear voltage output proportional to temperature, and second, a corrosion sensing module fabricated using dual ferrous electrodes. The corrosion sensor relies on the principle of variable electrical conductivity due to oxidation or deposition of moisture, yielding analog input signals corresponding to initial stages of corrosion or surface deterioration.

Sensor outputs are continuously digitized via the Arduino's 10-bit ADC, allowing for high-resolution monitoring of temperature and corrosion levels. A threshold-based decision algorithm is coded in firmware to process real-time sensor data. When the corrosion signal surpasses the predefined deterioration threshold or when temperature conditions indicate abnormal friction, the controller starts an actuation sequence. An actuation involving a 5V opto-isolated relay driver in the system triggers a 5V DC lubrication pump, supplying a controlled amount of lubricant to the mechanical contact points. This ensures appropriate on-demand lubrication and prevents under-lubrication as well as overuse of the lubricant.

The system uses an I2C-interfaced 16×2 LCD for low-latency visualization of sensor readings and system state. A piezoelectric buzzer provides alert tones during critical events.

The proposed technique couples embedded sensing, automated electromechanical actuation, and cloud-enabled predictive analytics of maintenance. This architecture achieves high reliability, minimum mechanical downtime, and much improved lubrication accuracy compared with conventional manual systems.

DESIGN & METHODOLOGY

The Smart Lubrication System has been designed using an embedded hardware–software architecture, which integrates sensing, decision-making, actuation, display, and IoT-based monitoring. A modular approach ensures the design is scalable, reliable, and easy to implement within any industrial environment.

1. System Architecture Design

This system is based on the Arduino UNO (ATmega328P), which acts as the controller for data acquisition from sensors, decision algorithms, and actuation. The system is divided into three major subsystems:

- Sensing Subsystem (LM35 temperature sensor + corrosion sensor using two nails)
- Control and Decision Subsystem (Arduino-based threshold algorithm)
- Display and IoT Subsystem (16×2 LCD with I2C)
- Actuation and Alerting Subsystem (5V DC pump, relay module, and buzzer)
- Each sub-system interfaces through Analogue/Digital I/O pins, thus guaranteeing synchronized operations with least latency.

2. Sensing Methodology

The LM35 outputs a linear analog voltage corresponding to machine temperature, thus providing accurate thermal monitoring. The corrosion sensor detects oxidation through changes in electrical conductivity across two metallic electrodes. Both sensor outputs are digitized using the Arduino's 10-bit ADC to generate high-resolution data.

3. Decision Making Algorithm

In the Arduino firmware, a threshold-based algorithm is implemented.

Steps:

- Continuously sample temperature and corrosion readings.
- Compare sensor values with pre-set safety thresholds.
- If corrosion or abnormal thermal rise is detected, trigger lubrication response.
- Log and display all sensor values for operator reference.

4. Actuation Mechanism

A 5V single-channel relay is used as an isolation and switching interface between the low-power Arduino and the 5V DC lubrication pump. When a threshold is reached, the relay energizes the pump, sending grease or oil to the machinery. A buzzer issues alerts in case of critical or abnormal conditions.

5. User Interface via I2C

A 16×2 LCD is employed to show temperature, corrosion levels, pump status, and alerts in an easy-to-read format for the operator.

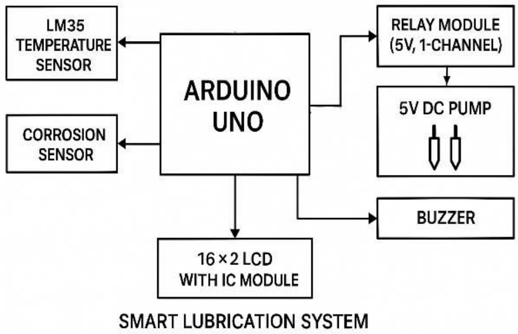

Fig 1. Block Diagram

HARDWARE IMPLEMENTATION

The hardware implementation of the Smart Lubrication System integrates sensing, control, actuation, and display components into a compact embedded design centered on the Arduino UNO microcontroller. The LM35 temperature sensor and a corrosion sensor made using two metallic nails are connected to the Arduino's analog input pins, allowing continuous monitoring of thermal variations and corrosion-related conductivity changes. The Arduino processes these readings using its 10-bit ADC and triggers a 5V DC pump through a single-channel relay module whenever the measured values exceed predefined thresholds, ensuring automated lubrication at the required time. A buzzer provides audible alerts during abnormal conditions, while a 16×2 LCD with an I2C interface displays real-time sensor data and system status with minimal wiring complexity.

SOFTWARE IMPLEMENTATION

The software implementation of the Smart Lubrication System is carried out using the Arduino IDE, where the Arduino UNO is programmed to continuously monitor temperature and corrosion levels, execute decision logic, and control the lubrication mechanism. The program initializes the LM35 temperature sensor, corrosion sensor, 16×2 I2C LCD, buzzer, and relay module. Inside the main loop, analog readings from both sensors are acquired using the Arduino's 10-bit ADC. The temperature value is computed in degrees Celsius, while the corrosion reading is compared against a predefined threshold that indicates excessive oxidation or insufficient lubrication. A threshold-based control algorithm determines whether lubrication is required, and when the sensor values exceed safe limits, the microcontroller activates the 5V DC pump through the relay to apply lubricant. The LCD is updated in real time to display temperature, corrosion levels, and pump status, while the buzzer alerts the operator to abnormal conditions. The software includes proper timing control, sensor calibration, and fault handling to ensure stable operation. Through this integrated logic, the system functions autonomously and reliably without manual intervention.

RESULTS & DISCUSSIONS

The development and testing of the Smart Lubrication System were completed to check its performance in friction-related condition detection and auto-lubrication. In all test cycles, the LM35 temperature sensor responded well, maintaining a stable and precise level of temperature measurement with a response time suitable for the gradual heating of mechanical surfaces. The corrosion sensor, fabricated with two metallic nails, worked well in detecting changes in conductivity caused by moisture and oxidation. The sensor was found to produce higher analog values when the metal surface is dry or rusted and lower values under lubrication during the testing, and it proved to be suitable for the early detection of friction and wear in applications.

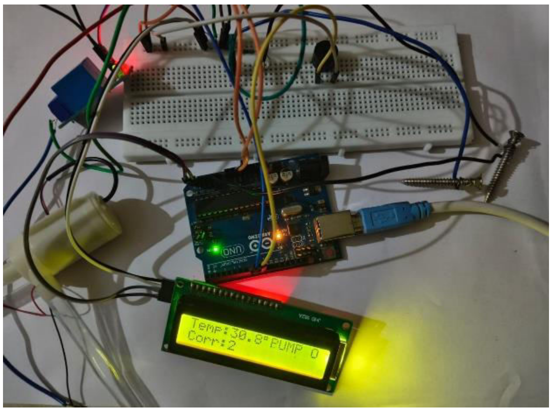

Fig 2. Prototype of Smart Lubrication System

When the level of corrosion exceeded the threshold value set, the relay module turned on the 5V DC pump forthwith, supplying a metered quantity of lubricant to the mechanical area. The actuation was smooth and consistent; when the cycle of lubrication was over, the pump automatically turned off. During abnormal conditions, the buzzer generated clear audible alerts for timely operator attention. All sensor values and the status of the pump were displayed on the 16×2 LCD in real time, thereby helping in observing the behavior of the system during the experiment.

In summary, test results have validated that the system was able to detect early signs of mechanical wear, avoid overheating, and guarantee smooth operation without manual lubrication. It also demonstrated that the system was reliable, economical, and independent in working, thus finding its perfect application in small industrial engagements and preventative maintenance scenarios. Moreover, the modular design is very capable of easy upgrading: adding real corrosion sensors or integrating IoT modules in the future.

FUTURE SCOPE

The Smart Lubrication System can be further improved in many aspects in order to enhance its performance, reliability, and adaptability for industrial applications. Advanced corrosion and vibration sensors may also be integrated for better machine wear and mechanical stress understanding. The system may also be upgradeable to support various types of lubricants and with variable pump flow control for precise lubrication conditions in various industrial applications. The fundamental relay-driven pump should be replaced by a motor driver-based control system, which will achieve smoother actuation and extended pump lifespan. Implementing remote wireless communication modules like ESP8266, ESP32, or Bluetooth can further expand the system with remote monitoring capability, automatic data recording, and predictive maintenance capabilities. Further development may expand the system with the integration of machine learning algorithms that analyze sensor data in a long time and predict a failure before it happens. For bigger-sized industries, the prototype may be transformed into a multi-node lubrication network capable of monitoring several machines at one time. With these improvements, the Smart Lubrication System has bright prospects for being fully automatic, intelligent, and industry-ready maintenance with decision-making and prediction capability.

CONCLUSION

The Smart Lubrication System described in this work effectively and automatically maintains machinery health through the timely detection of friction, temperature rise, and corrosion. The system, coupled with an Arduino UNO, LM35 temperature sensor, corrosion sensor, relay module, and 5V DC pump, effectively monitors the state of a machine and delivers lubrication exactly when needed. Real-time display on LCD and buzzer alarms enhance the system's performance in terms of reliability and usability. Experimental results prove that the system reduces mechanical wear, prevents overheating, and avoids the occurrence of unforeseen breakdowns by performing timely lubrication without reliance on human intervention. Its simple design, together with the low cost and high reliability of the system, makes it appropriate for both small-scale industrial applications and educational purposes. This system can be further enhanced to become a modern industry's intelligent, fully automated maintenance solution through additional sensing, flow control, and wireless connectivity features.

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