PERFORMANCE STUDY ON AUTOMATIC LUBRICATION SYSTEMUSING IOT

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Abstract—: This comprehensive study delves into the integration of Internet of Things (IoT) technology in an Automatic Lubrication System (ALS) to optimize the performance of industrial machinery. The modern industrial landscape demands efficient and reliable lubrication processes to mitigate wear and power loss resulting from friction-induced heat during machine operation. Lubricants play a pivotal role in safeguarding metallic components, making an effective lubrication system imperative for the seamless functioning of engines and machine elements.

The research focuses on the design and development of an ALS, incorporating IoT technology, which not only enhances operational safety for both machinery and personnel but also significantly reduces manual intervention in the lubrication process. By precisely dispensing grease oil to multiple greasing sites, over-lubrication, a common concern leading to potential damage, is effectively curtailed. In cases of lubrication failure, the risk of friction-induced heat buildup, subsequent machinery failure, and consequential damage are drastically minimized.

The study further explores the amalgamation of automation principles with IoT technology, exemplified in the automation of a crawler system utilized in large-scale excavator equipment. Central to this endeavor is the remarkable reduction in labor costs, affirming the economic viability of incorporating IoT-driven automation in industrial settings. Additionally, this research provides a thorough examination of the constituent components of the ALS, shedding light on their interplay within the system for seamless operation.

Keywords: Automatic Lubrication System, IoT (Internet of Things), Condition Monitoring, Predictive Maintenance, Machine Health, Industrial Automation, Performance Analysis

1. INTRODUCTION

The modern industrial landscape is characterized by the relentless pursuit of efficiency, reliability, and cost-effectiveness in the operation of machinery and equipment. Central to this pursuit is the imperative to mitigate the deleterious effects of friction-induced heat, a natural byproduct of the movement of machine parts, which can lead to wear and a reduction in power output. In response to this challenge, the integration of lubrication systems has emerged as a cornerstone in the maintenance and longevity of industrial machinery. Lubricants, specialized substances designed to reduce friction between metallic components, play a pivotal role in safeguarding the integrity and performance of these machines.

However, the efficacy of a lubrication system lies not only in the quality of the lubricant used but also in the precision and reliability with which it is distributed across various critical points on the machine. This precision is particularly vital in preventing over-greasing, a phenomenon that can inadvertently lead to damage to machine parts and, consequently, operational inefficiencies. Moreover, in the event of lubrication failure, the friction generated between metal or other components can result in a dangerous buildup of heat, potentially culminating in machinery failure and extensive damage.

Furthermore, this research extends its purview to the automation of a crawler system, a pivotal component in large excavator equipment. The infusion of automation principles, facilitated by IoT technology, heralds a paradigm shift in industrial operations.

In this context, the focus of this study is the innovative integration of Internet of Things (IoT) technology within an Automatic Lubrication System (ALS). The amalgamation of IoT technology with lubrication systems represents a leap forward in the quest for optimized machinery maintenance. By harnessing the power of IoT, the ALS not only administers lubricants with unparalleled precision but also establishes a dynamic feedback loop, enabling real-time monitoring and adjustments based on the unique operational requirements of the machinery.

To comprehensively address the innovation at hand, this study undertakes an in-depth exploration of the constituent components that comprise the Automatic Lubrication System. By elucidating the intricate interplay between these components, a holistic understanding of the system's functioning is established, providing a solid foundation for its implementation in diverse industrial contexts.

In summation, the integration of IoT technology within an Automatic Lubrication System represents a transformative step forward in industrial machinery maintenance. This integration not only ensures precise and efficient lubrication but also augments operational safety and financial viability. By addressing concerns such as over-greasing and mitigating potential damage, the IoT-enhanced ALS emerges as a pioneering solution, poised to revolutionize the contemporary industrial landscape, while promising increased efficiency and longevity of machinery.

Objective of the Study

Optimize Lubrication Efficiency: Develop an ALS with IoT for precise lubricant distribution.
Prevent Over-Greasing: Use real-time monitoring to avoid excess lubricant application.
Enhance Safety: Incorporate safety features to reduce accidents during lubrication.
Real-time Monitoring: Enable continuous monitoring and adjustments based on needs.
Automation Integration: Merge ALS with automation, especially in large-scale equipment.
Improve Economic Viability: Lower costs and increase competitiveness through ALS integration.

2. LITERATURE REVIEW

Automated lubrication systems play a crucial role in situations where manual lubrication isn't feasible for machine parts. After conducting a survey on automated lubrication, the correct lubrication can offer new opportunities for enhancing profitability. This includes cost reduction in machinery operation, improved reliability and safety, extended service intervals, and optimization of manpower resources. Lincoln and SRK highlight the importance of injecting the right amount of grease at appropriate intervals for bearing performance. Lincoln is working on a grease-based lubrication solution that provides advanced lubrication for various friction-related applications, saving time and labor compared to manual lubrication [1].
Muskat and Eviger from the Gulf Research and Development Company in Pittsburgh, Pennsylvania emphasize the distribution of an equal amount of lubricant on components to increase machine availability. They discuss the effects of pressure variation on viscosity in plane slider lubrication. Their study employs the Reynolds theory to calculate lubrication properties for a pivoted slider with viscosity increasing directly with pressure. The study also covers friction coefficient, film thickness, and lubricant flow concerning the wedge angle [2].

Bowden and Tabor, in their March 1947 research, delve into the role of thin metallic films in reducing friction and wear between metal surfaces. They explain that metallic film surfaces exhibit very low coefficients of friction [3].

Li Wang, from the School of Electrical Engineering and Automation at Henan Polytechnic University in Jiaozuo, China, highlights the need for a special lubrication system to ensure the operation and long service life of machinery. This paper describes the plan of the lubrication system, as well as the measurement of pressure and temperature [4].

Danilo de Jesus Oliveira and colleagues discuss the application of minimum quantity lubrication in grinding as an alternative to reduce the heavy flow of cutting fluids, thereby achieving cleaner production. They found that the use of the cleaning jet technique in minimum quantity lubrication had positive effects on reducing wheel wear compared to other lubrication cooling methods [5].

Evelyn George and her team recognize that retaining lubricant during the sliding of mating surfaces is a major challenge in industrial components, with engine efficiency being affected by frictional losses in engine linear piston ring incorporation. They propose improving lubrication by creating oil pockets on parts' surfaces [6].

Z. H. Nazri and his associates investigate the potential of bio-based lubricants as alternatives to conventional lubricants in industries. Their results indicate that at a constant speed, bio-based lubricants offer advantages in protecting surfaces from wear and damage when compared to mineral oil [7].

M. Shahabuddin and colleagues observe the friction and wear characteristics of jatropha oil-based bio-lubricants. Their investigation suggests that adding 10% jatropha oil to the base lubricant can be used as a lubricant to reduce the reliance on petroleum-based lubricants [8].

Muhamed Noor Harun and his team discuss the impact of wear factors on lubrication performance and establish that wear factors are related to the lambda ratio, which is associated with femoral head size and diametral clearance [9].

S.M. Hafis and his colleagues observe the effects of minimum quantity lubrication on the deformation of aluminum workpieces during tool use. They investigate the nature of load displacement during steady-state conditions and the resulting surface finish of the product [10].

3. METHODOLOGY

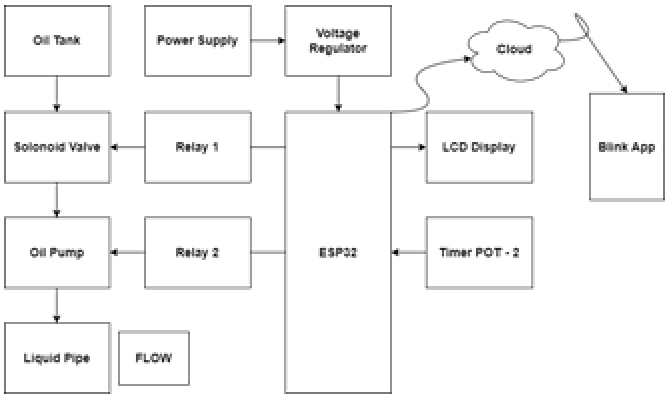

FIG: 1 Block Diagram of the System

The development and implementation of an IoT-integrated Automatic Lubrication System (ALS) is a multifaceted process that demands careful consideration of various technical and operational aspects. This section outlines the overarching methodology employed in this study.

First and foremost, a comprehensive review of existing literature pertaining to lubrication systems, industrial automation, and IoT technology was conducted. This literature review served as the foundation for understanding the state-of-the-art in ALS and provided valuable insights into the potential benefits and challenges of integrating IoT technology into such a system. It also helped identify critical components and technologies commonly utilized in ALS.

Following the literature review, a detailed analysis of the essential components was undertaken. This involved an in-depth examination of each component's specifications,

functionalities, and compatibility within the ALS framework. Components such as the ESP32 microcontroller, relays, solenoid valve, oil pump, liquid pipes, power supply, voltage regulator, LCD display, Blink app, and timer potentiometer 2 were scrutinized for their suitability and integration potential.
Next, the system architecture was meticulously designed. This entailed the conceptualization of how each component would interact and interface with one another within the ALS. Special attention was given to establishing communication protocols, data flow pathways, and control mechanisms. The architecture was devised to ensure seamless integration between the IoT technology, microcontroller, relays, and the various mechanical components responsible for lubricant distribution.

Once the architectural framework was established, the selection and sourcing of components were carried out. Factors such as component availability, compatibility, and reliability were paramount in the procurement process. Careful consideration was also given to the quality of components to ensure long-term durability and functionality of the ALS.
With the necessary components in hand, the assembly and integration phase ensued. This phase involved physically connecting and configuring the components according to the established architecture. Specialized tools and equipment were employed to ensure precise assembly and secure connections. Additionally, thorough testing procedures were implemented to validate the functionality of each component and their seamless integration within the ALS.

Subsequently, the ALS was subjected to a series of controlled experiments and operational tests. These tests were designed to evaluate the system's performance under various conditions, including different lubricant viscosities, operational temperatures, and load scenarios. Data was collected and analyzed to assess the system's ability to maintain optimal lubrication levels and respond dynamically to changing operational parameters.

Throughout the development and testing phases, a keen focus was maintained on safety protocols. Emergency shutdown procedures, fail-safe mechanisms, and hazard mitigation strategies were implemented to safeguard both the machinery and personnel involved in the operation of the ALS.

Lastly, the ALS was integrated with the crawler system of a large-scale excavator equipment, providing a real-world application scenario. This integration phase involved adapting the ALS to the specific requirements and operational nuances of the crawler system, ensuring seamless compatibility and functionality.

In summary, the methodology encompassed a systematic progression from literature review and component analysis to system architecture design, component procurement, assembly, testing, safety protocol implementation, and real-world integration. This comprehensive approach ensured a robust and functional IoT-integrated ALS capable of optimizing lubrication processes in industrial machinery.

4. COMPONENTS

1. Solenoid valve
2. Relay Module
3. ESP 32
4. Voltage Regulator
5. LCD
6. Timer Pot

1. SOLENOID VALVE

In an automatic lubrication system, a solenoid valve is a vital component. It's an electrically controlled valve that manages the flow of lubricant. Connected to a central unit or timer, it opens and closes at specified intervals. When open, it lets lubricant flow into pipes or hoses, delivering it to various points in the equipment. Solenoid valves offer precise control, minimizing waste and reducing energy usage. They're reliable and long- lasting, cutting maintenance needs. Using solenoid valves improves efficiency, reliability, and equipment performance while lowering maintenance costs

FIG: 2 Solenoid Valve

2. RELAY MODULE 5V

The relay module with a single channel board is used to manage high voltage, current loads like solenoid valves, motor, AC load & lamps. This module is mainly designed to interface through different microcontrollers like PIC, Arduino, etc.

5V Relay Module Pin Configuration
The pin configuration of the 5V relay module is shown below. This module includes 6-pins where each pin and its functionality are discussed below.

Normally Open (NO): This pin is normally open unless we provide a signal to the relay modules signal pin. So, the common contact pin smashes its link through the NC pin to make a connection through the NO pin

Common Contact: This pin is used to connect through the load that we desire to switch by using the module.

Normally Closed (NC): This NC pin is connected through the COM pin to form a closed circuit. However, this NC connection will break once the relay is switched through providing an active high/low signal toward the signal pin from a microcontroller.

Signal Pin: The signal pin is mainly used for controlling the relay. This pin works in two cases like active low otherwise active high. So, in active low case, the relay activates once we provide an active low signal toward the signal pin, whereas, in an active high case, the relay will trigger once we provide a high signal toward the signal pin.

However, these modules generally work on an active high signal which will strengthen the relay coil to make contact with the common terminal with the normally open terminal.

FIG: 3 Relay Module

3. ESP32 (MICROCONTROLLER AND WI-FI/BLUETOOTH MODULE)

The ESP32 is a versatile microcontroller with built-in Wi-Fi and Bluetooth capabilities. It features a dual-core processor and a wide range of GPIO pins, making it suitable for controlling and coordinating various functions of your robot. The ESP32 can handle data processing, sensor interfacing, and network communication. Its Wi-Fi and Bluetooth capabilities enable it to connect to networks, communicate with other devices, and provide remote control or monitoring options.

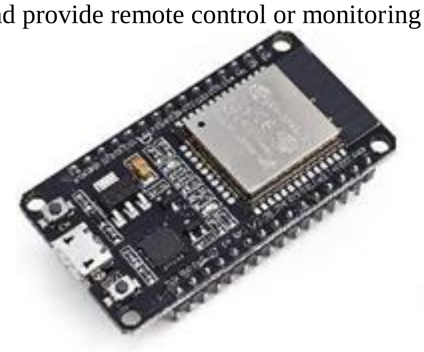

FIG:4 ESP 32

4. VOLTAGE REGULATOR

The function of a voltage regulator is to maintain a constant DC voltage at the output irrespective of voltage fluctuations at the input and (or) variations in the load current. In other words, voltage regulator produces a regulated DC output voltage.Voltage regulators are also available in Integrated Circuits (IC) forms. These are called as voltage regulator ICs.

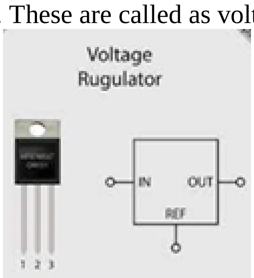

FIG: 5 Voltage Regulator

5. LCD

LCD is an abbreviation for liquid crystal display. This kind of electronic display module is used in many different circuits and gadgets, including computers, televisions, calculators, cell phones, and so forth. Seven segments and multi-segment light-emitting diodes are the most popular uses for these displays. The main benefits of using this module are that it is inexpensive, simple to programme, has animations, and allows you to display unique characters, special effects, animations, and more without any limitations.

FIG: 6 LCD

6. TIMER POT

An automatic lubrication system automatically delivers lubricant to machine parts at specific intervals. To control these cycles, a timer potentiometer is used. It adjusts cycle duration by changing circuit resistance. For instance, if a machine needs lubrication every 10 minutes, the timer potentiometer can be set to provide lubrication for 10 minutes, then pause for 10 minutes before the next cycle. This ensures the right amount of lubricant at the correct intervals, tailored to the machine's needs. Timer potentiometer specifications vary based on the system's requirements, including resistance values, power rating, accuracy, size, and mounting options

FIG: 7 Timer Pot

5. MECHANICAL PROCEDURE

The mechanical procedure of the automated lubrication system involves several key steps to ensure the proper and controlled delivery of lubricant to machine parts. The following outlines the general mechanical procedure of the system:

1. Lubricant Storage and Supply: The system begins with the storage of the lubricant in a dedicated reservoir or container. The lubricant can be in the form of oil, grease, or another suitable lubricating substance. The reservoir is connected to the system's pumping mechanism, which is responsible for supplying the lubricant to the machine parts.
2. Pumping Mechanism: The pumping mechanism, typically an electrically or pneumatically driven pump, is activated to initiate the lubricant flow. The pump draws the lubricant from the storage reservoir and pressurizes it for delivery to the machine parts. The flow rate and pressure of the lubricant can be adjusted based on the specific lubrication requirements of the machinery.
3. Distribution Network: The pressurized lubricant is

directed through a distribution network of pipes, tubes, or hoses to reach the different lubrication points on the machine. The distribution network is strategically designed to ensure the proper delivery of lubricant to each part that requires lubrication. Various types of fittings, connectors, and valves are used to control the flow and direction of the lubricant within the distribution network.

4. Lubrication Points: The distribution network branches out into individual lubrication points located throughout the machinery. These lubrication points may include bearings, gears, shafts, joints, or any other parts that require lubrication to minimize friction and wear. Each lubrication point is equipped with a delivery mechanism, such as a nozzle or a lubrication fitting, to dispense the lubricant onto the specific part.
5. Timing and Control: The system incorporates timing and control mechanisms to ensure lubrication occurs at appropriate intervals. These mechanisms can be based on preset time intervals or triggered by specific machine events. Timing and control devices, such as timers, sensors, or programmable logic controllers (PLCs), enable the system to regulate the lubricant flow and activate lubrication cycles as needed.
6. Monitoring and Maintenance: The automated lubrication system includes monitoring features to ensure its proper functioning and detect any potential issues. This may involve the use of sensors to monitor lubricant levels, pressure, or system performance. Maintenance personnel can periodically inspect the system, including checking for leaks, blockages, or any signs of malfunction, to ensure continuous and efficient lubrication.
7. System Integration: The automated lubrication system can be integrated with the overall machinery control system for seamless operation. This integration enables synchronization with other machine functions, such as shutdown or startup sequences, to optimize lubrication cycles and avoid unnecessary lubrication during idle or non-operational periods.

By following this mechanical procedure, the automated lubrication system ensures the efficient and controlled delivery of lubricant to machine parts, minimizing friction, wear, and potential damage. The system's mechanical components work together to provide consistent and optimized lubrication, resulting in improved machine performance, reduced maintenance costs, and extended equipment lifespan.

6. RESULTS AND DISCUSSION

In summary, an automatic lubrication system is a system designed to supply lubricant to machinery parts in a controlled and precise manner. It consists of several components, including the oil tank

or lubricant reservoir, pump, delivery system, and solenoid valves. The system works by storing lubricant in the reservoir, activating the pump to move the lubricant to the delivery system, distributing the lubricant to the machinery's various lubrication points through the delivery system, and controlling the amount of lubricant delivered to each point through the solenoid valves. Automatic lubrication systems offer several advantages over manual lubrication methods, including improved reliability, reduced maintenance costs, and increased safety for operators.

An automatic lubrication system is a specialized system that provides automated lubrication to machinery parts that require it, offering several benefits that include increased precision and consistency in the lubrication process, reduced downtime, improved safety, extended equipment life, lower maintenance costs, and environmental benefits. By automating the lubrication process, these systems provide consistent and accurate amounts of lubrication to machinery parts, ensuring optimal performance and reducing the risk of breakdowns or malfunctions. They also eliminate the need for manual lubrication, which can be time-consuming and potentially dangerous for workers, and can reduce maintenance costs and prolong equipment life by minimizing wear and tear. Additionally, automatic lubrication systems can help reduce the environmental impact of lubricants by reducing waste and minimizing the amount of lubricant used overall. Overall, automatic lubrication systems offer an efficient, cost-effective, and safe solution to the lubrication needs of various types of machinery, making them a valuable addition to many industrial operations.

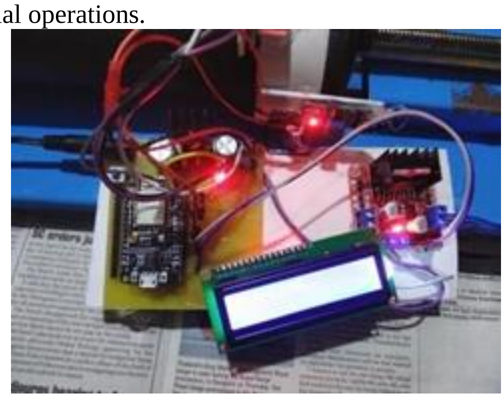

FIG: 17 Working Project Model

SOURCE CODE

```
#include <LiquidCrystal.h>
const int rs = 7, en = 6, d4 = 5, d5 = 4, d6 = 3, d7 = 2; LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
#define Time_pot_1 A0 #define Time_pot_2 A1 unsigned long On_Time = 0; unsigned long Off_Time = 0; #define Relay_Pump 8
#define Relay_solonoid 9
#define Select_SW 10
#define Buzzer 13
//          void setup() {
Serial.begin(9600); lcd.begin(16, 2);

lcd.setCursor(0, 0); lcd.print("WELCOME    ");
lcd.setCursor(0, 1);
lcd.print("          "); pinMode(Relay_Pump, OUTPUT); pinMode(Relay_solonoid, OUTPUT); pinMode(Buzzer, OUTPUT); pinMode(Select_SW, INPUT_PULLUP); digitalWrite(Relay_Pump, LOW); digitalWrite(Relay_solonoid, LOW); digitalWrite(Buzzer, LOW); delay(1000);
```



```
lcd.clear();
}
//-----------------------------------------------------------------
void loop() {

On_Time = analogRead(Time_pot_1);
//Serial.println(On_Time);
On_Time = map(On_Time, 0, 1023, 0, 60000);

Off_Time = analogRead(Time_pot_2); Off_Time =
map(Off_Time, 0, 1023, 0, 600000);

unsigned long time_1 = On_Time / 1000; unsigned long
time_2 = Off_Time / 10000; lcd.setCursor(0, 0);
lcd.print("ON:" + String(time_1) + String("
S ") + String("OFF:") + String(time_2)
+ String(" M "));
//
//

if (digitalRead(Select_SW) == LOW) { digitalWrite(Buzzer,
HIGH); digitalWrite(Relay_Pump, HIGH);
digitalWrite(Relay_solonoid, HIGH); lcd.setCursor(0, 0);
lcd.print("LUBRICATION "); lcd.setCursor(0, 1);
lcd.print("START "); delay(On_Time);

digitalWrite(Buzzer, LOW); digitalWrite(Relay_Pump,
LOW); digitalWrite(Relay_solonoid, LOW); lcd.setCursor(0,
0); lcd.print("LUBRICATION "); lcd.setCursor(0, 1);
lcd.print("STOP "); delay(Off_Time);
}
delay(100);

}
```

7. CONCLUSION

It is inferred from the Automatic Lubrication system using IoT that the expense and labour needed for lubricating the various grease points can be eliminated. An absence of Compared to hand greasing, grease during lubrication decreases. Both the operator and the lubricating component are kept secure by the system. After studying the Automatic Lubrication System, it was determined that control system optimization, which results in the right quantity of lubricant at the right point, reduces lubricant waste. It lowers the amount of labour needed to lubricate various grease points, maintenance expenses, and waste costs. It increases component production and decreases labour consumption. This system provides worker and tool protection. Compared to hand lubrication, there is less grease loss. This technology makes it possible to grease places that an operator cannot reach and it also cuts down on downtime. The lubricant consumption will be considerably reduced by control system optimization that is the right quantity of lubricant at the right part. Failure of bearings due to lack of lubrication is considerably reduced. Frequent lubrication run time is eliminated and pump motor energy consumption is considerably reduced by appropriate material of stator core material winding. Motor overloading is reduced by using thermal relay which has high sensitivity.

8. FUTURE SCOPE

The future scope for automatic lubrication systems lies in the integration of Internet of Things (IoT) and artificial intelligence (AI) technologies. By incorporating IoT sensors and devices, the system can provide real-time data on the equipment's performance, lubrication levels, and maintenance requirements. This data can be analysed using AI algorithms to optimize lubrication schedules, detect potential issues before they occur, and reduce downtime. Another area of future development is the use of sustainable and environmentally friendly lubricants. With increasing concerns about environmental impact, there is a growing need for lubrication systems that can use biodegradable and renewable lubricants. Automatic lubrication systems that are designed to use such lubricants will be in high demand in the future. Finally, there is potential for the integration of automatic lubrication systems with other maintenance and predictive technologies, such as vibration analysis and thermography. This integration would enable a more comprehensive maintenance approach, providing operators with a complete picture of their equipment's health and performance.

In the future, the automatic lubrication system is likely to become even more advanced and sophisticated. One potential area for development is the use of sensors and artificial intelligence to optimize the lubrication process further. For example, sensors could be used to monitor the condition of the lubricant, the operating conditions of the machine, and the wear and tear on the various components. This information could then be fed into an AI system, which could use algorithms to determine the optimal lubrication schedule and amount of lubricant required at each lubrication point. This would enable the system to adapt to changing operating conditions and optimize lubrication performance, resulting in even greater efficiency and cost savings. Additionally, the use of remote monitoring and control systems could allow operators to monitor the lubrication system's performance from a distance, providing real-time information on lubricant levels, system pressure, and other critical parameters. This would enable operators to quickly identify and address any issues before they result in downtime or equipment failure, further increasing equipment reliability and reducing maintenance costs. Finally, there is likely to be increased focus on environmentally friendly lubricants and systems that reduce the environmental impact of lubricants, such as biodegradable lubricants and systems that recycle and reuse lubricants.

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