Early Detection of Internal Leakage in Hydraulic Actuator

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Abstract - Hydraulic systems are widely used in industrial machines such as excavators, cranes, and manufacturing equipment. One of the major issues in hydraulic actuators is internal oil leakage, which reduces system efficiency and increases maintenance cost. This paper presents a sensor-based monitoring system for early detection of internal leakage. The system uses a liquid level sensor, microcontroller, and relay module to continuously monitor oil levels. When leakage is detected, the system automatically shuts down the pump and alerts the operator. A prototype model was developed using embedded systems and Python-based monitoring. The results show that the system effectively detects leakage and prevents damage. This method provides a simple, cost-effective, and reliable solution for hydraulic system safety.

Key Words **:** Hydraulic actuator, leakage detection, sensor monitoring, predictive maintenance, IoT monitoring

1. INTRODUCTION

Hydraulic systems play an essential role in industrial machines such as excavators, cranes, and manufacturing equipment. These systems use pressurized hydraulic oil to transmit power and control mechanical movement. However, leakage in hydraulic systems is a common problem that reduces efficiency and increases maintenance costs.

Internal leakage in hydraulic actuators can occur due to worn seals, damaged O-rings, improper installation, or high operating temperatures. Even small oil leaks can gradually lead to system failure if they are not detected early. In addition to mechanical problems, hydraulic oil leakage can also cause environmental contamination and workplace safety hazards.

Therefore, early detection and monitoring of leakage are important to improve machine reliability and reduce economic losses. This research proposes a smart leakage detection system that uses sensors and automatic control mechanisms to monitor oil levels and shut down the system during abnormal conditions.

2. Body of Paper

Section 1
(LITERATURE SURVEY)

The detection of faults in hydraulic systems has been an important area of research in recent years. Internal leakage in hydraulic actuators leads to reduced efficiency, increased maintenance cost, and possible system failure.

Yao et al. (2014) proposed a leakage fault modeling method based on system analysis. Zhao et al. (2015) conducted experimental studies to identify leakage characteristics in hydraulic systems. These methods provide good analytical understanding but require complex setups.

Sharifi et al. (2018) introduced predictive maintenance techniques using artificial intelligence to monitor system health. Liu et al. (2023) focused on signal-based monitoring for detecting abnormal conditions in hydraulic machines.

Recent studies by Huang et al. (2025) analyzed the impact of internal leakage on system performance and efficiency. These approaches improve detection accuracy but often require advanced equipment and high computational cost.

Therefore, this project focuses on a **simple, cost-effective sensor-based monitoring system** for early leakage detection, which can be easily implemented in practical industrial applications.

Section 2
(SYSTEM ARCHITECTURE)

The proposed system for early detection of internal leakage in hydraulic actuators consists of both hardware and software components integrated together.

The input layer includes a liquid level sensor that continuously monitors the hydraulic oil level in the tank. This sensor detects any abnormal drop in oil level, which may indicate leakage.

The processing unit consists of a microcontroller such as NodeMCU or Arduino. It receives sensor data and compares it with a predefined threshold value. The controller acts as the brain of the system and makes decisions based on real-time data.

The control system includes a relay module that is connected to the pump. When leakage is detected, the microcontroller sends a signal to the relay to shut down the pump automatically, preventing further oil loss and system damage.

The monitoring system includes a graphical user interface (GUI) developed using Python. It displays real-time oil level, system status, and alerts for the operator.

The output layer provides visual and alert-based feedback to the user. It ensures that the operator is informed immediately when leakage occurs.

Overall, the system provides a simple, reliable, and efficient method for real-time leakage detection and automatic control in hydraulic systems.

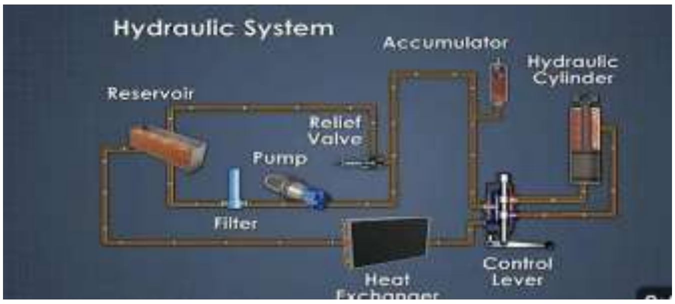


Fig.1 Hydraulic Working Diagram

Section 3
(METHODOLOGY)

The methodology is based on continuous monitoring of hydraulic oil level and detecting abnormal drops to identify internal leakage. The system uses sensors, a microcontroller, and automatic control for efficient operation.

1) System Setup:
The system includes a liquid level sensor, microcontroller (NodeMCU/Arduino), relay module, pump, and GUI monitoring software.

2) Data Acquisition:
The sensor measures the oil level in real time and sends signals to the microcontroller.

3) Processing and Calibration:
The microcontroller processes the data and compares it with a predefined threshold value set during calibration.

4) Leakage Detection:
If the oil level drops below the threshold, the system detects it as a leakage condition.

5) Control Action:
The relay module is activated to automatically shut down the pump and prevent further oil loss.

6) Alert System:
A warning is displayed on the GUI, indicating leakage and system shutdown.

7) Monitoring:
The GUI shows real-time oil level and system status (Running/Stopped).

8) Testing:
Leakage conditions are tested by reducing oil level and observing system response.

Flow:

Sensor → Controller → Comparison → Detection → Relay → Pump OFF → Alert

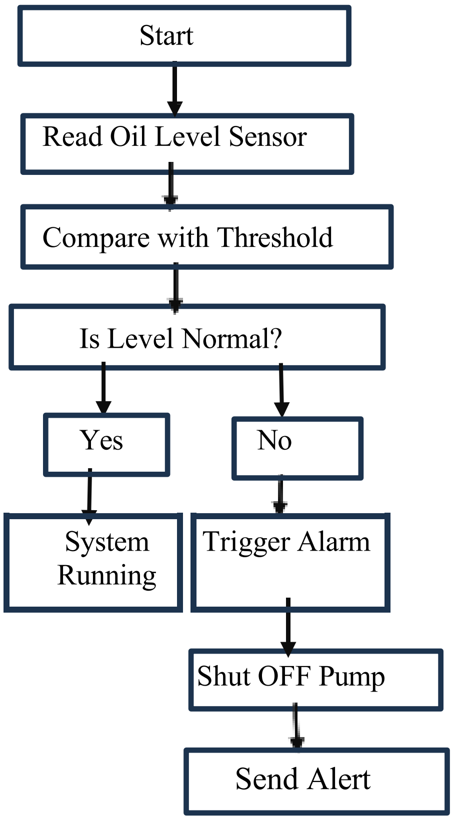


Table 1: Leakage Detection Control Algorithm

Section 4
(Results and & Discussions)

The developed prototype system was tested to evaluate its performance in detecting internal leakage in hydraulic actuators. The system successfully monitored oil levels in real time and responded accurately to leakage conditions.
When the oil level dropped below the predefined threshold, the system immediately detected the leakage and activated the relay module to shut down the pump. At the same time, an alert was displayed on the graphical user interface (GUI), indicating system shutdown.

Observed Results:

- Leakage detection was fast and reliable
- Automatic pump shutdown worked effectively
- Real-time monitoring was achieved through GUI
- System prevented further oil loss and damage

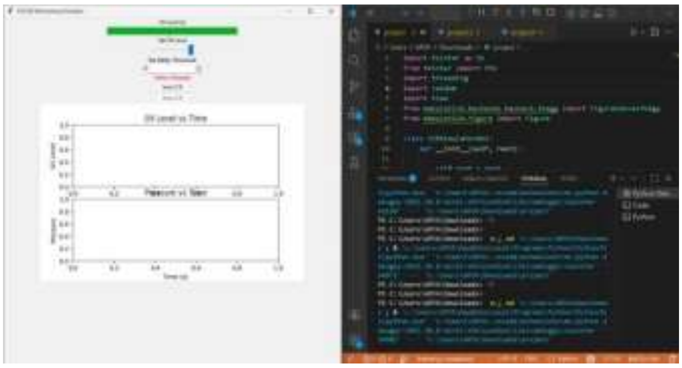
The system showed good accuracy in identifying abnormal oil level drops. It was also observed that the response time of the system was quick, which is important for preventing severe damage in hydraulic systems.

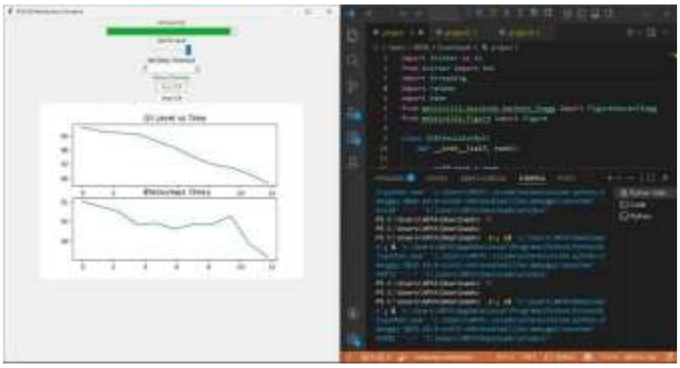
Discussion:
Compared to traditional manual inspection methods, the proposed system provides:

- Early detection of leakage
- Reduced maintenance cost
- Improved system safety and reliability
- Continuous monitoring without human intervention

The system is simple, cost-effective, and easy to implement, making it suitable for industrial applications. However, accuracy depends on proper sensor calibration and placement.

Overall, the results demonstrate that the proposed system is effective in detecting internal leakage and improving the performance and safety of hydraulic systems.





3. CONCLUSIONS

This paper presents a sensor-based system for early detection of internal leakage in hydraulic actuators. The system continuously monitors the oil level and detects abnormal drops using a predefined threshold. When leakage is identified, the system automatically shuts down the pump and provides an alert to the operator.

The developed prototype demonstrates that the system is capable of detecting leakage accurately and responding quickly to prevent further damage. It improves system safety, reduces maintenance cost, and minimizes oil loss.

The proposed solution is simple, cost-effective, and easy to implement in real industrial applications. With further improvements such as IoT integration and advanced monitoring techniques, the system can be enhanced for large-scale and smart industrial environments.

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