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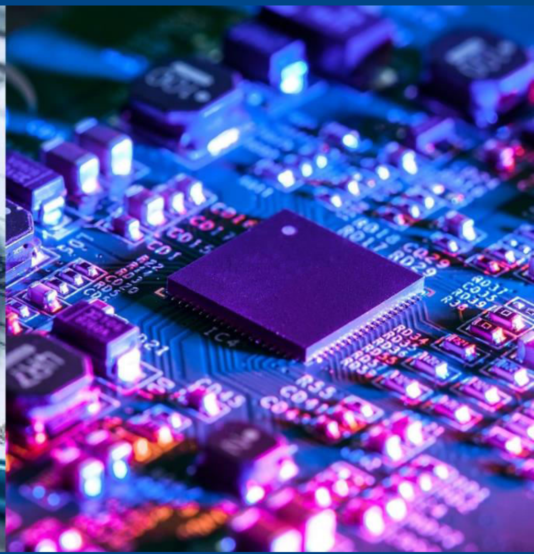

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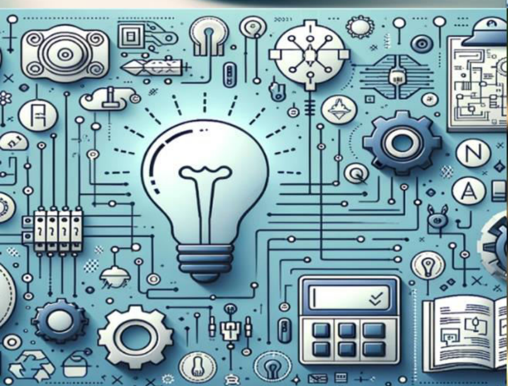

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A Review Paper on Automation of Leak Testing Machine

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ABSTRACT: Automation in leak testing has become vital in modern manufacturing, enhancing precision, efficiency, and safety. This paper reviews current advancements in automated leak detection, including timer-based systems, AI integration, image processing, and IoT-based solutions. It discusses key challenges like calibration, cost, complexity, and scalability, while highlighting automation's role in reducing human error and improving speed and reliability. Special focus is given to cost-effective solutions for small and medium-sized industries, and the integration of low-cost automation. The study also explores future trends such as predictive maintenance and real-time monitoring in line with Industry 4.0. Practical insights and recommendations are provided for optimizing industrial leak testing operations.

KEYWORDS: Leak Testing, Automation, Float Sensor, Solenoid Valve, Timer, Cost-effective Design, Mechatronics

I. INTRODUCTION

In modern manufacturing, ensuring the integrity of sealed systems is essential. Leak testing is commonly performed to detect flaws, cracks, or poor fittings in components such as castings, tanks, and pressure vessels. Manual methods often involve operator-driven visual inspection using bubble formation under pressure, which is slow and prone to inaccuracy. With increasing demand for fast and reliable processes, automation provides a promising solution. This review focuses on a leak testing machine automation project implemented during industrial training at Emmel Vheelers, with attention given to design, working principles, observed problems, and solutions. The review also compares related advancements through a detailed literature study.

II. LITERATURE REVIEW

J. Smith and M. Brown conducted a study on Automated Leak Detection Systems in Manufacturing, focusing on the shift from manual inspections to fully automated systems. Their research highlighted the improved consistency and scalability offered by automation, especially for small-scale industries. They explored cost-effective electromechanical and timer-based solutions, emphasizing the need for proper calibration to avoid false positives and ensure rapid detection (2021).

Prathyusha Nama examined the integration of Artificial Intelligence (AI) into leak detection. Her study showcased how machine learning can predict leaks by analyzing historical data, enabling predictive maintenance and improving performance. While AI offers high accuracy, she noted its computational demands, which may challenge adoption in smaller enterprises (2023).

R. Kumar and P. Sharma presented a case study on AI-Integrated Leak Testing, demonstrating how convolutional neural networks (CNNs) enhance pattern recognition and detection accuracy by over 30%. They acknowledged the system's high complexity and resource requirements, making it more suitable for high-precision environments than general use (2019).

S. Vongbunyong et al. developed a Vision-Based Automatic Leak Detection System for the waterworks sector. Using high-speed cameras and image processing, their system detected leak indicators such as bubbles and droplets with high accuracy. However, its reliance on specialized hardware limits its feasibility to larger installations (2020).

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Mehta and Singh discussed the Challenges and Benefits of Automation in Leak Testing, offering insights into practical implementation. They advocated for combining basic automation with human oversight, particularly in cost-sensitive settings. Their findings supported the use of relay and timer-based systems when components are well-integrated (2016).

S. Patel and T. Desai focused on IoT-Based Leak Detection Systems, where sensor data is sent to cloud platforms for real-time monitoring. While offering rapid detection and response, the authors noted that these systems require strong IT infrastructure, recommending edge computing as a viable alternative in areas with limited connectivity (2020).

T. Williams and D. Johnson reviewed Pipeline Leak Detection Techniques like acoustic monitoring and pressure drop analysis, widely used in oil and gas industries. Though effective, acoustic methods can be affected by environmental noise. The authors suggested a hybrid approach combining multiple techniques for enhanced safety and accuracy (2019).

H. Anderson and L. White proposed using Infrared Imaging and Faster R-CNN Models for real-time leak detection. Their method used thermographic imaging and deep learning to identify heat signatures of leaks with high precision. However, high costs and hardware needs may limit its accessibility for small-scale setups (2020).

M. Gupta and V. Rao researched Acoustic Intelligent Leak Detection in water networks, using sound wave interpretation to detect even micro-leaks. The technique proved highly sensitive but requires complex setup and expensive sensors, limiting its widespread use despite its effectiveness in critical infrastructure (2021).

J. Martinez and C. Lopez explored Machine Learning and IoT integration for water quality monitoring and leak detection. Their approach combined smart sensors, real-time analytics, and automation, aligning with Industry 4.0 standards. The system enhances leak detection while optimizing resource use, offering a forward-looking solution for sustainable automation (2024).

III. METHODOLOGY

The methodology adopted in this project stems from a real-time setup encountered during inplant training. The main aim was to develop a **cost-effective and reliable semi-automated leak testing machine** that reduces manual errors and improves testing efficiency.

Problem Identification

Initially, the leak testing process faced significant inefficiencies, particularly in the first cycle. The primary issue was the **delayed injection of air**, which occurred because water filled from the bottom of the testing chamber. This not only affected the **visibility of air bubbles**—used to detect leaks—but also led to **misinterpretation by the operator**.

Solution and Improvements

To resolve this issue, an **XT56 on-delay timer** was introduced into the system. This timer ensured a fixed delay after the clamping of the job, allowing the system to inject air only after the job was **firmly and accurately fitted**. This improvement eliminated premature air injection, reduced the chances of human error, and enhanced **leak detection accuracy**.

Component Selection

Key components selected for the machine are listed below along with their specifications and cost (if applicable):

- **Timer:** XT56 on-delay timer
- **Solenoid Valve:** 230V AC, used for water drainage (₹7500)
- **Float Sensor:** Used for water level feedback control (₹450)
- **Motor:** 2 HP
  - Running Current: 2.49A
  - Starting Current: 3.73A
- **Relay & Contactor:** 9A contactor, relay setting at 4A
- **SMPS:** 24V DC regulated power supply

- **Emergency Stop Button:** Normally Closed (NC) push button for safety

Working Flow

The testing process is carried out in a **step-by-step manner** as follows:

1. The operator **manually clamps** the job in the fixture.
2. The **XT56 timer activates**, introducing a set delay to ensure proper clamping.
3. Once the delay is complete, **air is injected** into the job.
4. The operator **visually observes for bubbles** in the water to check for leakage.
5. If no leak is detected, **water is drained** through the solenoid valve.
6. The cycle ends, and the **job is unclamped**. The system is then **reset for the next operation**.

Cycle Time

The total time taken to complete one full cycle of leak testing is **45 seconds**, distributed as follows:

- **Drainage Time:** 20 seconds
- **Remaining Operations:** 25 seconds (includes clamping, timer delay, air injection, and observation)
- **Visual Inspection Time:** The operator has around **15–17 seconds** to inspect for leaks during bubble formation.

IV. GENERAL DESIGN

The **Automated Leak Testing Machine** is designed to test the integrity of products by checking for leaks during the manufacturing process. The design incorporates various components that work together to ensure **efficient, accurate testing** while maintaining **low cost and high reliability**.

1. System Overview

The system design is based on a **simple yet effective timer-based mechanism** to ensure that the leak testing cycle is carried out with precision. The primary components in this system include:

- **Clamping Mechanism**
- **Pressure Injection System**
- **Timer Circuits**
- **Solenoid Valve** for water drainage

This system ensures that **air pressure is injected into the job only after proper clamping**, thereby preventing errors associated with air leakage due to improper fitting.

2. Components

The key components that make up the automated leak testing machine are:

- **XT56 Timer:**
  The XT56 on-delay timer controls the delay in air injection after clamping. This ensures air is injected only when the job is securely positioned, preventing leakage from improper fitting.
- **Solenoid Valve:**
- A **230V solenoid valve** is used for water drainage during the test cycle. This valve controls water flow, ensuring effective drainage to avoid blockages or contamination in the system.
- **Float Sensor:**
  The float sensor monitors the water level during the testing process. It detects changes in water levels, which may indicate a potential leak, providing feedback to the control system for further action.
- **Clamping Mechanism:**
  The clamping mechanism ensures the product is securely held in place during the test. It uses **manual clamping** followed by the activation of the air injection system, which is controlled by the timer.
- **Contactor and Relay:**
  A **9A contactor** and a **4A relay** are used to control the electrical flow to the motor and solenoid valve. The contactor ensures the system components operate within their rated current, while the relay manages the system's operation during different phases of the test cycle.

3. System Workflow

The leak detection process follows a **sequential workflow**, which ensures consistency and accuracy:

1. The operator manually **clamps the product** securely.
2. The XT56 timer **delays air injection** for a set time to ensure proper positioning.
3. After the delay, **air is injected** into the job.
4. The **float sensor** monitors any potential leaks by detecting changes in water level.
5. If no leak is detected, the product **passes the test**. If a leak is detected, an alert is triggered for further inspection.
    - **Cycle Time:** The total cycle time is **45 seconds**, broken down into:
        - **Drainage Time:** 20 seconds
        - **Remaining Operations (Air Injection and Inspection):** 25 seconds
        - **Visual Inspection Time:** The operator has **15–17 seconds** for visual inspection before moving to the next product.

4. Control Strategy

The system follows a **simple and cost-effective control strategy**. The manual start and reset buttons allow the operator to initiate and reset the cycle as required. Once initiated, the system automatically progresses through clamping, air injection, and drainage. The solenoid valve is controlled via the relay, ensuring synchronization with the rest of the testing cycle. The **emergency stop push button** ensures that the machine can be halted at any time in case of emergency, ensuring operator safety.

5. Integration with Existing Systems

The system is designed using components reused from an old **impregnation machine panel**, making it compatible with existing manufacturing setups. This approach ensures that the components can easily be integrated into existing production lines with minimal additional infrastructure required, thereby making it both cost-effective and efficient.

6. Safety Features

Safety is a critical aspect of the design. Key safety features include:

- **Emergency Stop Button:** Located for easy access to stop the machine in case of malfunction or emergency.
- **Pressure Relief Mechanisms:** Ensures no excessive pressure or fluid flow occurs, preventing damage to the product or machinery.
- **Flow Monitoring:** The system includes flow monitoring mechanisms to ensure smooth operation without any risks of blockage or over-pressurization.

V. FUTURE SCOPE

1. **Air-Drop Sensors for Leak Detection**
   Right now, we rely on the operator to visually check for leaks, which can lead to mistakes. By adding **air-drop sensors**, we could automate the leak detection process, making it more precise and removing the chances of missing leaks due to human oversight.
2. **Multiple Solenoid Valves for Faster Cycle Times**
   At the moment, the cycle time includes some delays, especially during drainage and air injection. If we added **multiple solenoid valves**, we could speed up these processes, making the overall cycle time shorter. This would help increase the machine's efficiency, especially in high-volume production.
3. **Buzzer or Alarm System for Leak Alerts**
   Sometimes, it might take time for the operator to notice a leak. By adding a **buzzer or alarm system**, we could instantly alert the operator if a leak is detected, allowing them to act quickly and reduce downtime.
4. **Pneumatic Actuators to Replace Manual Clamping**
   Currently, the clamping is done manually, and there's some room for inconsistency based on the operator's speed or pressure applied. Switching to **pneumatic actuators** would ensure that the clamping force is consistent every time, leading to more accurate tests and fewer errors.
5. **HMI Display for Real-Time Monitoring**
   We could add a **HMI (Human-Machine Interface)** display, where operators can easily monitor the system's status, cycle times, and see if there are any errors. This would make it easier to spot any problems and help operators stay on top of things more efficiently.

6. **Switch to PLC-Based Control**
   Moving to a **PLC-based control system** would allow us to have more flexibility in the machine's operations. We could program more complex logic, connect additional sensors, and improve overall control. It would also help with diagnosing any issues and make future upgrades easier.

VI. CONCLUSION

Automating leak testing systems can significantly reduce the chances of **manual errors**, enhance **inspection accuracy**, and ensure that the testing process remains **consistent**. This project showcases a **simple** yet **cost-effective** approach to automation, utilizing timers, sensors, and solenoid valves. By reusing existing components and relying on **electromechanical logic**, the system is an ideal solution for **small and medium-scale industries** that need efficient and affordable automation.

While future advancements may incorporate **AI**, **IoT**, and **vision systems** to make the system smarter, the current setup provides a highly **practical** and **scalable** solution, especially for industries working with limited budgets. This system offers a reliable way to enhance the leak testing process without breaking the bank, making it a great starting point for cost-conscious manufacturers.

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