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Methods of Pressure Measurement in Mechanical Engineering

Apta Humaira[1], Bagas Ade Rahmat[2], Abdul Muchlis[3]
[1,2,3]Mechanical Engineering Departmenrt, Gunadarma University, Depok, Indonesia

***Abstract**. Pressure measurement is a fundamental aspect of mechanical engineering used to monitor and control various fluid and mechanical systems. This study discusses different pressure measurement methods, including the use of manometers, pressure transducers, and microcontroller-based sensors. Experimental methods were conducted to compare the accuracy and sensitivity of various measuring instruments in different testing environments, such as hydraulic systems, pneumatic systems, and internal combustion engines. The results show that microcontroller-based sensors provide high accuracy and easy integration with industrial automation systems. Additionally, environmental factors such as temperature and vibration significantly affect the accuracy of pressure measurements. This study provides insights into the advantages and limitations of each method and recommendations for optimal applications in mechanical engineering.*

***Keywords** Pressure measurement, mechanical engineering, pressure sensors, microcontroller, fluid systems.*

INTRODUCTION

Pressure measurement plays a crucial role in mechanical engineering, particularly in monitoring, controlling, and analyzing various mechanical and fluid systems. Accurate pressure monitoring is essential for ensuring efficiency, safety, and optimal system performance in applications such as hydraulic systems, pneumatic systems, internal combustion engines, and manufacturing industries.

Various pressure measurement methods have been developed, ranging from conventional methods like U-tube manometers and Bourdon gauges to advanced technologies using digital sensors and microcontrollers. The evolution of technology allows for high-accuracy pressure sensors that can be integrated with automation and Internet of Things (IoT) systems, enhancing industrial monitoring efficiency.

This study aims to explore various pressure measurement methods in mechanical engineering, compare their advantages and disadvantages, and provide recommendations for the best applications based on specific operational conditions.

LITERATURE REVIEW

Pressure measurement techniques can be classified based on their working principles, such as mechanical, electrical, and digital methods. Some commonly used methods include:

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*Corresponding author, muchlis07@staff.gunadarma.ac.id

1. Manometer: Simple pressure measuring devices using liquid indicators.
   - U-tube Manometer: Measures pressure based on liquid level differences.
   - Bourdon Gauge: Uses elastic deformation of a metal tube to indicate pressure.
2. Pressure Transducers: Convert pressure into electrical signals for digital processing.
   - Strain Gauge: Measures pressure through mechanical deformation.
   - Piezoelectric Sensors: Generate electrical voltage upon experiencing pressure changes.
3. Microcontroller-Based Sensors: High-precision sensors integrated into industrial automation.
   - IoT-Enabled Sensors: Real-time data transmission for remote monitoring.

     Recent developments focus on integrating sensors with digital monitoring systems to enhance measurement accuracy and response time.

METHODS

This study categorizes pressure measurement methods based on the type of equipment used and evaluates their accuracy in different environments. The methods analyzed include:

1. Thermobath Calibration System: Uses thermocouple sensors and pressure transmitters for temperature calibration.

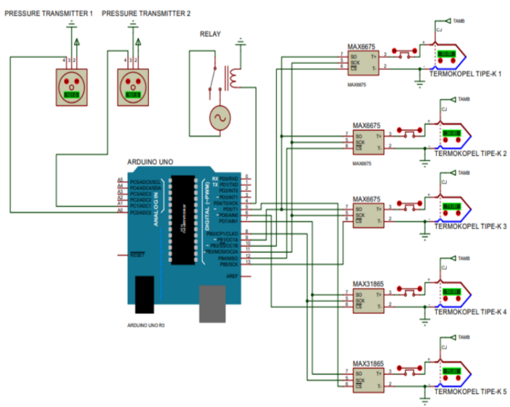

Figure 1. Letak sensor pengukuran

2. Spreadsheet-Based Engine Temperature & Compression Gauge: Uses DS18b20 sensors with ESP8266 microcontrollers.

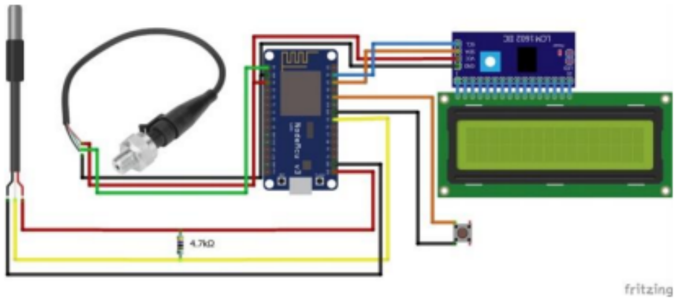

Figure 2. Wiring Design

3. Turbine Inlet Pressure Variation Measurement: Evaluates turbine efficiency under different pressure conditions.

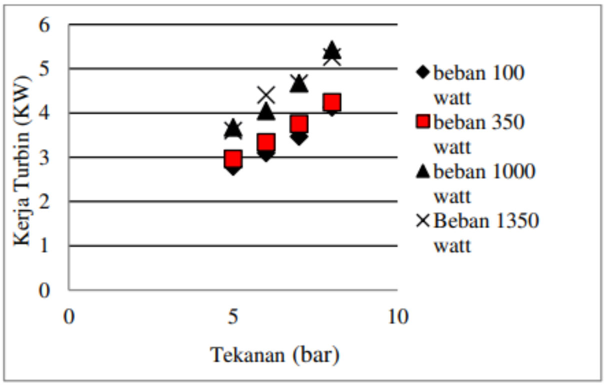

Figure 3. Turbine work graph as a function of turbine inlet pressure

4. IoT-Based Air Pressure Monitoring with Thingsboard: Uses wireless communication for real-time pressure monitoring.

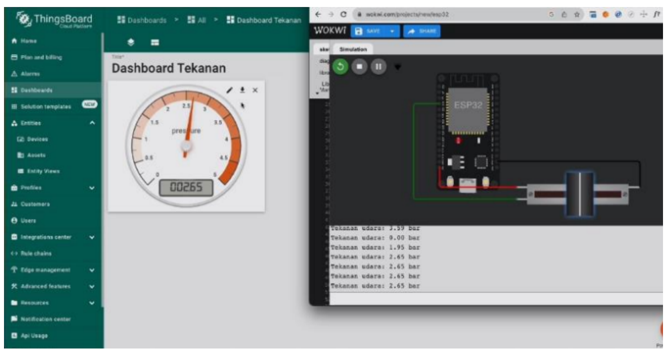

Figure 4. Dashboard Thingsboard

5. Microcontroller-Based Mechanical Pressure System: Implements AT-Mega 16 for pressure control in industrial applications.

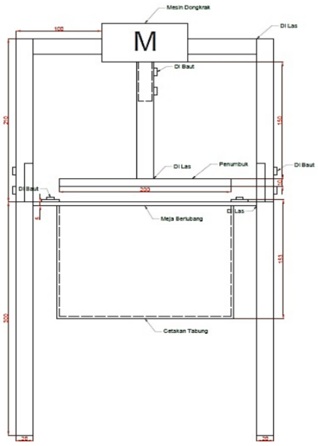

Figure 5. Frame Design

6. Bioethanol-Premium Fuel Blending System Pressure Monitoring: Utilizes MPX5050GP pressure sensors.

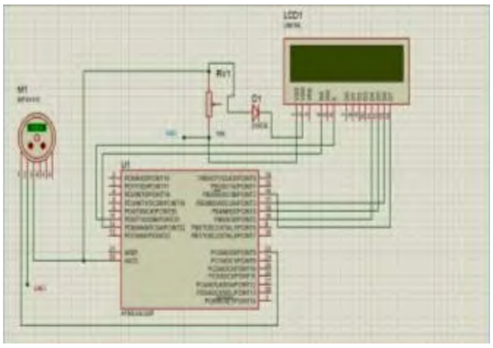

Figure 6. Wiring Scheme LCD and sensor MPX5050GP

7. Bernoulli-Based Pump Performance Tester: Uses pressure gauges for hydraulic analysis.

Figure 7. *Pressure Gauge*

8. Zero Calibration for Pressure Transmitter: Calibration method for industrial pressure transmitters.

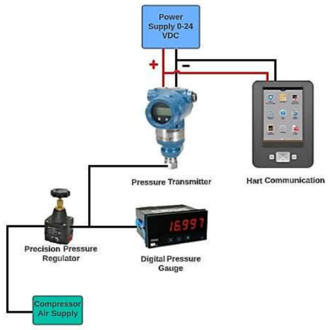

Figure 8. Wiring Calibration Pressure Transmitter Process

9. Compression Tester: Measures compression pressure in engine cylinders.

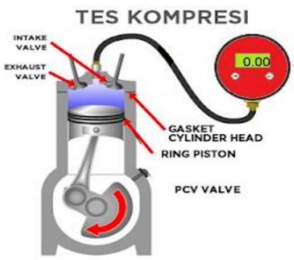

Figure 9. Compression Test

10. Pressure Gauge Calibration Equipment: Uses Westinghouse calibration methods.

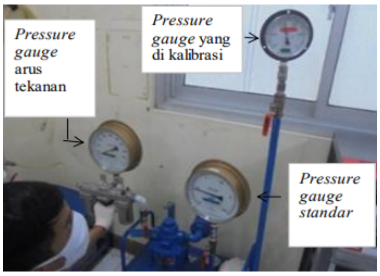

Figure 10. Calibration Power Hydraulic Equipment Process

11. Air Conditioning System Performance Measurement: Measures pressure variations in air conditioning systems.
12. HP03 Barometric Pressure Measurement: Uses digital sensors for atmospheric pressure monitoring.

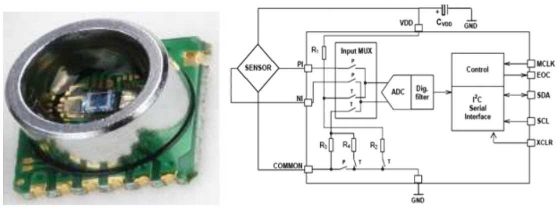

Figure 11. Sensor HP03SA

13. Hydrostatic Test for Pressure Vessel Durability: Uses ASME standards for vessel strength assessment.

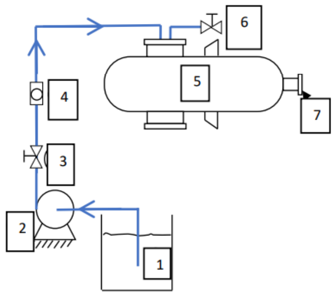

Figure 12. Scheme Testing

14. Microcontroller-Based Sea Level Pressure Monitoring: Uses BMP180 sensors.

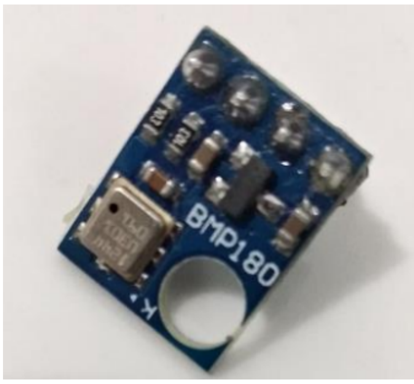

Figure 13. Sensor BMP180

15. Fuel Pump Pressure Tester: Evaluates pressure in fuel injection systems.
16. Comparison of Injection and Mechanical Fuel Pump Pressure: Efficiency analysis of different fuel pump systems.

Figure 14. Fuel Injection Pump Pressure Measurement

17. Simple Manometer-Based Air Pressure Measurement: Uses basic equipment for pressure simulation.

Figure 15. Manometer Sederhana

18. Tread Brake System Pressure Measurement: Evaluates braking efficiency based on air pressure.

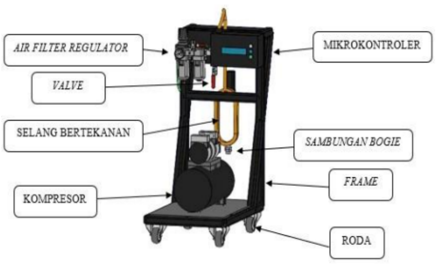

Figure 16. Design

19. Blow-By Pressure Measurement for Diesel Engines: Determines crankcase leakage levels.

Figure 17. Measurement Blow By

20. Water Distribution System Pressure & Velocity Analysis: Uses sensors for flow and pressure measurement.

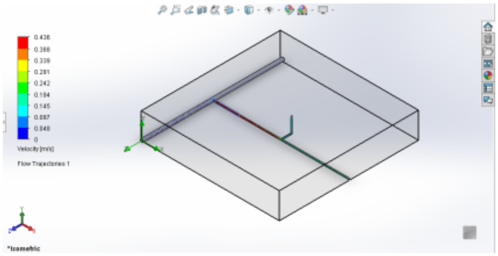

Figure 18. Flow Simulation

RESULTS

The study found that each pressure measurement method has specific advantages and applications. Microcontroller-based sensors showed the highest accuracy and real-time data transmission capability. However, mechanical methods like U-tube manometers remain useful for low-cost and simple applications.

DISCUSSION

- Accuracy & Reliability: Digital sensors provide high precision but require proper calibration.
- Environmental Factors: Temperature and vibration significantly affect measurement accuracy.
- Industry Application: IoT integration improves real-time monitoring and automation.
- Limitations: Each method has trade-offs in cost, complexity, and application range.

CONCLUSION

This research highlights the importance of choosing the appropriate pressure measurement method based on application needs. While traditional methods remain relevant, advancements in digital sensor technology and IoT integration provide significant improvements in accuracy and efficiency. Future research should focus on enhancing sensor durability and wireless communication capabilities for broader industrial applications.

LIMITATION

This study acknowledges several limitations that may impact the findings and applications of pressure measurement methods:

1. Environmental Influence: Factors such as temperature variations, humidity, and mechanical vibrations can affect the accuracy of pressure sensors, requiring frequent calibration.
2. Equipment Cost: High-precision digital sensors and IoT-enabled devices are costly, limiting their accessibility in small-scale industries.
3. Data Transmission Delays: IoT-based pressure monitoring systems may experience latency issues due to network constraints, affecting real-time decision-making.
4. Calibration Complexity: Some pressure measurement techniques require frequent recalibration to maintain accuracy, increasing maintenance costs.
5. Application-Specific Constraints: Different measurement methods may not be suitable for all environments, requiring careful selection based on operational conditions.

Future studies should focus on improving sensor durability, minimizing calibration complexity, and enhancing wireless communication reliability for industrial applications.

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