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HEM Efficiency Comparison: Ethanol vs Water in a Double Pipe Heat Exchanger Using Arduino Uno

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Introduction

The **HEM** in this research refers to the **Heat Exchanger Metric**. This metric is used to evaluate the efficiency of the double-pipe heat exchanger (DPHE) based on the measured temperature and pressure differences between the working fluids (ethanol and water).

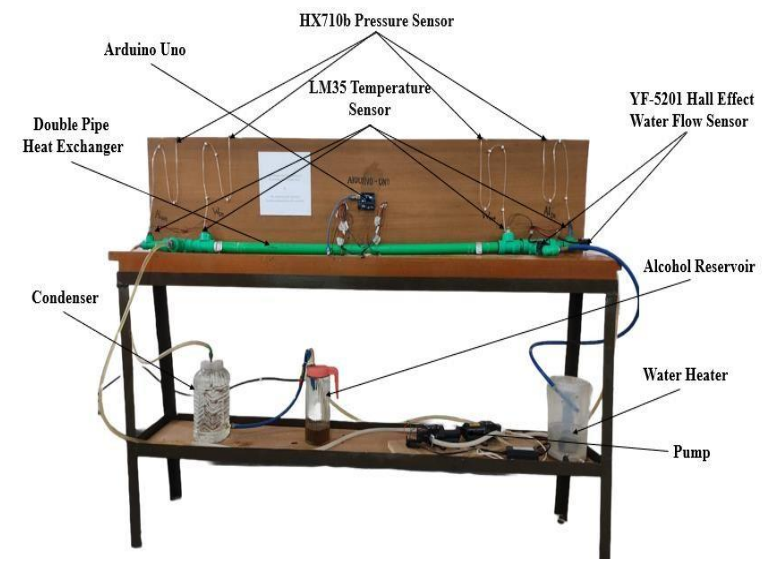


Figure 1. HEM Prototype

- **Double-Pipe Heat Exchangers (DPHEs):** Essential components in diverse industries.
- **Working Fluids:** Ethanol vs. Water.
- **Heat Exchanger Metric (HEM):** Measure of efficiency.
- **Dimensionless parameter:** Quantifies heat exchanger effectiveness.
- **Evaluation tool:** Compares working fluids and operating conditions.
- **Calculation:** Based on temperature and pressure differences.
- **Components:** Double-pipe heat exchanger, temperature sensors, pressure sensors, flow rate sensors, microcontroller (Arduino Uno).
- **Data Collection:** Various operating conditions (flow rates, inlet temperatures, fluid properties).

Research objectives

- Evaluate the heat transfer efficiency of a double-pipe heat exchanger (DPHE) using ethanol and water as working fluids.
- Assess the reliability of the HEM as a metric for evaluating heat exchanger performance.

Methodology

The research followed a structured approach, starting with a theoretical design for the double-pipe heat exchanger (DPHE). This design was then physically created using SolidWorks software. After building the DPHE, all sensors were calibrated to ensure accuracy. An Arduino Uno microcontroller was programmed to collect data from these sensors. Experiments were conducted under various conditions, and the collected data was analyzed to determine the efficiency of the DPHE using ethanol and water.

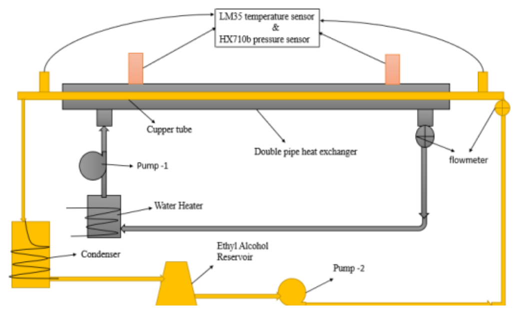


Figure 2 Block Diagram of HEM

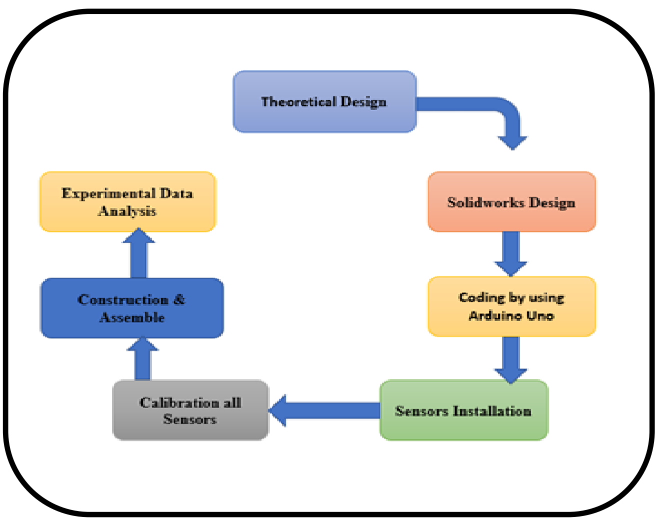


Figure 3. Methodology

3D Model & Components

Construction of Double-Pipe Heat Exchanger for HEM

- The project was designed to test a double-pipe heat exchanger under various conditions.
- The outer pipe was made of uPVC and the inner pipe was made of copper, which has high thermal conductivity.
- M-seal was used to prevent leaks and ensure safety.

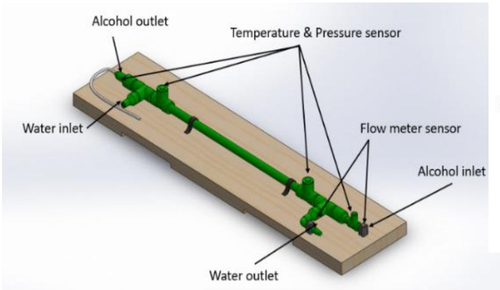


Figure 4. 3D design of double pipe heat exchanger

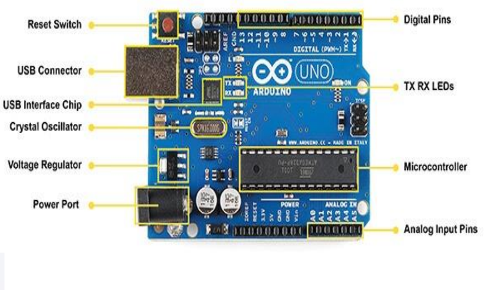
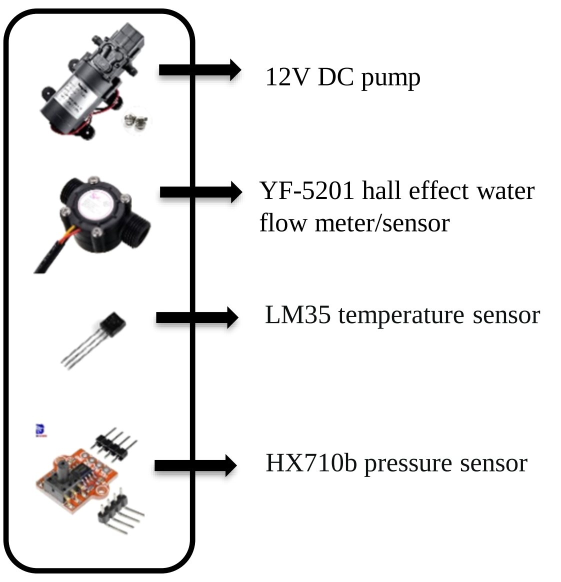
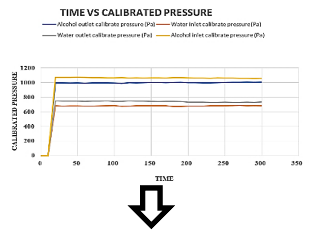
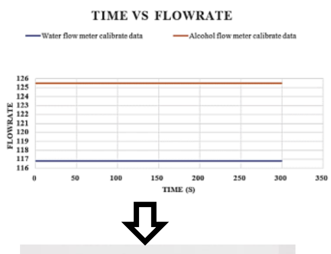


Figure 4. Components of Arduino UNO board



Research Finding





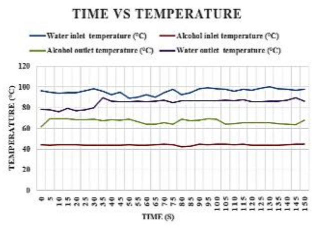


Figure 5. pressure and vacuum gauge U-tube and inclined manometer

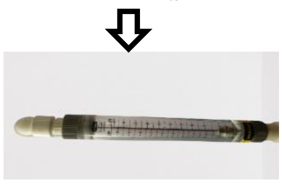


Figure 4. Flow Meter

All HEM sensors are Calibrated using Standard Measuring Instrument.

- The study used an Arduino Uno to gather precise data. The data was organized into a table and then visualized in graphs. These graphs were used to calculate the practical nest of HEM.

Calculation

$Tw_{in} = 92.55℃$

$Tw_{out} = 87.26℃$

$T_{A_{in}} = 43.92℃$

$T_{A_{out}} = 66.52℃$

$Q_w = \dot{m}\, Cp\, (\Delta Q)$

$= \dot{m}\, Cp\, (Tw_{in} - Tw_{out})$

$= 0.334 \times 4.204 \times 5.29$

$= 7.428$ wat

$Q_A = \dot{m}\, Cp\, (\Delta Q)$

$= \dot{m}\, Cp\, (T_{A_{in}} - T_{A_{out}})$

$= (0.036 \times 2.93 \times 22.6)$

$= -2.383844$ watt

$Q_{loss} = (\dot{Q}w - \dot{Q}_A)$

$= (7.428 - 2.383844)$

$= 5.044$ watt

Efficiency, $\in = \frac{\dot{Q}_A}{\dot{Q}w}$

$= \frac{2.383844}{7.428} = \mathbf{0.3209} = \mathbf{32\%}$

Conclusion

- **Optimal Performance:** The system achieved maximum hot temperature when water flow rate was 0 L/sec, pressure was 0, and inlet temperature was 0.
- **Efficient Phase Change:** Alcohol successfully underwent liquid-to-gas phase transition under increased pressure and temperature, and vice versa in the condenser..
- **Versatile Sensor Integration:** The combination of pressure, temperature, and flow meter sensors enabled comprehensive performance measurement and analysis.

Acknowledgement

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References

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2. Kumar, A., & Sharma, A. (2015). Experimental investigation on heat transfer performance of a double pipe heat exchanger using ethanol-water mixture. International Journal of Engineering Research & Technology, 4(1), 1-5