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Application of Arduino smart MQ-2 sensor for early detection of gas influx in water base drilling fluids

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ABSTRACT
This study explores the predictive analysis of gas inflow events during drilling using water-based muds using sensors built into Arduino. Early detection of influx patterns is made possible by a specially designed monitoring system that uses the MQ-2 sensor and Arduino Uno to record real-time gas concentration data. The study shows that prediction models for upcoming gas kicks may be constructed by combining variations in mud properties (density and viscosity) with changes in gas sensors. This method presents a useful smart well control tool for field operations and training, and it represents a step forward in digitizing kick detection.

تطبيقات استخدام حساس MQ-2 الذكي المعتمد على اردوينو في الكشف المبكر عن تسرب الغاز في الابار اثناء استخدام سوائل حفر ذات اساس مائي

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الملخص
تستكشف هذه الدراسة التحليل التنبؤي لحالات تسرب الغاز أثناء الحفر باستخدام سوائل الحفر المائية، وذلك من خلال استخدام حساسات ذكية مدمجة في نظام أردوينو. ويتيح النظام المراقب المصمم خصيصًا، والذي يستخدم حساس MQ-2 ووحدة اردوينو -اونو ، الكشف المبكر عن أنماط التسرب من خلال تسجيل بيانات تركيز الغاز في الزمن الحقيقي. تُظهر الدراسة أنه يمكن بناء نماذج تنبؤية لحالات تسرب الغاز المحتملة من خلال دمج التغيرات في خواص سائل الحفر (مثل الكثافة واللزوجة) مع قراءات حساسات الغاز. ويُعد هذا الأسلوب أداة ذكية فعالة للتحكم في الآبار، سواء في العمليات الميدانية أو في أغراض التدريب، كما يُمثل خطوة متقدمة في رقمنة عمليات اكتشاف تسرب الغازات.

الكلمات المفتاحية
سوائل حفر مائية
اردوينو
طينة الحفر
تدفق الغازات
رفسة الغاز
تحليل بيانات
حساس *MQ-2*

1. Introduction:

Drilling activities represent some of the most technically demanding tasks in the oil and gas sector due to the unpredictable characteristics of underground formations and the changing conditions of the wellbore environment [1].

The use of drilling fluids is essential in these activities as they help to stabilize the wellbore, transport cuttings to the surface, cool and lubricate the drill bit, and maintain hydrostatic pressure to prevent the inflow of formation fluids. Among these fluids, water-based mud (WBM) is still preferred for its affordability and environmental benefits [2].

Nonetheless, one of the most significant hazards during drilling is the occurrence of a gas kick which is an uncontrolled influx of formation gas into the wellbore when the hydrostatic pressure of the drilling fluid cannot counterbalance the formation pressure. Gas kicks can quickly escalate into blowouts, which pose risks to the safety of personnel, the environment, and operational equipment. Although traditional gas detection systems are generally effective, they are often expensive, complex, and limited in their ability to provide real-time, high-resolution data under varying drilling conditions [3].

The rapid development of low-cost microcontroller platforms, such as Arduino, presents new possibilities for smart well-control systems. When combined with sensitive gas sensors like the MQ-2, these systems can offer real-time monitoring of gas influx occurrences at significantly lower operational costs. While the application of Arduino-based monitoring systems has been investigated in other industrial settings, their potential for the early detection of gas influx in WBM drilling operations has not been fully realized [4].

Research Problem: Current methods for gas detection in drilling are often expensive, lack portability, or do not provide precise real-time readings in water-based mud systems. There is a necessity for a dependable, cost-effective, and easily deployable system to identify early signs of gas influx, especially in areas and operations where access to sophisticated equipment is restricted.

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Table 1: Key Differences between Conventional Gas Detection Methods and the Proposed Arduino-Based System

Comparison Aspect	Conventional Gas Detection Systems in Oil & Gas Wells	Proposed Arduino + MQ-2 Sensor Approach
Operational Cost	High, due to reliance on industrial-grade equipment such as gas chromatographs, infrared analysers, and flame ionization detectors	Low, using low-cost electronic components
Technical Complexity	High complexity; requires specialized training for operation and maintenance	Low complexity; user-friendly programming and straightforward operation
Response Time	May be delayed due to mechanical processes or laboratory analysis	Near-instantaneous, with real-time data visualization
Portability and Field Deployment	Bulky, heavy equipment; challenging to transport and install at remote sites	Compact, lightweight, and easily deployable in various field conditions
Flexibility for Modification	Limited; hardware changes require expert intervention and specialized tools	High flexibility; software and sensor configurations can be modified with minimal resources
Measurement Accuracy	Very high accuracy but dependent on frequent calibration and preventive maintenance and preventive maintenance	Good accuracy with potential for enhancement through calibration and improved algorithms and improved algorithms
Integration with Other Systems	Integration requires specific protocols and complex data communication setups	Easily integrated with digital platforms, IoT systems, and cloud-based monitoring solutions

Significance of the Research: This study addresses this gap by developing and accessing an Arduino-based MQ-2 sensor system for detecting hydrocarbon gases in drilling fluids. The research demonstrates the feasibility of integrating low-cost electronics into drilling operations to enhance safety, training, and decision-making concerning well control. The findings contribute to the progress of digitalizing drilling safety practices and provide a scalable model for operations with limited resources within the oil and gas sector.

Arduino-Based Gas Monitoring in Harsh Environments

Created an IoT gas monitoring system using Arduino, specifically designed for underground coal mining. This system effectively monitored levels of CO, CH_4, and CO_2 through cloud connectivity. It achieved approximately 87.5% sensitivity and 77.7% positive predictive value even in difficult conditions, showcasing the capacity of low-cost sensors to function reliably in demanding settings [5].

2. Smart Gas Leak Detection in Residential Settings

Developed an intelligent LPG leak detector powered by Arduino, which dispatches SMS notifications when a leak is detected. This demonstrates the ability of Arduino systems for real-time monitoring and alerting of leaks—frameworks that can be readily adapted for use in drilling fluid systems. [6]

3. Low-Cost Smart Gas Leakage Detector (2024)

introduced a smart gas leak detection system utilizing an Arduino gas sensor designed for use in industrial, automotive, and residential environments. The device is noted for its cost-effectiveness, quick reaction time, and strong detection capabilities [7].

2. Materials and Methods:

2.1 System Design:

The proposed system consists of the following components:

- **Arduino board**: Serves as the central processor for data acquisition and signal processing.
- **MQ-2 Sensors**: sensor detects flammable gases like propane, methane, and smoke by measuring changes in gas concentration in the air[8].
- **LCD Display:** Provide real-time alerts and visual feedback when thresholds are exceeded.

3. Arduino:

The Arduino integrated development environment is a platform for creating microcontroller programs, featuring an intuitive programming language. The Arduino may turn from scratch into a programmable "brain" that can work with practically any control system by adding sensors, actuators, lights, speakers, shield modules, and other integrated circuits from scratch into programmable brain, which can serve any control system [8]. As shown in figure (1)

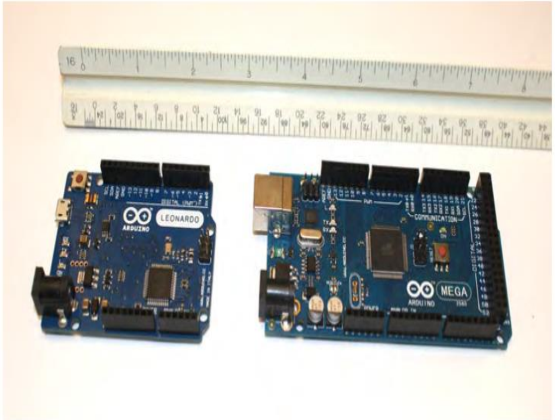

Figure 1: Relative sizes of Arduino boards

3.1 Arduino Functionality

All Arduino boards share a few key characteristics and capabilities. Take a time to examine the Arduino Uno in Figure (2) this will be the initial setup.

• Microcontroller: it is the main component of any Arduino device.

• Programming: it is the software for running Arduino and its changeable to match the required work

• I/O: Input/output (I/O) circuitry allows Arduino to interface with sensors, actuators, and other devices.

• Power: There are several ways to supply power to an Arduino board. Most Arduino boards can automatically switch between multiple power sources, such as USB and a battery. [8]

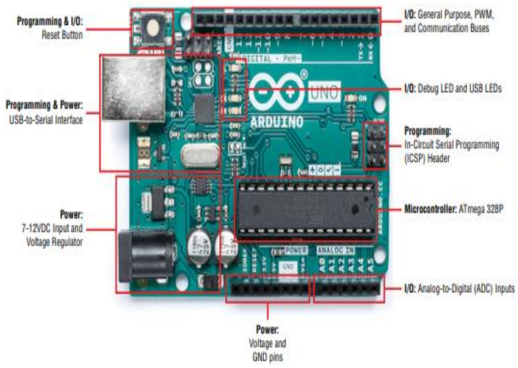

Figure 2: Arduino Functionality

3.2 Arduino Sensor:

An Arduino sensor is any machine, gadget, module, or other mechanism that senses changes in its surroundings. Sensors send a signal to electronic devices informing them of these changes. Electronic devices shows in figure (3) readily read the output signal and frequently work with sensors [8].

Figure 3: Arduino MQ-2 sensor

3.3 Calibration and Setup:

Calibration of sensor by using standard fluids is mandatory step to ensure accuracy of the experiment, closed loop of circulation mud tank was form to provide full stimulation of drilling conditions with applying of gas at controlled rates to match influx scenarios.

3.4 Data Acquisition and Processing:

The Arduino system collecting and analyzing pressures and density data continuously. A custom script was implement for threshold logic to trigger alerts when abnormal changes were detect. Different mud weights and gas concentrations were used to test system.

4. Experiment steps:

Setup: A clean 500 ml tank was prepared, and mechanical mixing was chosen to ensure uniformity.

Material: First, 350 cc of water was gradually added to 22.5 grams of bentonite, stirring continuously to prevent lumps from forming.

Mixing: Blend the mixture with an electric mixer until a homogeneous liquid is obtained.

5. Results and Discussion:

The study investigated the effectiveness of Arduino – based on MQ-2 Sensor for the detection of the presence of hydrocarbon gases, propane & butane in drilling muds. Furthermore, the effects of these gases on fluid viscosity and density as they are important properties to achieve success of drilling.

5.1 Affection of Gas injection on drilling fluid density and viscosity:

- Density before addition of gas recorded 8.70 gm/c³ while after addition of gas decreased to 8.20 gm/c³ due to addition of lighter gas lead to decrease the overall weight of the fluid
- Viscosity was recorded initially of 8 cP, it increased to record 10 cp after the addition of gas and this increment due to gas-fluid component interactions that led to surface tension and bubble forming.

5.2 Sensor's readings with addition of gas:

- Steady reading of sensor MQ-2 was recorded when it was free of gas, this stability indicates an environment with no gas, thus proofing the sensor's effectiveness under different conditions as show in figure (4).

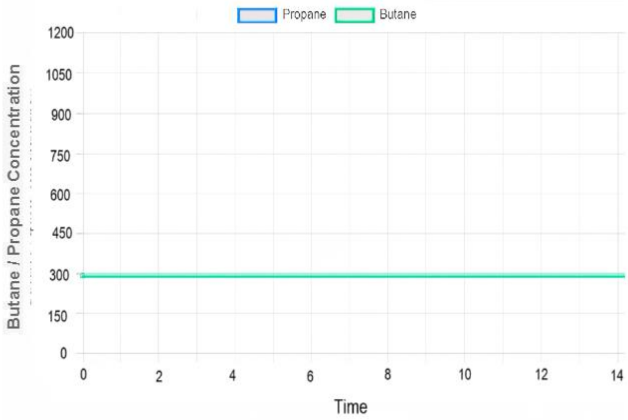

Figure 4: Gas does not pass through.

- Low values at the very beginning indicates presence of very small amount or no propane concentration followed by sharp spiked shows that the sensor exposed to propane gas at higher values which ended to increment in captured signal
- The signal gradually increased between times zero and two, indicating the beginning of propane gas entering the sensor.
- Fluctuation was noticeable between points 18 & 22 proofing varies gas concentration followed by sharp increment of concentration results from exposing of sensor to higher concentration of propane Figure (5) illustrates different concentration of propane.

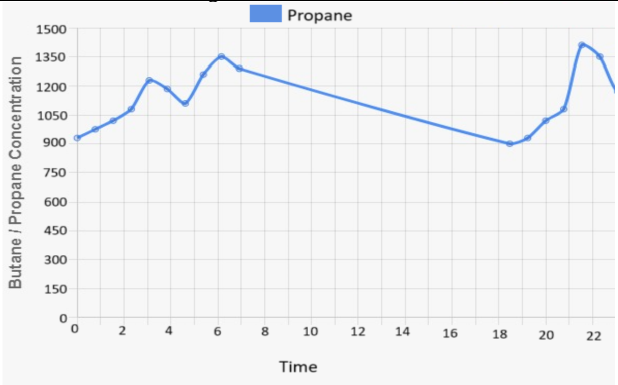

Figure 5: Propane concentration with time

Table 2: Propane gas concentration measurement data

Concentration of gas(ppm)	Time(sec)	Case
900 ppm	0 sec	The beginning of gas entry
1050 ppm	2 sec	Increase in the amount of gas
1400 ppm	22 sec	Maximum gas level

- At first glance, at point 0, the butane concentration appears low, and it gradually increases at point 2, indicating that the sensor was initially exposed to butane gas. Then, the gas concentration increases significantly between points 19 and 21, indicating that the sensor was exposed to a higher concentration of butane gas.
- Figure (6) shows the temporal changes in concentration of the gas interaction with- -ambient conditions that analyzing the behavior of the gas in drilling fluids.

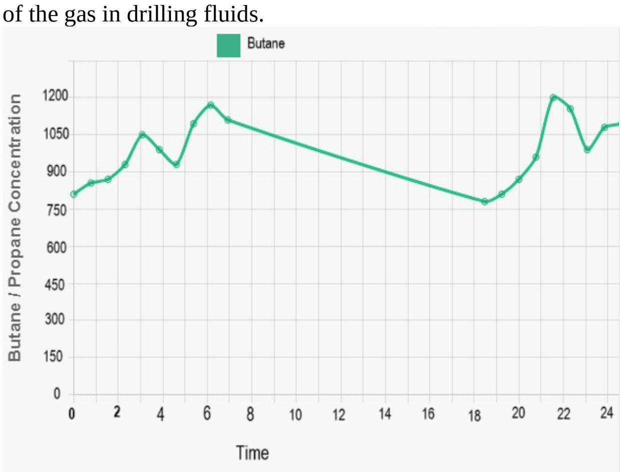

Figure 6: Butane gas concentration measurement data

Table 3: Butane gas concentration measurement data

Concentration of gas(ppm)	Time(sec)	Case
800 ppm	0 sec	The beginning of gas entry
1000 ppm	2 sec	Increase in the amount of gas
1200 ppm	4 and 22 sec	Maximum gas level

The following figure shows the sensor reading for the two gases passing through it.

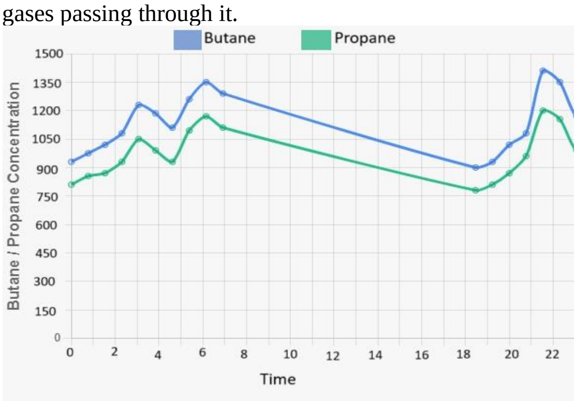

Figure 7: Butane and propane gases concentration measurement data

5.3 Interpretation of Results of Density & Viscosity:

1. As a result of gas injection into drilling fluid, the fluid become lighter due to the sticking of fluid on gas bubble's surface which lead to decrement of fluid density
2. The communication between fluid and gas have strengthened the internal structure of fluid, which lead to the noticeable increment of viscosity.
3. The initial density of the fluid was measured at 8.70 g/cm³, and the viscosity was recorded at 8 cP Upon injecting the gas, When 250 units of gas were introduced, the viscosity increased to 8.50 cP, while the density decreased to 8.575 g/cm³. These results indicate that gas injection leads to an increase in viscosity and a simultaneous decrease in density, as the injected gas is of a lighter weight compared to the base fluid

Table 4: Changes in density and viscosity with respect to gas flow.

Viscosity (cP)	Density (g/cm³)	Gas Flow (ppm)
8	8.7	0
8.5	8.575	300
9	8.45	600
9.5	8.325	900
10	8.2	1400

6. Conclusion:

- MQ-2 sensor is capable of sensing and early detecting the presence of gases into drilling fluid such as propane and butane in case of any influxes enter the wellbore while drilling operation.
- The MQ-2 sensor is capable to identify certain gases depending on changes in concentration measurements and their impacts over time.
- The ideal state serves as reference point of the observation changes in concentrations.
- MQ-2 sensor is able to monitor the concentration changes over real time.
- The MQ-2 sensor provides reliable and accurate data, making it useful for a wide range of industrial applications.
- Arduino use may become low-cost application of gas monitoring in few years which would help improving early detection of gas influxes
- This technology will provide high resolution and rapid-response applications of early detection of formation gases in wellbore.

7. Recommendations:

1. Sensors outer led must not exceed 75 microns the internal composition of bentonite particles has the smallest parts in any drilling fluid which is equal to 75 microns , therefore the sensor doesn't plugged to optimize correct readings .
2. Development and upgrading is required for the sensos MQ-2 to operate properly in varies ranges of drilling fluids
3. Development should cover other types of MQ-8 sensor in \terms of reading hydrogen sulfate gases (H2S)
4. Enhancing the accuracy of early gas influx detection by integrating multiple sensor types at one machine.
5. Integration with existing rig monitoring platforms could allow seamless real-time alerts for operators.
6. Subsequent research could investigate automated control measures activated by identified gas influxes, enhancing operational safety even further

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