Innovative Development of Exhaust Fan with Smart Gas Detector System Powered by Arduino Uno for Welding Workshop Safety Enhancement

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ABSTRACT – In welding workshops, gas leaks pose serious safety risks, including potential fires and explosions. This research introduces a novel Exhaust Fan with Smart Gas Detector System designed to enhance safety through Arduino Uno technology. The study focuses on developing an automated, reliable system for detecting hazardous gas leaks, activating an exhaust fan for gas removal, and providing user notifications both on-site and remotely. The system integrates an MQ5 gas sensor for detecting dangerous gases, an Arduino Uno microcontroller for data processing and system control, and a motorized exhaust fan for effective gas extraction. The effectiveness of the system was tested under controlled conditions, demonstrating its ability to detect gas leaks in real time, activate the exhaust fan, and alert users. This development represents a significant advancement over traditional gas detection methods by combining real-time detection, automated response, and remote notifications. This innovative approach offers a scalable, cost-effective solution for improving safety in welding workshops and sets the stage for future advancements in industrial safety technologies

KEYWORDS: Arduino Uno, Gas Detection System, Remote Notification, Welding Workshop Safety, Industrial Safety Technology

1.0 INTRODUCTION

The Exhaust Fan with Smart Gas Detector project employs an Arduino microcontroller to automate the detection and management of gas leaks in welding workshops. This system addresses the frequent safety hazards associated with gas leaks, which can lead to dangerous incidents such as fires or explosions. By integrating an exhaust fan, a gas sensor, and an alert mechanism, this project provides a comprehensive solution for early gas leak detection and response. The key features of the system include, exhaust fan to removes gas from the workshop environment, gas sensor (MQ5), to detects the presence of hazardous gases and alert mechanisms**,** includes LEDs and a buzzer as a notification system for user alerts. Gas leaks in welding workshops present significant safety risks, including potential fires and explosions due to delayed detection. Traditional methods often fail to provide timely alerts, resulting in severe accidents. This innovation system addresses this problem by detecting gas leaks in real-time and taking corrective actions.

1.1 OBJECTIVE

i. **To Innovate a Gas Detection and Extraction System:** The primary goal of this project is to design and develop a novel tool specifically for the detection and extraction of hazardous gases in the welding workshop at Politeknik Sultan Salahuddin Abdul Aziz Shah. This tool aims to offer a new approach to gas leak management through the integration of advanced technologies.
ii. **To Develop a Gas Leak Monitoring System:** Another key objective of this project is to create an effective monitoring system capable of detecting gas leaks in real-time and mitigating the associated fire risks. This system will leverage state-of-the-art sensors and control mechanisms to ensure timely and accurate detection of hazardous gases.
iii. **To Enhance Welding Process Safety:** The project aims to improve the safety protocols associated with welding processes by implementing advanced gas detection technology.

Through the development of this system, the project seeks to enhance the overall safety of welding operations and reduce the risks of fire and explosion in the workshop environment.

Figure 1. Exhaust Fan with Smart Gas Detector

2.0 LITERATURE REVIEW

Welding workshops such as Shielded Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW) are high-risk environments due to hazardous gases and fumes. Traditional ventilation systems often lack the responsiveness needed to handle sudden increases in toxic gas levels. This review explores integrating smart gas detection with exhaust fans, using Arduino Uno for real-time monitoring and control. Welding produces hazardous gases like carbon monoxide (CO), nitrogen oxides (NOx), and ozone (O3), which can cause severe health problems. Traditional ventilation systems, which usually operate at a constant rate, are not capable of dynamically responding to fluctuating gas levels (Laitinen et al., 2018). Gas detection has advanced with sensors like metal oxide, electrochemical, and infrared sensors, each having unique advantages. Smart systems combine these sensors with microcontrollers to enable real-time monitoring and automatic responses, such as activating exhaust fans or alerting operators when gas levels are unsafe (Chen et al., 2021). Gas detection technology has evolved considerably, with sensors capable of detecting various gases with high accuracy. Common types include metal oxide sensors (MOS), electrochemical sensors, and infrared sensors, each with specific advantages and limitations.

Table 1. CO concentration (PPM) exposure effects on health

CO Concentration (ppm)	Effects on Health	Exposure Duration
0-9 ppm	Normal background levels; generally safe.	Continuous exposure.
10-29 ppm	Headaches, fatigue, and shortness of breath may occur in sensitive individuals.	Continuous exposure.
30-49 ppm	Headaches and dizziness in some individuals; possible heart effects.	1-2 hours exposure.
50 ppm	Headaches and other symptoms may occur after 8 hours of exposure; OSHA PEL.	8-hour exposure.
100 ppm	Symptoms include headache, dizziness, and nausea after 10-40 minutes.	10-40 minutes exposure.
150-200 ppm	Increased severity of symptoms; confusion, disorientation, and impaired judgment.	4-15 minutes exposure.
200-400 ppm	Life-threatening; loss of consciousness, risk of death.	20 minutes exposure.
>400 ppm	Severe symptoms, risk of death in minutes; high risk of brain damage.	Minutes.

Arduino Uno is a versatile, easy-to-program microcontroller, supporting various sensors and actuators. It is widely used in safety applications, benefiting from a large community that provides extensive resources for developing custom systems (Banzi & Shiloh, 2014; Kushner, 2018). The proposed system integrates gas sensors with Arduino Uno and an exhaust fan. Sensors monitor gas levels continuously, and Arduino activates the fan based on set thresholds. Testing focuses on sensor accuracy, response time, and the fan's effectiveness in real-world welding workshops (Jones et al., 2023). Prototype development and testing are crucial steps in system validation. Initial tests focus on sensor accuracy, response time, and the effectiveness of the exhaust fan in reducing gas concentrations. Field testing in a welding workshop environment provides data on system performance under real-world conditions.

3.0 METHODOLOGY

Methodology refers to a system encompassing the methods and principles used in a particular activity or discipline. It also implies techniques, styles, patterns, rhythms, and systems. Modern technology has greatly advanced the field of electronics, resulting in sophisticated tools that simplify and enhance various industrial processes. One such innovation is the Smart Gas System, a project designed to improve safety in environments prone to gas leaks, such as welding workshops.

3.1 Project Development

The development of the Smart Gas System for welding workshop safety involved a multi-phase approach that includes research, design, implementation, and testing. This section outlines the detailed steps undertaken to develop this innovative gas detection and extraction system, focusing on the project's objectives and technical challenges. The initial phase of the project involved extensive research on existing gas detection technologies and safety systems. Study have shown that older systems provided basic detection while modern electronic systems offer more sophisticated and reliable solutions. This phase also included reviewing the capabilities of the Arduino platform for building a cost-effective and programmable system. Conceptual Design, is based on the research findings, the conceptual design of the Smart Gas System was formulated. The primary goal was to create a system that could detect gas leaks, activate an exhaust fan, and provide immediate alerts through visual, auditory, and remote notifications. The design incorporated the MQ5 gas sensor for gas detection, Arduino Uno for system control, and exhaust fan for gas extraction.

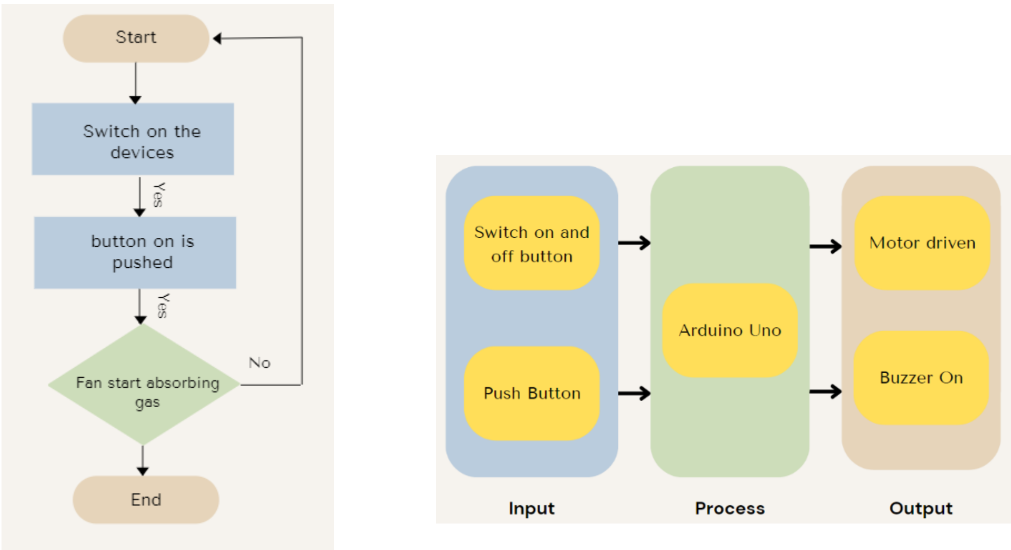

Figure 2. Flowchart and Block Diagram of the Exhaust Fan with Smart Gas Detector

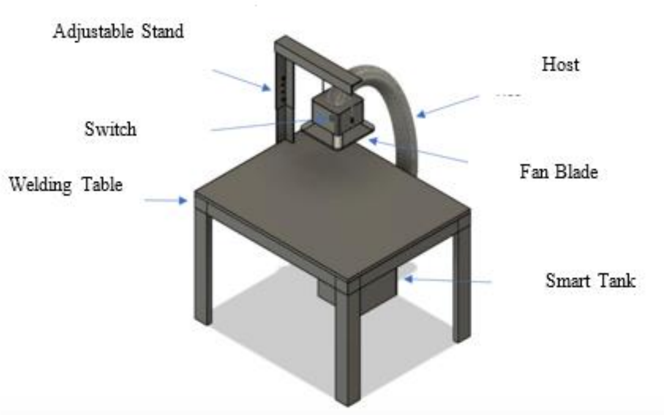

Figure 3. 3D Design of Exhaust Fan with Smart Gas Detector

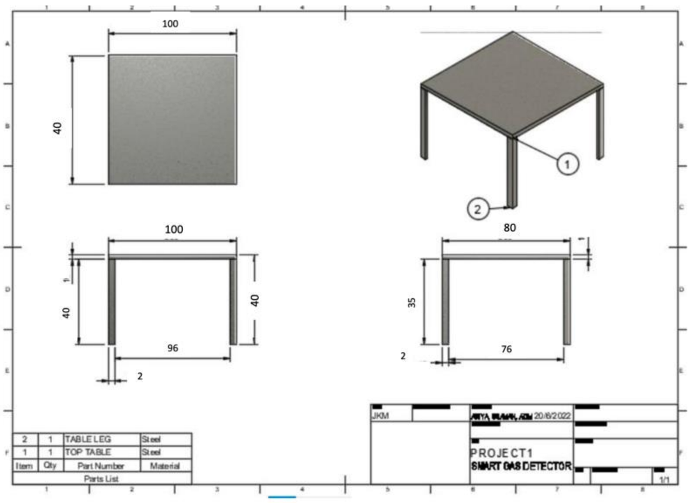

Figure 3. 2D Drawing of Exhaust Fan with Smart Gas Detector

4.0 RESULT

4.1 Questionnaire

A questionnaire was distributed to students and lecturers who use the welding workshop at Politeknik Sultan Salahuddin Abdul Aziz Shah. The survey findings indicate that, on average, the workshop is utilized 2 to 3 times per week. A significant safety concern highlighted by respondents is the lack of adequate leak prevention equipment in the welding area, compounded by the absence of exhaust fans or blowers. This deficiency makes it difficult for students to promptly detect gas leaks during welding processes, leading to a perceived safety hazard among users. It is strongly recommended that the welding workshop be equipped with appropriate gas leak prevention tools and ventilation systems to enhance safety measures.

4.2 GAS DETECTION SENSOR SYSTEM RESPONSE TIME

Based on the experiment conducted during welding operations, it was found that the use of the MQ5 sensor for detecting gas and smoke emitted during welding is more efficient, being 50% more effective than the MQ2 sensor. When the sensor readings reach 220ppm, the LED will illuminate and the buzzer will sound notification to the user.

Table 2. The relationship between type of gas detected levels and the time taken during welding

TIME	MQ2	MQ5
3 Second	170	190
6 Second	220	260
9 Second	250	290

4.3 EFFECTIVENESS OF EXHAUST FAN

The smart gas detection system is designed to enhance safety in a single welding bay by monitoring harmful gas levels, particularly carbon monoxide (CO), and activating an exhaust fan to ventilate the workspace. The response time of the system is a critical performance measure, as it directly impacts the system's ability to prevent hazardous gas accumulation and ensure a safe working environment. The system’s response time refers to the total duration from the detection of elevated gas concentrations to the activation of the exhaust fan. This was measured by simulating controlled releases of CO in the welding bay and recording how quickly the system responded.

Table 3. The effectiveness of CO responds using Exhaust Fan with Smart Gas Detector System

Test No.	Initial CO Concentration (ppm)	Time to Detect (seconds)	Time to Fan Activation (seconds)	Total Response Time (Detection + Fan Activation)	Time to Reduce CO to Safe Level (< 50 ppm)
1	70 ppm	3 seconds	2 seconds	5 seconds	120 seconds
2	100 ppm	2 seconds	2 seconds	4 seconds	160 seconds
3	150 ppm	2 seconds	1 second	3 seconds	180 seconds
4	200 ppm	2 seconds	1 second	3 seconds	220 seconds
5	250 ppm	1 second	1 second	2 seconds	300 seconds

The total response time of the system—ranging from 2 to 5 seconds depending on the initial CO concentration meets the critical safety requirements for the welding bay. According to the Occupational Safety and Health Administration (OSHA), the permissible exposure limit (PEL) for CO is 50 ppm over an 8-hour workday. Exposure to CO concentrations above 150 ppm can lead to acute symptoms such as headaches, dizziness, and nausea, while levels above 400 ppm pose serious health risks, including loss of consciousness or death. In the tests conducted, the system responded within 5 seconds when CO concentrations were at 70 ppm, and as quickly as 2 seconds when the concentrations reached 250 ppm. This response time is fast enough to ensure that CO levels are addressed promptly before workers are exposed to dangerous concentrations. Even in the case of rapid gas accumulation if the equipment is malfunction, the system’s response time falls within a range that is considered acceptable to prevent harmful exposure. Based on industry standards for gas detection systems, a response time of 2-5 seconds is within the effective range for high-risk environments such as welding workshops. OSHA and other regulatory bodies mandate immediate action when gas levels exceed safety thresholds. Industrial-grade gas detection systems typically operate within a 2-10 second response window, with 2-5 seconds being the norm for environments where toxic gases can accumulate rapidly.

The system's 2-5 second response time, therefore, aligns well with these expectations, making it suitable for the welding bay where hazardous gas build-up can occur.

4.4 Limitations of the System

Welding environments pose significant challenges for electronic components, including exposure to dust, temperature fluctuations, electromagnetic interference (EMI) from welding equipment, and high humidity. These factors were identified as potential sources of interference that could impact the long-term reliability and performance of the smart gas detection system. One of the primary limitations observed during the long-term testing phase was the effect of dust and particulate accumulation on the gas sensors. Welding activities typically generate large quantities of dust, metal particles, and fumes, which can accumulate on exposed electronic components. Over a period of 3 months, it was noted that dust build-up on the gas sensors particularly the MQ-5 sensor used for carbon monoxide (CO) detection that can lead to intermittent false positive readings. The dust interference significantly impacted the accuracy of gas detection after prolonged exposure to welding conditions. The false positive readings posed a challenge for maintaining accurate gas monitoring, as the system occasionally responded to non-existent gas hazards. While the exhaust fan activation due to false positives does not directly endanger workers, it can decrease the system's operational efficiency over time, potentially masking real gas leaks or hazards if the system becomes less reliable. frequent false alarms could lead to user complacency or disregard for actual alarms, potentially undermining the safety protocols in the workshop. Additionally, regular cleaning and maintenance were required to mitigate the effects of dust accumulation, increasing the system's upkeep requirements and maintenance costs.

4.5 *Future Research Direction*

To address the limitations of this research, several mitigation strategies can be implemented, including the installation of protective casings equipped with specialized filtration mechanisms to block larger particulates while maintaining airflow for accurate gas detection; regular maintenance schedules to clean sensor surfaces and prevent dust build-up that could degrade performance and the incorporation of self-cleaning mechanisms, such as periodic purging with air jets or vibrations, to automate dust removal and reduce the need for manual intervention. Additionally, deploying multiple sensors to create system redundancy allows for cross-validation of readings, mitigating the risk of false positives or inaccurate measurements caused by dust accumulation on any one sensor. In such systems, if one sensor becomes compromised, the others can still provide accurate data, enabling the system to make reliable decisions, such as triggering alarms or activating ventilation systems, thus ensuring continued functionality and fault tolerance in environments prone to dust and particulate interference. Together, these strategies enhance sensor reliability, accuracy, and longevity, helping to maintain efficient and accurate gas detection even in challenging industrial or environmental conditions where dust and fumes are prevalent.

5.0 CONCLUSION

In conclusion, the Exhaust Fan with Smart Gas Detector System presents a significant advancement over traditional safety measures in welding workshops, by offering a proactive and automated approach to mitigating gas leak risks. The system's integration of advanced technology enables early detection of hazardous gases, automated exhaust fan activation, and real-time alerts, providing a clear improvement over traditional safety method. Controlled testing validated the system's reliability, with CO concentrations detected within 1 to 3 seconds and fan activation within 1 to 2 seconds, resulting in a total response time of 2 to 5 seconds, depending on initial gas levels. Additionally, the system effectively reduced co concentrations below 50 ppm in 120 to 300 seconds, minimizing the risk of accidents and exposure. The research highlights the system's scalability and cost-efficiency, offering a solution that combines real-time monitoring, automated responses, and remote notifications to enhance safety in industrial settings. To further improve the system, the integration of gsm modules for SMS notifications would ensure prompt alerts, even when users are off-site, enhancing response times to potential hazards. This research lays a foundation for future developments in industrial safety technologies, aiming to create safer work environments and prevent potential hazards more effectively, with the potential for broad application across diverse settings.

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