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A Smart Technology Based Digital Stove with Gas Leak Detection and Automatic Shut off

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Abstract

The increasing concern over gas leaks and kitchen fires in Bangladesh needs new solutions to improve household safety and efficiency. This paper introduces a smart technology-based digital stove with an integrated gas sensor, a cutting-edge kitchen equipment created to solve these issues. The stove has a gas sensor alarm system that detects gas leaks and sounds an audible warning, allowing users to take early preventative action to avoid mishaps. Along with its safety features, the stove provides accurate temperature control, automatic shut-off and a timer, making cooking more efficient and easier. The stove is designed to be compatible with the local gas infrastructure, which mostly utilizes propane or natural gas, and is reasonably priced to assure widespread availability. The paper also describes the creation of the functional structure, which included a black box and transparent box model, as well as the execution of a Quality Function Deployment (QFD) method to align the product's features with client needs. The design parameters and a comparative comparison highlight the product's unique value, which prioritizes safety, cost, and user ease.
Keywords: Smart Stove, Digital Logic Method, QFD, MQ-6 Gas Sensor, Shut off Mechanism.

1. Introduction

All throughout the world and in our country, gas is the most effective, efficient, environment-friendly fossil fuel for cooking and heating in our homes, restaurants, and many other institutions. Among the gases, the most used gases are natural gas and liquefied petroleum gas (LPG). Both of these are unique compositions of hydrocarbon gases, and those mixes of hydrocarbons are so combustible, and any mishap of those hydrocarbons is so much harmful [1]. Basically, in household kitchens, LPG cylinders are used. The LPG is filled only up to 85% of the cylinder above which will be fumes. This is due to the expansion feature of the LPG and subsequently, contributes as a safety precaution to avoid any dangers. For every 1 degree rise in temperature, the pressure of LPG inside the cylinder will increase by 15 kg/cm3 which makes the LP gas cylinder more unsafe and extremely inflammable gas [2].

In a developing country like Bangladesh, kitchen safety is often neglected and compromised, and sometimes tragic accidents occur. Gas pipe explosion has claimed many lives and it's increasing day by day. A common scenario is when people leave their homes, they shut off their windows and doors to prevent theft. But sometimes after cooking they forget about properly turning their gas line off, resulting in gas leakage. Since there is no ventilation the gas accumulates in the enclosed space, it becomes trapped, turning the house into explosive hazard. In any case if somehow fire is ignited or electric spark occurs a devastating explosion would most likely happen [3].

Incorporating smart technologies into home appliances is transforming our mindset on how we approach safety and efficiency in the kitchen. Among these developments, the smart stove with gas leak detection and automated shut-off features stands out as a major one in helping to reduce home disasters brought on by gas leaks. Particularly in highly inhabited areas, the potential of gas leaks seriously compromises household safety given the increasing urbanization and reliance on gas stoves for cooking.

This smart stove goes beyond traditional designs by adding additional performance features, like precise temperature control, automatic shut-off, and a timer for enhanced cooking efficiency and convenience. The system is meant to be compatible with the current gas infrastructure in Bangladesh, making it available to a wide range of households. This paper discusses the development of this smart stove, beginning with a market analysis that points out the growing demand for safer kitchen appliances. It also includes the functional design, safety measures, and technological architecture that supports the gas leak detection and shut-off system. By addressing

both safety and convenience, this smart burner intends to offer a modern, inexpensive answer to one of the most important challenges in household kitchen safety.

2. Literature review

Information acquired during the literature survey is presented in this section. The paper [4] discusses an Automatic Safety Gas Stove with an AT89C51 microcontroller-based embedded application for safety, including gas shut-off. It doesn't mention gas leak detection, focusing on turning off the stove in various situations. Moreover, in this paper delay was observed due to nonlinearities in setup. In the paper [5], the authors presented an intelligent gas stove, which can be utilized for automatically flaming out at regular time to realize safety protection and automatically initiating combustion at a preset time, and has the characteristics of energy saving, and environmental friendliness. However, gas leak detection is not specifically included and also the system's dependence on electric supply for operation may limit its usability in areas with unreliable electricity. In [2] shutting off the gas burner in different situations is covered. However, if the meal is kept in a vessel for cooking purposes, then there are risks of it getting overcooked or even undercooked. These cases are not identified in the work mentioned in [2] because of not having timer circuit advancement just automation of switching the stove on and off is done. From reviewing the paper [7], we see that digital stoves equipped with sensors like MQ-2 and MQ-4 provide real-time monitoring of gas levels, allowing for precise detection of leaks. In [8] Semiconductor sensors, specifically MQ-6 gas sensors are utilized. MQ-6 sensor detects LPG gas concentrations from 200 to 10,000 pp. The MQ-6 sensor has a detection range of 300-10,000 ppm, which may not be sensitive enough for very low gas concentrations, potentially leading to delayed detection.

3. Methodology

Market Analysis

The development approach began with intensive market research to identify potential customers and measure customer interest in an IoT-based smart stove. We performed an online survey with 245 respondents from various locations of Bangladesh, including Dhaka, Khulna, and Rajshahi, to identify customer needs and preferences. The poll targeted both urban and rural families that use gas stoves, with the demographic consisting of mostly middle- to upper-class safety-conscious individuals. The results of this poll guided the feature set of the smart stove, stressing safety systems like gas leak detection and automated shut-off.

Design Process

The smart stove's design was developed using a systematic process comprising the establishment of transparent box model. A thorough House of Quality (HoQ) was designed to match client requirements with technical standards. The design process integrated elements such as a gas sensor, safety warning system, and automated shut-off mechanism, ensuring user safety and convenience. The final product design was also affected by consumer preferences for size, durability, and cost, obtained from survey data.

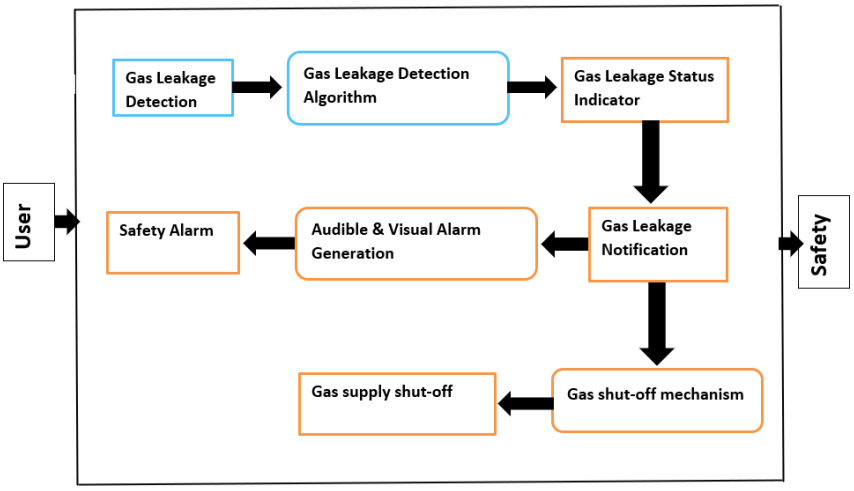


Fig. 1. Transparent Box for smart stove

Material Selection

Materials selection can be done by digital logic method and weighted properties analysis. We basically applied digital logic method for selecting materials for different parts of the stove. Material selection of the main body was done by priority decisions with relative emphasis co-efficient (weighting factors). Alongside, relative evaluation as well as calculation of scaled properties were done. We also calculated the performance index of

different materials. According to performance index stainless steel is chosen for main body while cast iron was picked for the pan holder for its strength and heat resistance. The burner was composed of aluminum for its lightweight qualities. These materials were evaluated based on variables such as strength, affordability, machinability, and availability, assuring optimal performance and cost-efficiency.

Quality Function Deployment

Quality Function Deployment, or QFD, is a useful method for product design since it makes it easier to match product characteristics with customer requirements. To prioritize our customer requirements and map them to engineering characteristics, we have performed QFD analysis. This ensures that the product will match both market demands and customer expectations.

Here, our QFD analysis gave manufacturing cost and price the highest priority, followed by marketing initiatives. The stove should be small, strong, and light to satisfy consumer demands. These elements must be balanced for the smart stove to have a solid market position and satisfy customers.

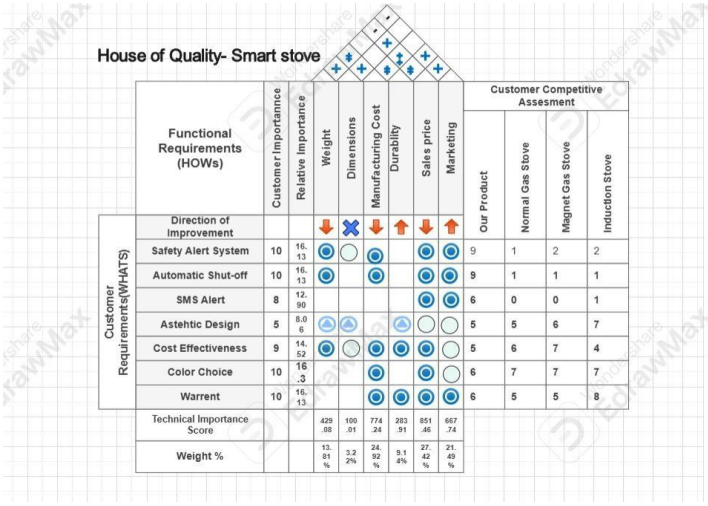


Fig.2. House of Quality (HoQ)

Circuit Diagram:

The circuit diagram of the smart stove includes numerous components for seamless operation. It features an Arduino nano microcontroller to process inputs from the gas sensor (MQ-6), which detects gas leaks. Upon detection, the buzzer and LED indicator are activated to inform the user, while the servo motor automatically shuts off the gas valve. Potentiometer is used to control gas emission as a knob. Power is supplied via a DC adapter, ensuring reliable performance of all components during operation.

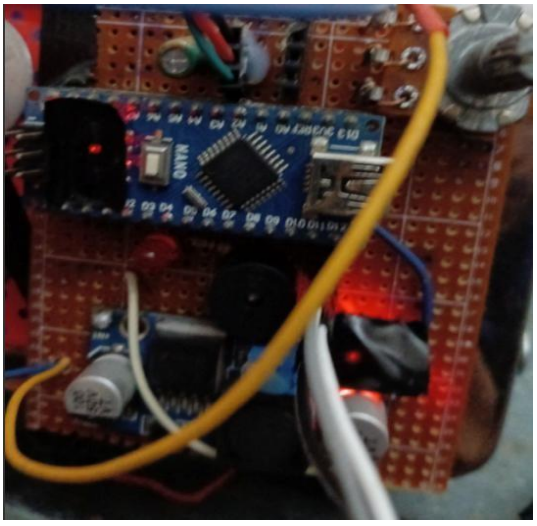


Fig.3. Real time circuit diagram

Manufacturing Process

The production of the smart stove followed a planned process spanning numerous steps. The body of the stove was produced utilizing welding, as it was considered to be the most effective approach based on a performance index comparing riveting and welding procedures. Key electrical components, such as the Arduino circuit board and gas sensor, were made by standard techniques like surface mount technology (SMT) and validated for operation before integration. The stove's components were integrated into the finished product, followed by thorough testing to guarantee compliance with safety and performance regulations.

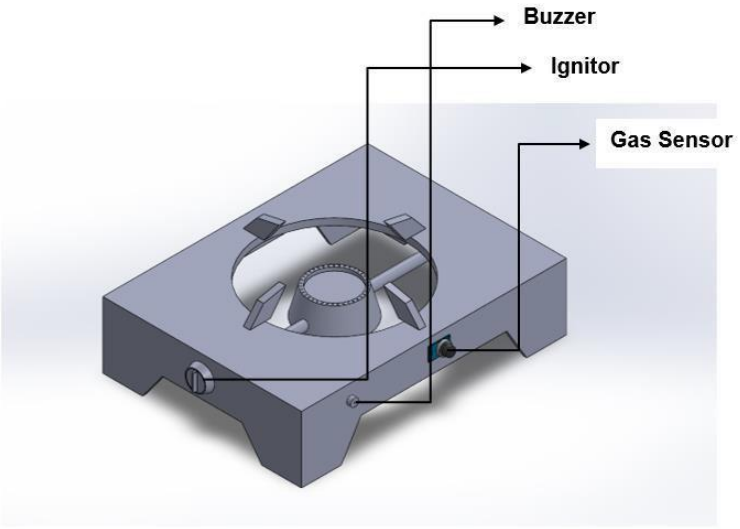


Fig. 4. 3D simulated model of smart stove

Testing and Validation

The smart stove was tested thoroughly to verify its functioning and safety. This involved evaluating the gas leak detection system, alarm operation, and the automatic shut-off mechanism. Each component, such as the buzzer, gas sensor, and servo motor, received individual testing during the construction phase. Additionally, user feedback from the initial prototype was collected to make essential modifications in design and functionality.

Cost and Lifecycle Analysis

A cost study was undertaken to ensure the product would be competitively priced while retaining quality. The Bill of Materials (BOM) was generated, accounting for the cost of components such as the frame, burner, and electronic elements. A lifecycle cost analysis was also undertaken, incorporating production, marketing, and customer service costs over five years. A break-even analysis was carried out to calculate the number of units required to cover initial fixed costs, helping to plan production and price strategies.

Stress and Durability Testing

Stress analysis using SolidWorks and ANSYS ensured structural integrity under typical load and heat conditions. The maximum stress of 1.166e+08 N/m² was well within the material's safety limits, with a factor of safety of 5.322.

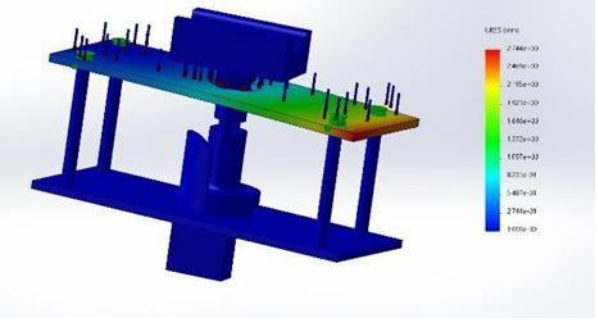


Fig. 5. Stress Analysis of 3D

4. Results

The developed smart stove successfully integrated gas leak detection and automatic shut-off mechanisms, considerably boosting family safety. The gas sensor displayed exceptional sensitivity in detecting propane and natural gas leaks, sounding the alarm within seconds after leak onset. In all test circumstances, the automatic shut-off mechanism responded instantly, cutting off the gas supply and eliminating the risk of fire or explosion.

The temperature control system gave consistent results during cooking tests, with real-time monitoring assuring correct temperature adjustment. The system was able to maintain consistent heat levels and respond efficiently to user inputs. The timer and automated shut-off mechanism also performed reliably, minimizing overcooking and overheating, helping to energy economy.

User responses showed that the stove was straightforward to operate, with most participants praising the enhanced safety features and better cooking efficiency. Additionally, the stove's cost-effectiveness was proven with comparative testing, proving that it offered improved safety and performance at a comparable price range compared to standard stoves. Overall, the prototype met all design objectives, proving to be a safer and more efficient choice for household kitchens in Bangladesh, especially in areas where gas leaks are a major worry.



Fig. 6. Our designed smart stove

5. Discussion

The smart stove's combination of gas leak detection and automatic shut-off mechanisms directly solves family safety issues in Bangladesh. The system's rapid responsiveness to gas leaks and accurate temperature control offers substantial benefits over conventional stoves. User response revealed excellent satisfaction, particularly regarding ease of use and safety features. However, additional refinement could incorporate improved remote monitoring capabilities and compatibility with other fuels. Additionally, the stove's cost provides larger accessibility, but increasing production and distribution will be necessary for widespread adoption.

6. Conclusion

The developed smart stove successfully promotes kitchen safety with its integrated gas leak detection, automatic shut-off, and temperature control capabilities. The prototype met major design goals, showing to be a realistic solution for avoiding gas-related mishaps in Bangladeshi families. Its cost and user-friendly interface make it a viable tool for lowering household dangers while enhancing cooking efficiency. Further study should focus on incorporating IoT-based remote monitoring to enhance user control and safety.

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