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Smart Knocking Assist (Ska) System

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ABSTRACT

The **Smart Knocking Assist (SKA) system** is an advanced technology designed for precise detection, analysis and response to knocking abnormal combustion events in internal combustion engines. Leveraging high-sensitivity sensors and intelligent data processing, SKA accurately identifies knocking by monitoring specific sound and vibration frequencies, displaying the knocking level in real-time as a percentage value. The system categorizes knocking intensity into low, medium and hard levels, providing clear feedback on engine performance. With real-time analysis and machine learning, SKA differentiates knocking from normal engine noises and can even predict potential issues before they arise, enabling proactive maintenance to prevent damage, extend engine life, and enhance fuel efficiency. By integrating enhanced detection, adaptive response, and predictive capabilities, the Smart Knocking Assist system ensures safer, more efficient, and longer-lasting engine operation across diverse applications.

Keywords: Smart Knocking Assist (SKA), Knocking Detection, Internal Combustion Engine, Real-time Monitoring, Vibration Analysis, Predictive Maintenance, Engine Performance, Fuel Efficiency

1. INTRODUCTION

Motorcycles with engine capacities of 150cc and below are commonly used in Malaysia, especially among teenagers. One of the most popular types is the underbone motorcycle, which dominates the market in the Asian region. These motorcycles primarily use petrol, a flammable mixture of hydrocarbons that powers internal combustion engines (ICEs).

In ICEs, the air-fuel mixture is ignited to generate power [3]. However, if the combustion process occurs prematurely or irregularly, it can lead to a condition known as knocking [1]. Knocking can cause abnormal vibrations, loss of power, and long-term engine damage [4]. To prevent this, knock sensors are installed to detect specific vibration patterns and provide feedback to the engine control unit (ECU) for correction. Despite advances in automotive systems, most motorcycles below 150cc do not have an integrated knock detection system. Riders often rely on mechanics to identify knocking issues, which can lead to unnecessary maintenance costs. The development of a smart, compact, and affordable knock detection tool can help monitor engine performance more accurately and efficiently [5].

Currently, there is no dedicated knock detection tool designed specifically for motorcycles with engine capacities below 150cc. Users often cannot distinguish between regular engine noise and actual knocking, leading to unnecessary workshop visits or overlooked mechanical issues. Moreover, existing sensors used in larger vehicles are not compact or cost-effective enough for motorcycles. There is a need for a knock sensor that is compact and user-friendly, capable of withstanding engine heat, vibration, and harsh environmental conditions. It should be accurate enough to detect low, medium, and high levels of engine knocking, while also being able to display knock intensity in a simple and readable format, such as a percentage. Additionally, it must be able to distinguish between actual engine knock and normal operating noise to ensure precise diagnostics and performance monitoring.

The goals of this project are to design a compact and functional knock sensor specifically for motorcycles with engines of 150cc or less, and to monitor and display engine knocking levels in real-time. Additionally, the project aims to support improved ignition tuning and optimize the air-fuel ratio (AFR) for enhanced engine performance [2] . Another key objective is to detect abnormal combustion events, such as pre-ignition and detonation, to ensure engine reliability and efficiency.

2. Methodology

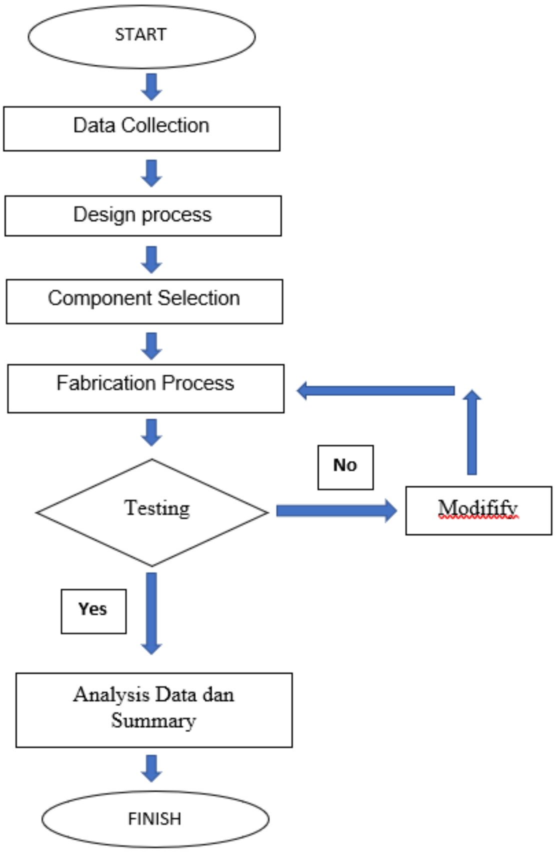


Fig. 1: The methodology of project

The development of the Smart Knocking Assist System for motorcycles with engine capacities ≤150cc follows a structured methodology that begins with the collection of vibration and acoustic data under various engine conditions to identify knock-specific frequencies and distinguish them from normal operating noise, forming the basis for tuning detection algorithms and setting sensitivity thresholds the system is then designed with a compact, heat-resistant, and user-friendly architecture using a modular approach for sensing, processing, and display functions, including a piezoelectric vibration sensor sensitive to high-frequency knock vibrations (5–15 kHz), a real-time capable microcontroller (Arduino) for FFT-based signal processing, a compact OLED or LCD for displaying knock intensity, and a 12V to 5V buck converter for power regulation undergoes rigorous bench testing with simulated knock conditions and on-road trials to validate performance, revealing over 90% accuracy in knock detection, effective differentiation between knock and normal combustion, and real-time feedback with less than 200 ms latency. This methodology ensures a robust, precise, and practical solution that supports real-time knock monitoring, improved ignition tuning, AFR optimization, and early detection of pre-ignition and detonation, contributing to enhanced engine performance and longevity.

2.1 Concept Selection and Study Design

In the Concept Selection and Study Design phase, three innovative design proposals for the Smart Knocking Assist system have been identified, each demonstrating significant potential for development. These proposals offer different approaches to solving the challenges associated with enhancing user interaction and convenience through smart technology. The next step involves a careful evaluation of each concept to determine its feasibility, effectiveness, and alignment with project goals, followed by an in-depth study and design process to bring the most promising idea to life.

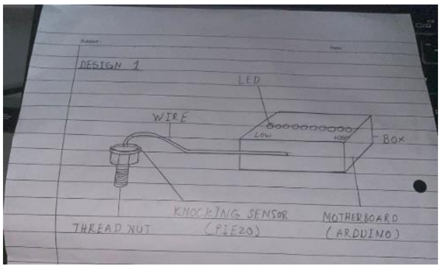


Fig. 2: Concept A

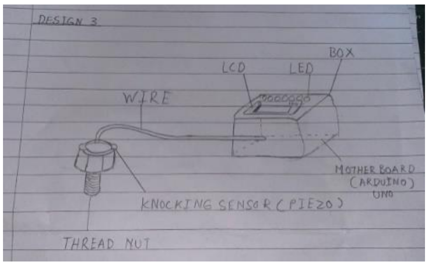


Fig. 3: Concept B

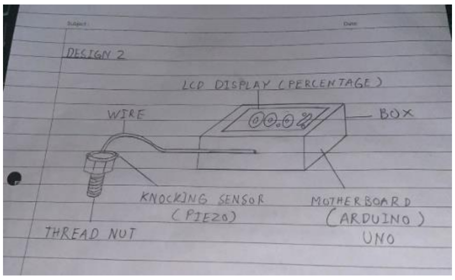


Fig. 4: Concept C

2.2 Product Design Specifications

Product Design Specification enable a well-defined idea to understand the required specification to design this device. Major elements involved were enlist in the Table 3.2. Main operation element of this knocking device is the coding on Arduino, the box, bracket and the sensor. Monitoring process will be performed by the sensor give the signal to the Arduino and display to the lcd screen in percentage. This machine is aimed to achieve light weight and low cost.

Table 1. Product Design Specification

No.	Description	Specification
1	Name	Smart Knocking Assist
2	Main Mechanism	Arduino uno R3, Pvc Box, Piezoelectric sensor
3	Target Customer	Motorcycle user, tuner, specialist
4	Monitoring process	Knocking percentage
5	Material	Steel metal for bracket, piezoelectric for sensor
6	Weight	Approximately 0.80Kg
7	Safety	Mount bracket to avoid contact heat
8	Cost	Approximately RM200

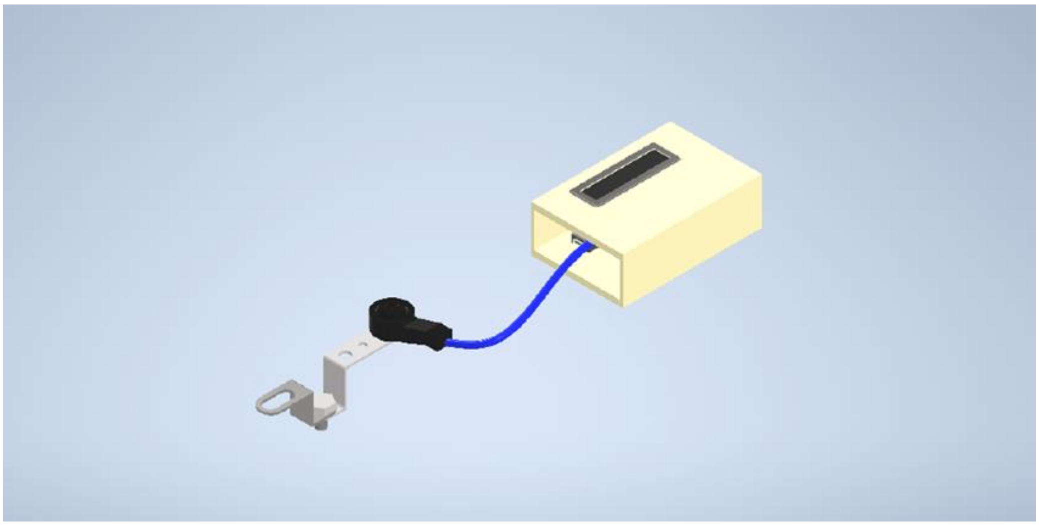


Fig. 5: Final design of knocking asist

The CAD drawing of the Smart Knocking Assist (SKA) system serves as the visual representation of how all components come together in a single machine. It provides a detailed and precise layout of the knock sensor, ECU, wiring, and related components, ensuring that everything is correctly positioned, integrated, and protected. The CAD design helps engineers visualize the system's overall function, optimize the arrangement of components, and address any issues before the physical assembly and manufacturing process begins.

By including the right level of detail, such as precise dimensions, safety features, and component connections, the CAD drawing serves as an invaluable tool for both the design and implementation stages of the project, ensuring a functional and reliable final product.

2.3 Circuit Schematic / Wiring

Figure 6 depicts the schematic circuit and the port-to-port connection of each component. First and foremost, the Arduino Uno R3 receive signals from the knock sensor in order to transmit to display percentage to show the level of knocking. The knock sensor connected with GND and A3 pins. The I2C LED Display connect VCC to 5v, GND to GND, SDA to A4 and SCL to A5 pins. With this schematic circuit the Smart Knocking Assist will function smoothly.

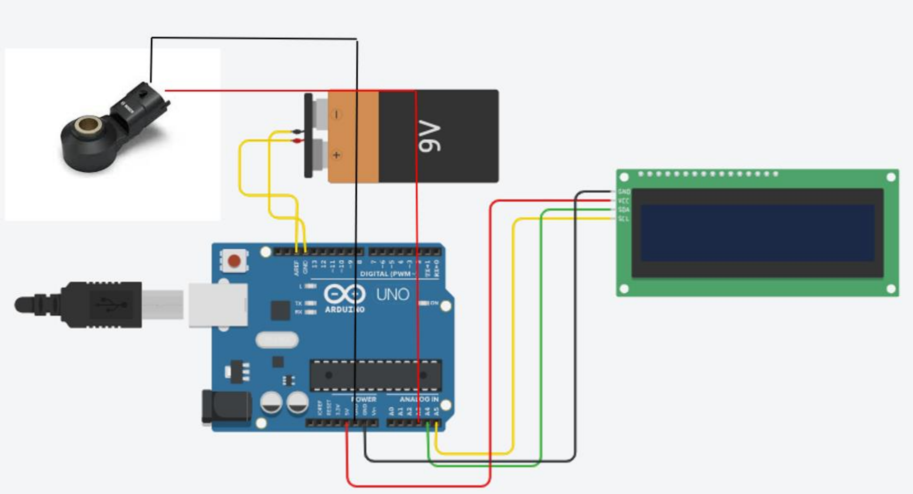
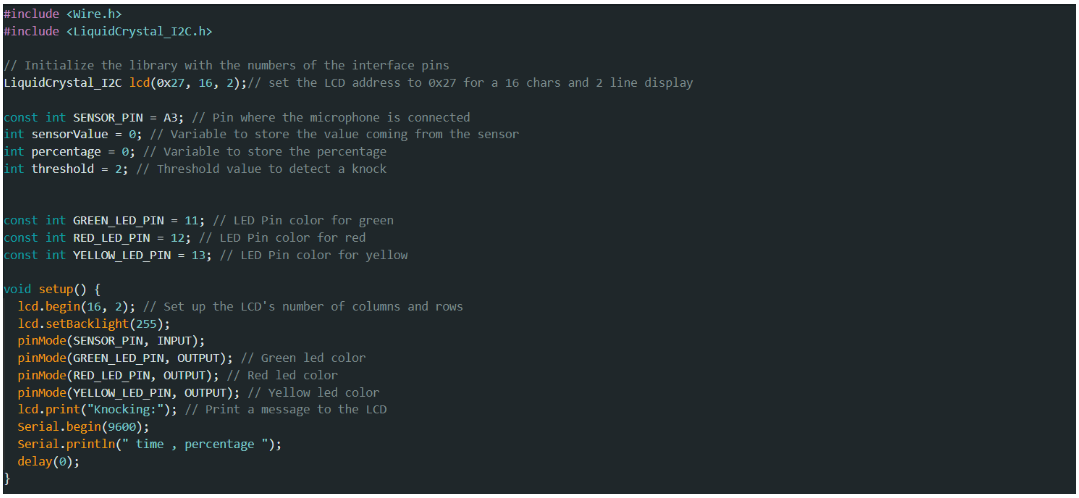


Fig. 6: The schematic circuit of the project

2.4 Coding Process

The coding process of Smart Knocking Assist for in order to ensure the process runs smoothly. This chapter will provide a detailed explanation of every task arrangement that has been used.



```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

// Initialize the library with the numbers of the interface pins
LiquidCrystal_I2C lcd(0x27, 16, 2);// set the LCD address to 0x27 for a 16 chars and 2 line display

const int SENSOR_PIN = A3; // Pin where the microphone is connected
int sensorValue = 0; // Variable to store the value coming from the sensor
int percentage = 0; // Variable to store the percentage
int threshold = 2; // Threshold value to detect a knock


const int GREEN_LED_PIN = 11; // LED Pin color for green
const int RED_LED_PIN = 12; // LED Pin color for red
const int YELLOW_LED_PIN = 13; // LED Pin color for yellow

void setup() {
  lcd.begin(16, 2); // Set up the LCD's number of columns and rows
  lcd.setBacklight(255);
  pinMode(SENSOR_PIN, INPUT);
  pinMode(GREEN_LED_PIN, OUTPUT); // Green led color
  pinMode(RED_LED_PIN, OUTPUT); // Red led color
  pinMode(YELLOW_LED_PIN, OUTPUT); // Yellow led color
  lcd.print("Knocking:"); // Print a message to the LCD
  Serial.begin(9600);
  Serial.println(" time , percentage ");
  delay(0);
}
```

Fig. 7: The input and output of each component

The coding of input and output components is implemented to ensure that the system runs in sequence and does not interfere with other components during operation, resulting in an organized system. The coding of the LCD is created to display data to users, making the information easily understandable and convenient. The coding for the knocking sensor is developed to ensure that sensor values are calibrated to the correct specifications, thereby avoiding potential errors. Finally, the coding for the LED is designed to alert the user about the engine's knocking level by using red, yellow, and green lights.

2.5. Operational Process

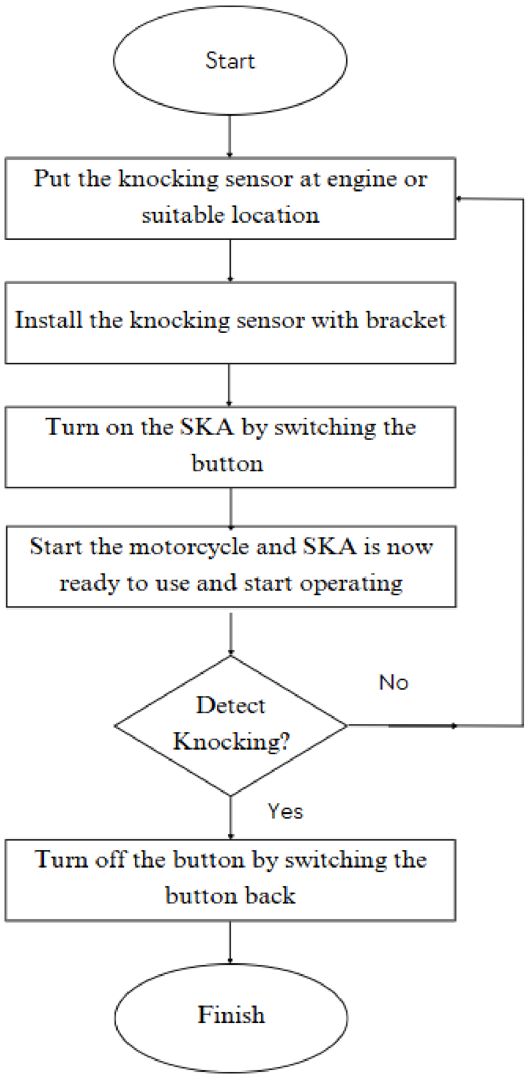


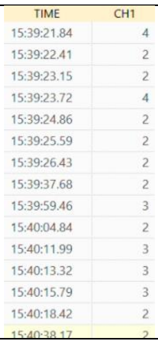
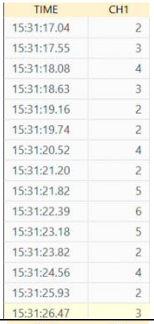
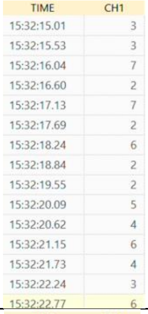
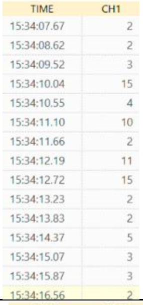
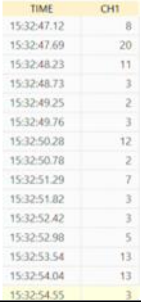
Fig. 8: The process of Smart Knocking Assist (SKA)

The Arduino Uno R3 receive a signal from the knock sensor when a motorcycle engine produces a knocking. The knock sensor detects knocking that occurs from engine. Then, it transmits to the Arduino by electrical signal to show the value how loud the knocking produce in engine by showing percentage.

3. Results and Discussion

This chapter demonstrates the testing of samples by Dyno Testing in different Rotation per Minute (RPM) to determine the difference of knocking occur has been produce in Average. Table 2 shows the detailed of Sample testing in different Rotation Per Minute (RPM)

Rotation (RPM)	Result of Knocking (%)	Max Knocking (%)

Idle	 TIME CH1 15:39:21.84 4 15:39:22.41 2 15:39:23.15 2 15:39:23.72 4 15:39:24.86 2 15:39:25.59 2 15:39:26.43 2 15:39:37.68 2 15:39:59.46 3 15:40:04.84 2 15:40:11.99 3 15:40:13.32 3 15:40:15.79 3 15:40:18.42 2 15:40:38.17 2	4
1000 - 2000	 TIME CH1 15:31:17.04 2 15:31:17.55 3 15:31:18.08 4 15:31:18.63 3 15:31:19.16 2 15:31:19.74 2 15:31:20.52 4 15:31:21.20 2 15:31:21.82 5 15:31:22.39 6 15:31:23.18 5 15:31:23.82 2 15:31:24.56 4 15:31:25.93 2 15:31:26.47 3	6
2000 - 3000	 TIME CH1 15:32:15.01 3 15:32:15.53 3 15:32:16.04 7 15:32:16.60 2 15:32:17.13 7 15:32:17.69 2 15:32:18.24 6 15:32:18.84 2 15:32:19.55 2 15:32:20.09 5 15:32:20.62 4 15:32:21.15 6 15:32:21.73 4 15:32:22.24 3 15:32:22.77 6	7
4000 - 5000	 TIME CH1 15:34:07.67 2 15:34:08.62 2 15:34:09.52 3 15:34:10.04 15 15:34:10.55 4 15:34:11.10 10 15:34:11.66 2 15:34:12.19 11 15:34:12.72 15 15:34:13.23 2 15:34:13.83 2 15:34:14.37 5 15:34:15.07 3 15:34:15.87 3 15:34:16.56 2	15
6000 - 7000	 TIME CH1 15:32:47.12 8 15:32:47.69 20 15:32:48.23 11 15:32:48.73 3 15:32:49.25 2 15:32:49.76 3 15:32:50.28 12 15:32:50.78 2 15:32:51.29 7 15:32:51.82 3 15:32:52.42 3 15:32:52.98 5 15:32:53.54 13 15:32:54.04 13 15:32:54.55 3	20

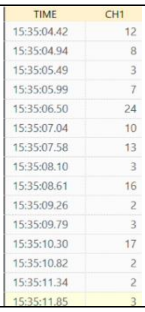
7000 - 8000	 TIME CH1 15:35:04.42 12 15:35:04.94 8 15:35:05.49 3 15:35:05.99 7 15:35:06.50 24 15:35:07.04 10 15:35:07.58 13 15:35:08.10 3 15:35:08.61 16 15:35:09.26 2 15:35:09.79 3 15:35:10.30 17 15:35:10.82 2 15:35:11.34 2 15:35:11.85 3	24

Table 2: Testing in Different Rotation Per Minute (RPM)

Table 2 provides a detailed breakdown of the knocking device performance, spanning from 1000 RPM to 8000 RPM. This data shows how the engine's knocking behaviour changes over a wide range of operating conditions. The table allows us to correlate engine performance with specific RPM ranges, providing valuable insights into how the engine behaves under different stress levels.

The results of the knocking device tests demonstrate a clear relationship between engine RPM and knocking percentage. Initially, at low RPMs, the knocking percentage is relatively low, starting at around 2%. As the engine speed increases, the knocking percentage rises, reaching a maximum of 24% at higher RPMs. This gradual increase is expected, as higher engine revolutions typically result in more vibration and stress, which can lead to knocking or detonation.

The key takeaway from this analysis is that the engine produces a healthy sound and operates efficiently when the knocking percentage remains below 30%. The findings suggest that, for motorcycle engines, the knocking percentage can serve as an important indicator of engine health. When knocking is kept under 30%, the engine is likely functioning optimally, without excessive knocking or detonation. As the knocking percentage increases beyond this threshold, it may signal that the engine is experiencing increased stress or damage, potentially affecting performance and longevity.

4. Conclusion

In conclusion, the knocking percentage test results highlight the importance of real-time engine monitoring for maintaining optimal performance and health. The ability to detect and quantify knocking provides a reliable method for users to evaluate their motorcycle engine's condition and take action when necessary, contributing to both safety and long-term reliability.

To enhance the Smart Knocking Assist (SKA) system, it is recommended to make the design more compact for easier integration into a wider range of engine systems, upgrade the system to support Bluetooth and Wi-Fi connectivity for real-time data transmission to mobile devices, and expand its application beyond motorcycles to include industrial systems such as power plants, compressors, generators, and pumps, thereby increasing its efficiency, versatility, and ability to monitor engine health and improve preventative maintenance across various sectors.

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