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E-Nose for Piston Ring and Cylinder Block Condition Detection of Motorcycle Engine Based on MyRIO LabVIEW Programming

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Abstract— **This study has created a system capable of identifying the condition of the piston ring and cylinder block of a 4-stroke motorcycle engine using petrol or similar through exhaust emissions. Multisensory gas, sensitive to changes in CO, CO2, NOx, and HC gas elements and compounds, is installed as an input to the exhaust channel and integrated using LabVIEW programming on the NI myRIO module. Multisensory data is processed using the FFT and the backpropagation method to classify whether the piston rings and engine cylinder block are in good or damaged condition. Tests have been carried out on motorbikes with piston rings and engine cylinder blocks that are in good, damaged, or unknown condition. During the test, the target error value for motorcycles with piston rings and engine cylinder blocks in good or damaged condition is less than 1%. The system can distinguish the condition of the piston ring and cylinder block of a motorcycle engine that is 100% optimal and 100% damaged with an error of 0% compared to the compression test method, and the maximum error is 20% Compared to the technician's manual method. Ten motorcycles were randomly tested in unknown conditions; 50% were in good condition, and 50% were damaged. For further development, an electronic nose system can detect engine combustion conditions and damage to cylinder rings and 4-stroke motorbike engine blocks based on exhaust emissions.**

Keywords— **Multisensory; emission; backpropagation; cylinder block.**

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I. INTRODUCTION

Based on data from the Central Bureau of Statistics of the Republic of Indonesia, the City of Padang had 477,499 motorized vehicles in 2021. approximately 72.5% of those vehicles are motorcycles [1]. Motorcycles require preventive and corrective maintenance to maintain optimum condition and prevent damage or interruptions. One example of a frequently damaged component includes the piston ring and the engine cylinder block or combustion chamber components [2]. Motorcycle exhaust emissions from gasoline or similar motorcycles contain various compounds and gases released through the exhaust emission channels because of the engine combustion process in the combustion chamber. Among these compounds are CO (carbon monoxide), CO2 (carbon dioxide), NOx (nitrogen oxide), HC (hydrocarbon), and other components [3]–[5].

The condition of the piston rings and the engine cylinder block should be regularly and periodically monitored to prevent potentially irreparable damage to motorized vehicle engines, especially in the combustion chamber [6]. Compression testing is a technique used to determine the condition of the piston rings and engine cylinder block. Another approach is visual observation of exhaust emissions, typically done manually by mechanical personnel. However, this method lacks standard protocol, leading to disagreements among repair technicians.

An electronic nose is an AI-based artificial olfactory system that analyzes aromas. The e-nose system can be applied in various sectors to recognize valuable aromas and determine elemental components and gas compounds detected by environmental sensors [7]–[12]. The use of the e-nose system to detect levels of gas elements and compounds in motor vehicle exhaust emissions has been applied to understand the combustion situation in the engine room. This is accomplished by measuring the concentration of CO, CO_2, NOx, and HC gas elements and compounds produced during combustion in a 4-stroke motorcycle engine [13]–[16]. It is the responsibility of every vehicle owner to regularly monitor and measure the level of exhaust emissions from motorized vehicles to ensure that the levels of exhaust emissions produced remain within the threshold limits set by the government [17].

In exhaust emissions, the levels of elemental compounds and gases, such as CO, CO2, NOx, and HC, increase when some engine lubricant is burned. The piston rings dynamically close the gap between the moving piston and the liner surface of the engine cylinder block to prevent the escape of combustion gases from the combustion chamber into the engine crankcase and the entry of lubricant from the engine crankcase into the combustion chamber [18]. Based on this background, developing a tool for detecting the condition of the piston rings and engine cylinder block is necessary as an alternative method for quickly assessing their condition in advance.

The study developed an electronic nose system utilizing a gas multisensory with the ability to recognize the levels of gas elements and compounds near the sensor. Gas sensors operate through changes in resistance, Surface Acoustic Wave (SAW) that results in modifications of voltage and current values, and Quartz Crystal Microbalance (QCM) when gas elements and compound levels vary [8], [9]. Subsequently, the analog voltage data obtained from each sensor is processed using LabVIEW programming based on the myRIO module and converted to a magnitude data pattern using the Fast Fourier Transform (FFT) technique. The system uses Neural Network (NN) Backpropagation to classify the piston rings and engine cylinder block condition. The output results are displayed on the Personal Computer/Laptop as a virtual instrument display to detect whether the condition of the piston ring and engine cylinder block is optimal or damaged.

II. Materials and Method

This experimental study focused on motorcycle exhaust emissions as the subject of investigation. The study used 4-stroke motorized vehicles fueled by petrol or similar, both at motorcycle workshops and in the Computer Laboratory of the Electrical Engineering Department at Politeknik Negeri Padang. Tests were carried out on motorcycles exhibiting indications of either excellent or damaged piston rings and engine cylinder blocks, as well as those in unknown conditions. Before the experimental runs, each bike used in the study underwent a compression test and manual inspection by workshop technicians to ensure the condition of the piston rings and cylinder block of the motorcycle's engine. This study comprised two main stages:

A. System Design and Manufacturing Stage

The initial stage involved developing a multisensory system to serve as the input component. This system was designed to accurately detect gas elements and compounds in motorcycle exhaust emissions. It comprises electronic sensor components sensitive to variations in CO, CO2, NOx, and HC gas elements and compounds, enabling the component to be an aroma detector [9]–[14].

This study, the MQ-7 sensor was employed for CO gas sensing, the MQ-135 for CO_2 detection, and the TGS 2201 for NOx and HC measurement. These sensors were configured in parallel, forming sensor arrays to simultaneously detect levels of CO gas, CO_2, NOx, and HC [19]–[22]. Subsequently, data from multisensory detection results were processed using LabVIEW programming, enabling the presentation of data with sensor response graphs and modified data patterns using the FFT method. LabVIEW was chosen due to its graphic-based interface and the ability to display measurement data as a virtual instrument, enhancing ease of interpretation by users [23]–[25].

The outcomes of the FFT method are divided into four distinct data patterns, with specific magnitude values for each pattern. Any data pattern underwent NN Backpropagation training with an architecture comprised of four inputs, two hidden layers, and one output. The output values are designated as 1 (good piston ring and/or cylinder block conditions were indicated) and 0 (damaged piston ring and/or cylinder block conditions were indicated).

Overall. This program is embedded into the myRIO 1900 module from National Instrument and serves as a hardware interface between the multisensory system and the display system on the Personal Computer (PC) or laptop [26]–[29]. This system is designed to be portable and capable of communicating with the display system through wireless network communication. Personal Computers, mobile phones, and Laptops were able to be used. The overall system relationship diagram is seen in Figure 1. The display provides information about the levels of elements and gas compounds in the sensor response graph, besides the magnitude data pattern on the laptop. The Virtual Instrument (VI) has been viewed on a PC/Laptop [30]. The results of the piston rings and engine cylinder block conditions are identified, including whether it is in excellent or damaged condition. The system displayed in VI is shown in Figure 2. Meanwhile, the program block diagram created using LabVIEW is depicted in Figure 3.

B. NN Training Stage and Identification Test

It included the system's ability to identify the condition of the piston rings and cylinder block of a 4-stroke motorcycle engine run on petrol or similar fuel. The testing phase consists of several processes:

1) NN Training Processes: This process aims to train the neural network to assess the piston rings and engine cylinder block condition according to the desired target. The NN training targets were set as 1 (representing the excellent condition) and 0 (indicating a damaged condition). The backpropagation NN architecture utilized four inputs, two hidden layers, and one output. The training results were expressed as weight and bias values, then inputted into the main LabVIEW myRIO program.

2) *Identification Test:* This test was conducted after the performance had been demonstrated on ten units of 4-stroke motorcycles with piston rings and engine cylinder blocks in good condition and 10 units of 4-stroke motorcycles with damaged piston rings and engine cylinder blocks. Random tests were also performed on ten motorcycles with piston rings and engine cylinder blocks in unknown conditions. The test results will determine whether the condition of the piston rings and engine cylinder block was good or damaged.

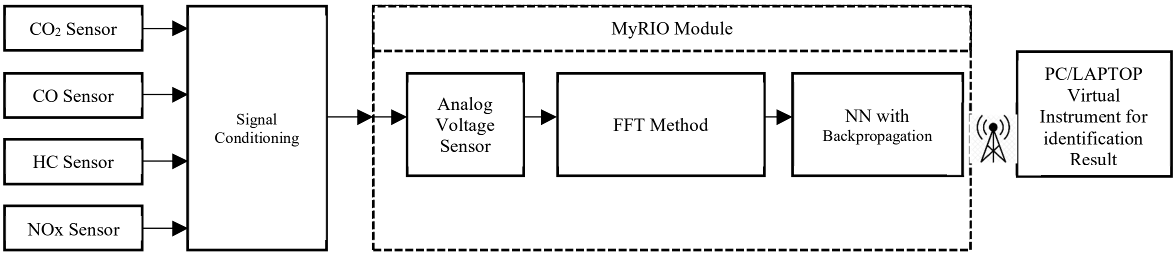

Fig. 1 System Block Diagram

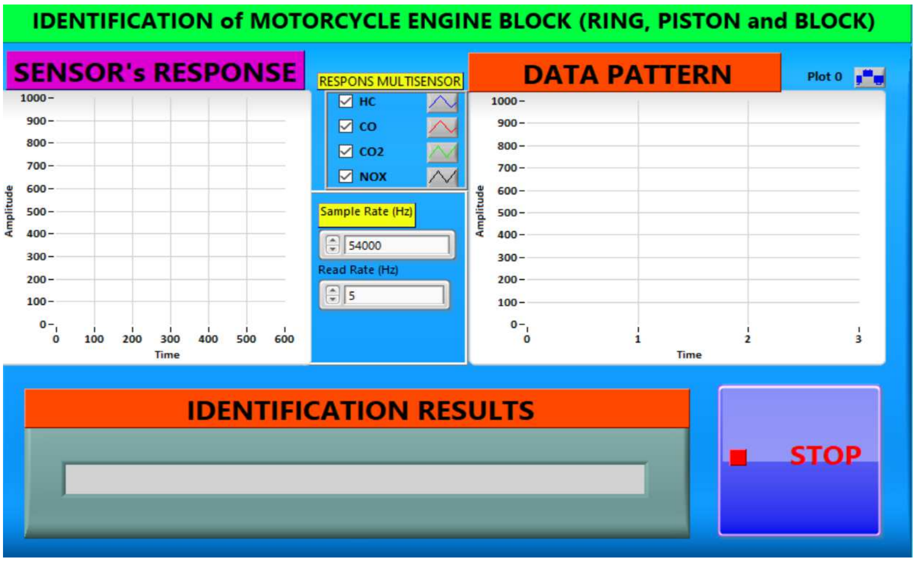

Fig. 2 User interface

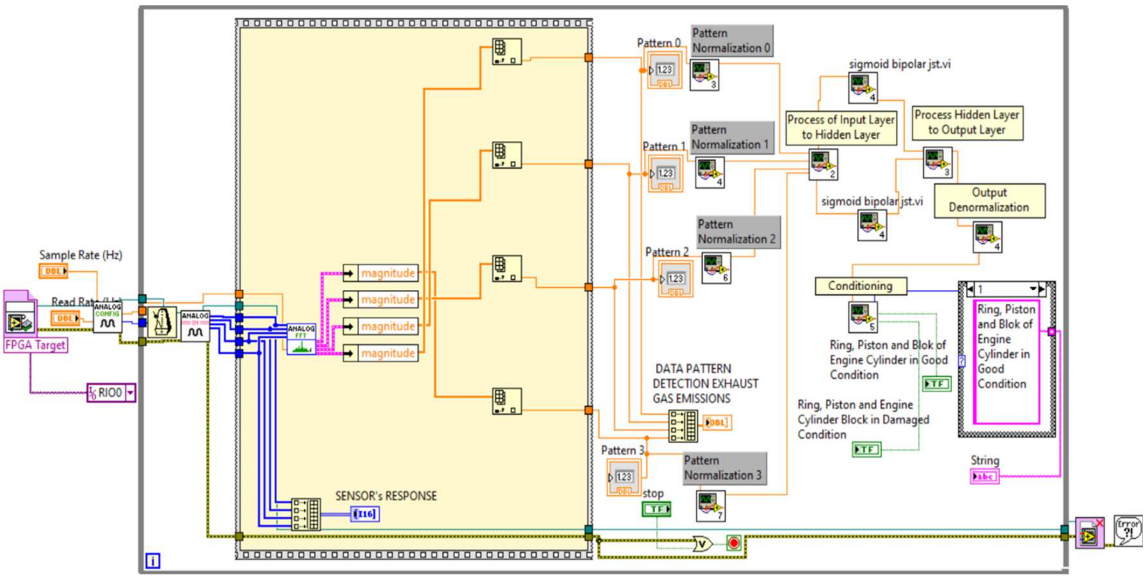

Fig. 3 LabVIEW Programming Block Diagram

III. Results and Discussion

After the system was created, NN Backpropagation training was conducted on ten 4-stroke motorcycles with intact piston rings and engine cylinder blocks and 10 motorcycles with damaged piston rings and engine cylinder blocks. Motorcycles with piston rings and engine cylinder blocks in good condition are given a logic one target, while those with damaged components were assigned a logic target of 0. All paragraphs must be indented. All paragraphs must be justified, i.e., both left-justified and right-justified. The difference between the obtained results and the given target can be determined by calculating the error value using the following formula:

$$e = \frac{\text{DS data} - \text{Target data}}{\text{Target data}} x100\% \qquad (1)$$

In Table 1., the system created has an average error value of <1%.

The NN Backpropagation training results in Table 1 yielded an error value of less than 1% for the piston ring and engine cylinder block in good condition. Table 2 displays the training process for the piston ring and engine cylinder block in a damaged state, in which a logic target of 0 was achieved with an error of 0%. Thus, the training results for the given target align with the desired results, allowing the weights and biases to be employed for the identification process.

TABLE I
TRAINING RESULTS ON 4-STROKE MOTORCYCLES CONDITION OF THE PISTON RINGS AND OR ENGINE CYLINDER BLOCK IN GOOD CONDITION

		Output		Error	
No.	**Motorcycle Brand**	**Target**	**Detection Results**	**Value**	**%**
1	2021 Honda Beat Street 110	1	1.00004	0.00004	0.00380
2	2020 Honda Beat Deluxe FI 110	1	1.00004	0.00004	0.00387
3	2019 Honda Vario 125 LED	1	1.00004	0.00004	0.00363
4	2018 Honda Sonic 150 R	1	0.99995	0.00005	0.00537
5	2020 Honda Vario 150 LED	1	1.00003	0.00003	0.00265
6	2021 Honda Scoopy Gray 110	1	1.00001	0.00001	0.00053
7	2015 Scoopy 110	1	0.99752	0.00248	0.24861
8	2011 Absolute Revo Fit motorcycle	1	1.00090	0.00090	0.09032
9	2022 Honda Beat FI	1	0.99504	0.00496	0.49846
10	2021 Honda Scoopy Red 110	1	1.00004	0.00004	0.00391

TABLE II
TRAINING RESULTS ON FOUR STROKE MOTORCYCLES CONDITION OF THE PISTON RINGS AND OR ENGINE CYLINDER BLOCK IN DAMAGED CONDITION

		Output		Error	
No.	**Motorcycle Brand**	**Target**	**Detection Results**	**Value**	**Percent**
1	2005 Suzuki Shotgun 125 SP	0	3.429E-07	3.429E-07	0
2	2006 Bajaj Pulsar 180 UG III	0	-2.832E-06	2.832E-06	0
3	2006 Honda Vario 110	0	-2.803E-06	2.803E-06	0
4	2005 Suzuki Smash	0	-2.789E-06	2.789E-06	0
5	2007 Honda Supra X 125	0	-1.937E-06	1.937E-06	0
6	2005 Honda Supra X 125	0	-3.054E-06	3.054E-06	0
7	2008 Suzuki Smash 110	0	-2.789E-06	2.789E-06	0
8	2002 Honda Kharisma	0	-2.790E-06	2.790E-06	0
9	2009 Vario Techno	0	1.549E-05	1.549E-05	0
10	2001 Honda Astrea Legend 1	0	-2.129E-06	2.129E-06	0

Figure 4 illustrates the training process for the piston ring and cylinder block of the 2021 Honda Beat Street motorcycle engine, which appears to be in good condition. The JST Backpropagation produced a response result of 1.00002, close to the target value of 1. The weights were multiplied with input, bias was added, binary sigmoid activation was used in the hidden layer, and purelin activation was employed at the output.

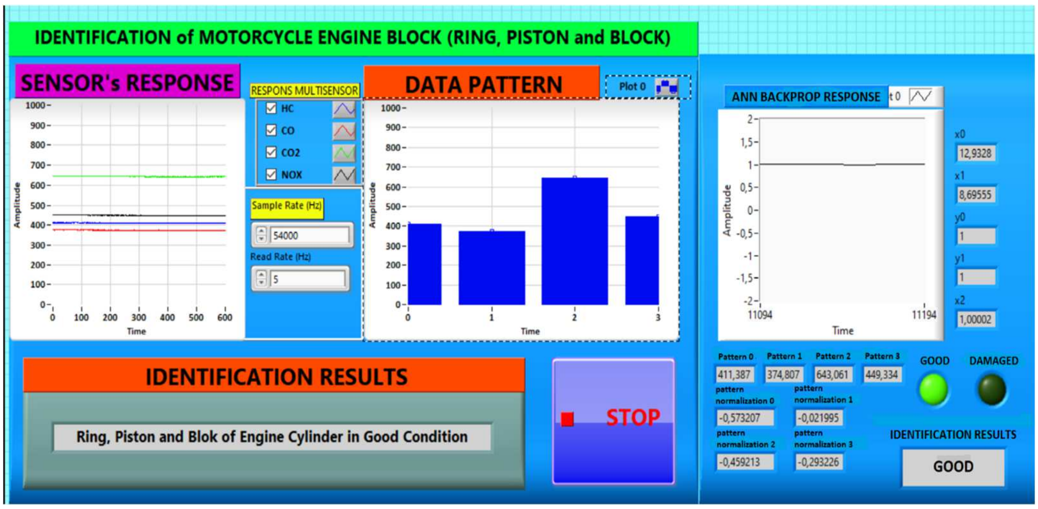

Fig. 4 Training process on the 2021 Honda Beat Streat engine with the piston rings and cylinder block in good condition

Figure 5 shows the training results on the condition of the piston rings and cylinder block of the 2010 Yamaha Vega engine in damaged condition. The NN Backpropagation response yielded a value of -1.00001, which was normalized to 0 using 1+$\frac{-1.00001}{2}$. The weights were multiplied with the input and added bias, and binary sigmoid activation was employed in the hidden layer, while purelin activation was used in the output layer.

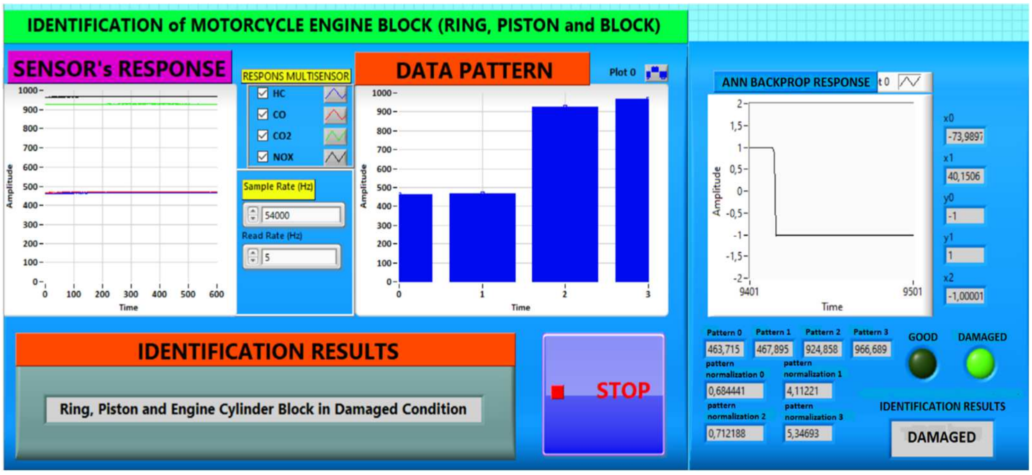

Fig. 5 Training process on the 2010 Yamaha Vega engine with the piston rings and cylinder block in a damaged condition

The results of NN Backpropagation training determined the condition of the piston ring and engine cylinder block. This process included collecting training data, establishing a network architecture with four outputs, two hidden layers, and one output, conducting NN Backpropagation training in MATLAB, and obtaining the bias weights of the perfect training result at epoch/iteration 83. Table 3 displays the identification results of detecting the condition of piston rings and cylinder blocks in motorbike engines with good piston rings and engine cylinder blocks belonging to 10 motorbikes of different brands and years of manufacture.

TABLE III
IDENTIFICATION RESULTS OF PISTON RING AND CYLINDER BLOCK IN GOOD CONDITION

No.	Motor Brand	Detection Result	
		Condition of Piston Rings and Engine Cylinder Block	Compression Test
1	2021 Honda Beat Street 110	Good	Good
2	2020 Honda Beat Deluxe FI 110	Good	Good
3	2019 Honda Vario 125 LED	Good	Good
4	2018 Honda Sonic 150 R	Good	Good
5	2020 Honda Vario 150 LED	Good	Good
6	2021 Honda Scoopy 110	Good	Good
7	2015 Scoopy 110	Good	Good
8	2011 Absolut Revo Fit	Good	Good
9	2022 Honda Beat FI	Good	Good
10	2021 Honda Scoopy 110	Good	Good

The recognized outcomes of the system exhibit 0% error compared to the results of the compression test detection. Therefore, the identification results of the system and detection through compression tests were the same. Table 4 shows the identification results of the motorcycle engine's piston ring and cylinder block display damage. The system's compression test yielded a 0% error rate, whereas visual tests executed by workshop technicians resulted in a 10% error rate. This discrepancy indicated a variation in results between the system and manual detection methods, although the system's outcomes align with the compression test.

TABLE IV
IDENTIFICATION RESULTS OF PISTON RING AND CYLINDER BLOCK IN DAMAGED CONDITION

No.	Motor Brand	Detection Result		
		Condition of Piston Rings and Engine Cylinder Block	Compression Test	Workshop Technician
1	2005 Suzuki Shotgun 125 SP	Damaged	Damaged	Damaged
2	2006 Bajaj Pulsar 180 UG III	Damaged	Damaged	Damaged
3	2006 Honda Vario 110	Damaged	Damaged	Damaged
4	2005 Suzuki Smash	Damaged	Damaged	Damaged
5	2007 Honda Supra X 125	Damaged	Damaged	Damaged
6	2005 Honda Supra X 125	Damaged	Damaged	Damaged
7	2008 Suzuki Smash 110	Damaged	Damaged	Damaged
8	2002 Honda Kharisma	Damaged	Damaged	Damaged
9	2009 Vario Techno Motorcycle	Damaged	Damaged	Good
10	2001 Honda Astrea Legend 1	Damaged	Damaged	Damaged

Table 5 compares the engine detection results of 10 4-stroke motorbikes with unknown piston ring and cylinder block conditions. The created system shows a 0% error compared to the compression test results. However, it has a 20% error compared to the visual observations of technicians in the workshop. Despite this, the system's detection results were as reliable as the compression test method compared to the manual method used by workshop technicians.

TABLE V
IDENTIFICATION RESULTS OF PISTON RING AND CYLINDER BLOCK IN RANDOM CONDITION

No.	Motor Brand	Detection Results		
		Designed System	**Compression Test**	**Workshop Technician**
1	2007 Honda Supra X 125	Damaged	Damaged	Damaged
2	2010 Yamaha Vega ZR	Damaged	Damaged	Good
3	2013 Honda Absolute Revo	Damaged	Damaged	Damaged
4	2002 Honda Kharisma X	Damaged	Damaged	Damaged
5	2022 Honda Beat Street	Good	Good	Good
6	2020 Honda Scoopy Stylish	Good	Good	Good
7	2022 Hodan Vario 160 CBS	Good	Good	Good
8	2021 Yamaha Mio M3 125	Good	Good	Good
9	2015 Honda Vario 125	Damaged	Damaged	Good
10	Honda Supra X 125 FI CW Luxury	Good	Good	Damaged

IV. CONCLUSION

From the test results and data analysis that have been conducted, this system employs the exhaust emission analysis method as a non-intrusive tool for identifying potential damage to the primary engine components, specifically the engine cylinder blocks and piston rings. The NN model employing Backpropagation can identify intricate patterns and correlations between exhaust emissions' elemental composition and compounds and the damage to the piston rings and engine cylinder blocks. A detection error (0%) occurs when the system and compression test method are used to identify the piston ring and cylinder block condition in a 4-stroke motorcycle engine.

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