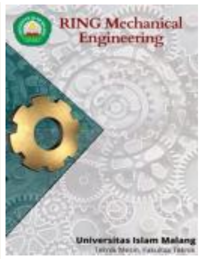
ISSN 2828-5174
Ring Mechanical Engineering (RING ME)
Vol. 5 | No. 2 | Desember | Hal. 80-91



DESIGN AND CONSTRUCTION OF INTERNAL COMBUSTION ENGINE SPEED CONTROL BASED ON FUZZY LOGIC

Taufig Widianto[1], Edi Kurniawan[2*)], Jaka Septian Kustanto[3]
[1,2*),3]Teknologi Rekayasa Kelistrikan Kapal, Politeknik Pelayaran Surabaya, Surabaya, Indonesia
[*)]Corresponding author: edi.kurniawan@poltekpel-sby.ac.id

ABSTRACT
As an archipelagic nation, ships are essential for maritime transportation. Currently, almost all ships use 2-stroke or 4-stroke diesel engines as their main engines due to their advantages over other engine types. Diesel engines generate power through a fuel combustion system called an internal combustion engine (ICE). ICE motors are one of the most common types of motors used on ships due to their substantial power output as prime movers. However, changes in load will cause the motor speed to change, affecting the ship's power output. To regulate the speed of an ICE motor, a control system and various types of controllers are required, including fuzzy logic methods. This research aims to develop a fuzzy logic-based control system for ICE motor speed control on a trimaran vessel. The design of ICE motor speed control on ships using the Fuzzy Logic method is very suitable for controlling non-linear systems. The controller is implemented on an STM32 microcontroller to regulate the ICE motor. The control performance shows very stable and efficient results in various wave conditions, with stability in meeting the set point. The Fuzzy Logic method has proven effective in maintaining RPM and fuel consumption. Tests show that the components used have good accuracy with an average error of less than 5%, and the control system is more stable than without control. Based on these findings, it is recommended that the fuzzy logic control system be further optimized and adapted for larger-scale marine engines, as well as integrated with advanced sensors to enhance fuel efficiency and operational reliability in diverse maritime conditions.

Keywords: Internal Combustion Engine, Fuzzy Logic, Trimaran Vessel

INTRODUCTION

As an archipelagic nation, maritime transportation by ship is the primary means of meeting the needs of the community, both for the efficient distribution of goods and passenger mobility [1]. Ships require a main engine as a propulsion system to operate optimally. Currently, almost all ships use diesel engines, both 2-stroke and 4-stroke, as they are considered superior to other types of main propulsion systems. The existence of a main propulsion system is vital, because without a properly functioning and safe engine, a ship cannot be declared seaworthy. If it continues to operate, it could endanger the safety of the crew and its cargo.

A diesel engine is a device that generates power by converting heat energy into mechanical energy through the combustion process of fuel [2]. In the Internal Combustion Engine (ICE) system, an engine is defined as a motor that produces mechanical work from the combustion of fuel that occurs in the engine room, examples of which are diesel engines and gasoline engines. In ICEs, also known as internal combustion engines, the combustion process takes place inside the

(cc) BY-SA
Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

engine [3]. ICE-type motors are widely used on ships because they can produce power between 70 and 100,000 HP, depending on the type of engine and the vessel used. However, changes in load can cause variations in motor speed, which ultimately affects the ship's power.

An ICE motor's speed will be difficult to stabilize when the load changes [4]. Applying a load to the motor can affect its rotational speed. The greater the load, the greater the motor's torque, thereby reducing its speed. One way to regulate the motor's rotational speed is by controlling the amount of fuel entering the ICE motor [5].

Despite extensive research on fuzzy logic applications in motor control systems, previous studies have predominantly focused on electric motor applications in automotive and industrial sectors. The implementation of fuzzy logic for Internal Combustion Engine (ICE) speed control in maritime applications, particularly for trimaran vessels, remains significantly limited. While conventional vessels have been studied with traditional PID controllers, the unique dynamic characteristics of trimaran vessels require specialized control approaches that have not been adequately addressed in existing literature. This research gap is particularly critical given that trimaran vessels offer superior stability and fuel efficiency compared to monohull vessels, yet their distinct hydrodynamic behavior demands tailored engine control strategies.

This study contributes to filling this research gap by developing a specialized fuzzy logic-based speed control system specifically designed for ICE motors on trimaran vessels. The novelty of this research lies in the optimization of fuzzy logic parameters tailored to the unique operational characteristics of trimaran vessels and the integration of real-time monitoring capabilities using STM32 microcontroller architecture.

Based on these challenges and research opportunities, a device capable of controlling the motor's rotational speed is needed to assist and lighten human workload [6]. The method chosen is Fuzzy Logic, because this method is considered appropriate for controlling non-linear systems through a rule-based approach and its flexibility in dealing with uncertainty and complexity. The process in Fuzzy Logic consists of three main stages: fuzzification, rule evaluation, and defuzzification. Next, the speed data generated from the Fuzzy Logic method will be forwarded to a PC (Personal Computer) as an interface [7]. This aims to facilitate monitoring of speed changes so that analysis of possible damage to the motor can be carried out more effectively.

METHOD

This study uses an experimental method to determine the effect of certain variables on other variables under controlled conditions. This method was chosen based on the research objective, which is to test the effectiveness of a fuzzy logic-based Internal Combustion Engine (ICE) speed control system on a prototype trimaran vessel [8], [9].

The unit of analysis in this study is a prototype trimaran ship equipped with a Zenoah Engine type Internal Combustion Engine (ICE) as the main propulsion, which is capable of producing a rotational speed range between 1,200 and 11,000 RPM depending on throttle input. Several supporting components are integrated into the system. The STM32 Nucleo-64 microcontroller (ARM Cortex-M, 72 MHz, 64 KB Flash) functions as the data processing center and the implementation platform for the fuzzy logic controller [10]. A photodiode sensor with an accuracy of ±0.1% is employed to measure motor rotation speed (RPM) by comparing sensor readings with a standard tachometer [11]. A flowmeter sensor (Hall-effect based, operating range 1–30 L/min) is used to determine real-time fuel consumption with an average error of 1.71% [12]. A standard servo motor (operating angle 30°–330°, precision ±5°, powered at 5 V) serves as an actuator to regulate the throttle opening of the ICE motor. An ESP32 module (dual-core 240 MHz, Wi-Fi and Bluetooth enabled) is utilized as a wireless communication medium for sensor data transmission. Meanwhile, a 16×2 Liquid Crystal Display (LCD) with I^2C interface is used to display RPM and fuel consumption readings clearly and efficiently. All of these components are

(cc) BY-SA
Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

designed to work in an integrated manner, ensuring that the ICE speed control system can be tested comprehensively under static and dynamic conditions [10], [11], [12].

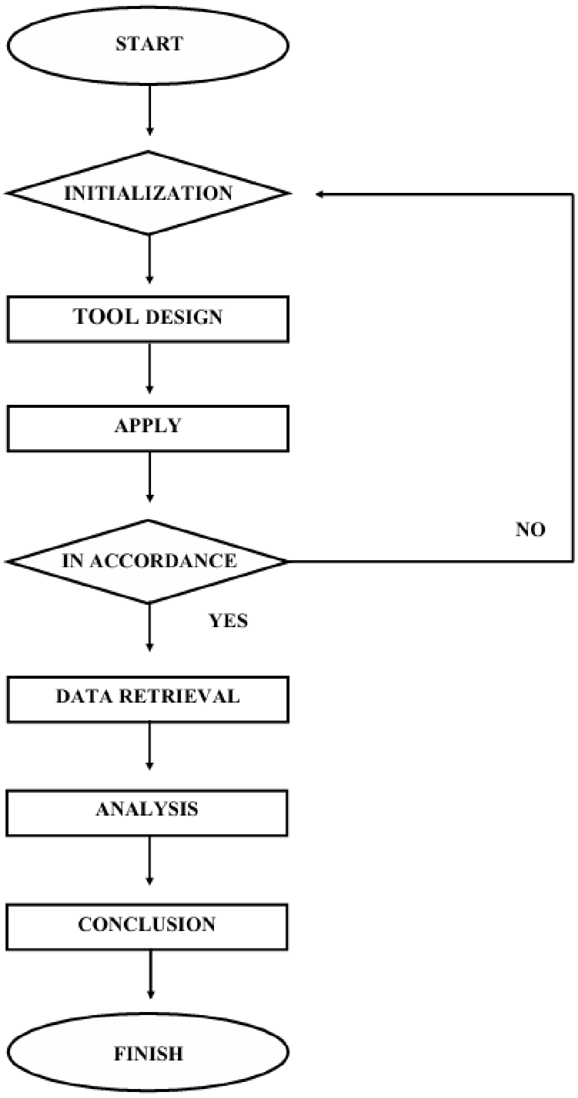


Figure 1. The Research Flow Diagram
Source: Personal Documents

This research was conducted through several stages as shown in the research flow diagram in figure 1. The process began with the system design stage, including block diagrams, flowcharts, and wiring diagrams, followed by hardware assembly of microcontrollers, sensors, servo motors, and supporting components [13]. The next stage was fuzzy logic controller design, consisting of three steps: fuzzification, rule evaluation, and defuzzification [14]. Afterward, system testing was carried out in two stages: static testing and dynamic testing. Static testing aimed to ensure that each component functioned correctly, while dynamic testing involved performance trials on the trimaran prototype with variations in load and wave simulations, both with and without fuzzy logic control [15], [16]. The final stage involved analyzing the test results by comparing performance with and without fuzzy logic control, including RPM accuracy, system stability, throttle response, and fuel consumption efficiency [17].

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

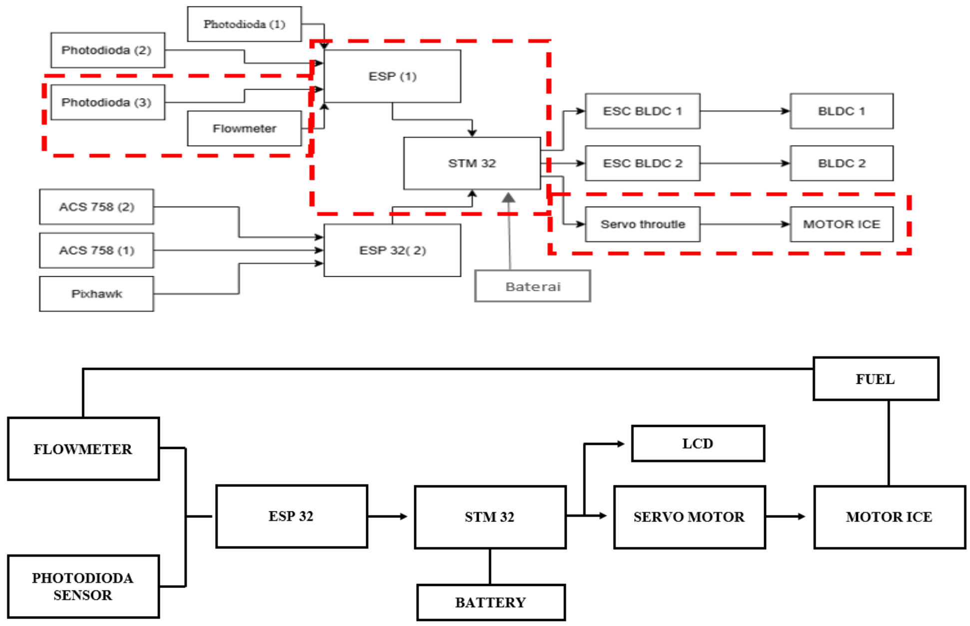


Figure 2. Fuzzy Controller Block Diagram
Source: Personal Documents

The fuzzy logic controller used in this study was designed with one input variable, namely RPM error (difference between set point and actual RPM), and one output variable, namely servo angle adjustment for throttle control. The input RPM error ranged from –5000 to +5000, while the output servo adjustment ranged from –1° (decrease throttle) to +1° (increase throttle). Five membership functions were defined for the input: Negative Large (NL), Negative Small (NS), Zero (ZE), Positive Small (PS), and Positive Large (PL), using triangular and trapezoidal shapes to represent the fuzzy sets. The rule base consisted of five fuzzy rules in the form of IF–THEN statements, for example: IF error is NL THEN decrease throttle; IF error is ZE THEN hold position. Defuzzification was carried out using the Modified Weighted Average method. A block diagram of the fuzzy logic controller is provided in Figure 2 to illustrate the data flow from sensor input to throttle actuation.

Although this research demonstrates promising results, it has certain limitations. The experiments were conducted at laboratory scale using a prototype trimaran and a wave simulator; therefore, the system has not yet been validated under real sea conditions with natural disturbances. Future research should extend testing to open water trials to better evaluate the reliability and robustness of the proposed control system.

RESULTS AND DISCUSSION

1. Static Testing

Static testing was conducted to ensure each component in the system functions properly and minimize errors during integration. The components tested included the Zenoah Engine, STM32 Nucleo-64, servo motor, photodiode sensor, flowmeter sensor, ESP32 microcontroller, and LCD. This step is crucial to ensure the system runs stably before dynamic testing.

Testing the STM32 showed that the board was able to run basic programs successfully. The onboard LED was successfully controlled via the PA5 pin, turning on at HIGH logic and off at LOW logic. This proves that the STM32's inputs and outputs function accurately and responsively. Similar testing on the ESP32 was also successful, indicated by the internal LED on the GPIO2 pin turning on and off every 1 second according to instructions. These results indicate that the ESP32 is ready for more complex system development.

BY-SA
Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

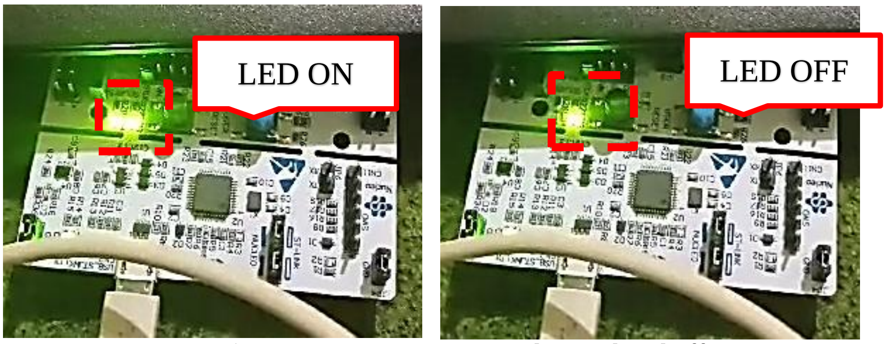


Figure 3. Testing STM32 Led on and Led off
Source: Personal Documents

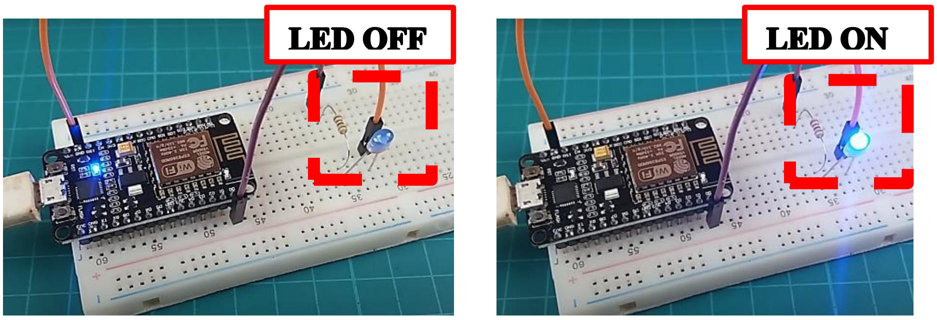


Figure 4. ESP32 Testing with LED
Source: Personal Documents

Next, the servo motor was tested by applying a PWM signal through the STM32 to adjust the servo's travel angle between 30° and 330°. The test results showed that the servo could follow commands well, with a maximum deviation of ±5° and an average error of 1.26%. This high level of accuracy indicates that the STM32's PWM control is quite precise, although there is still a small tolerance due to mechanical factors and manual measurement limitations.

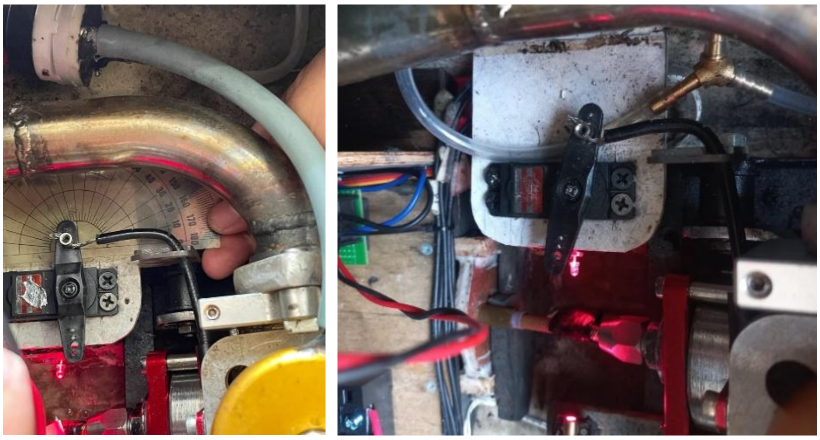


Figure 5. Servo Testing; Initial Position and Angular Movement of Servo Motor
Source: Personal Documents

Tests on the Zenoah Engine showed that increasing the throttle angle from 0° to 15° resulted in a gradual increase in RPM, ranging from approximately 1,200 to 8,400 RPM. This indicates that the engine can respond well to throttle changes, making it suitable for use as the main engine in the system. The accuracy of the photodiode sensor for reading speed was also tested by comparing the results with a tachometer. The results were very good with an average error of only 0.104%, so this sensor is able to read speeds almost identical to the actual value.

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

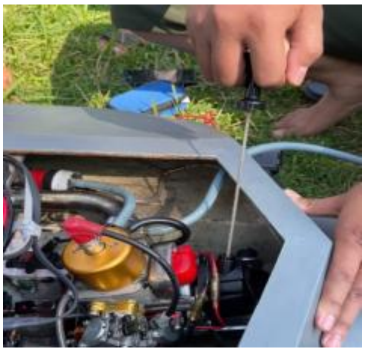


Figure 6. Starter Zenoah Engine
Source: Personal Documents

Table 1. Engine test results

No	Arc Angle (°)	Photodiode (RPM)	Tachometer (RPM)
1	0	1200	0
2	2	1200	0
3	4	1200	0
4	6	1200	0
5	8	1200	0
6	10	1200	0
7	12	4.800	4.897
8	13	6.000	5.923
9	14	7.200	7.301
10	15	8.400	8.264

Source: Personal Documents

Flowmeter sensor testing showed accurate results with an average error of 1.71% and a maximum error of only 2.88%. This indicates that the flowmeter is reliable for measuring fluid flow and volume effectively. Furthermore, the LCD used in the system was also tested and proven to function normally, capable of displaying output data according to the program input without any problems. Based on these test results, it can be concluded that all components in the system are functioning properly and are ready for use in the integration and dynamic testing stages.

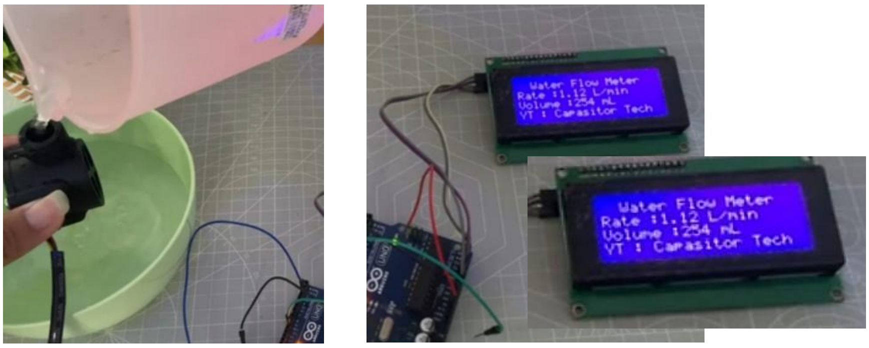


Figure 7. Flowmeter Sensor Testing
Source: Personal Documents

Afterward, the researchers also conducted LCD testing to ensure that the LCD was in good condition and could display output consistent with the input without any problems or errors. The test results showed that the LCD was functioning properly and could display output consistent with the program being run.

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

Figure 8. LCD Testing
Source: Personal Documents

Based on the results of the tests above, the Zenoah engine is able to increase RPM quickly from 4800 to 8400 RPM with a very significant change in throttle angle, while the STM32 successfully executes basic input-output logic well. The servo motor shows high accuracy with a maximum error of ±5° and a precision above 96%, the photodiode sensor has a very small error below 0.002%, and the flowmeter sensor shows accuracy with an average error below 3%. In addition, the ESP32 and LCD also function normally according to the basic response test. Thus, all components are declared suitable for use in the integration of dynamic control systems.

2. Dynamic Testing

Dynamic testing was conducted to assess the performance of the motor speed control system when operating directly on a prototype trimaran, both without and with fuzzy logic control, at various setpoints (6000–11000 RPM). The results were analyzed using graphs of speed, RPM, throttle, and fuel consumption.

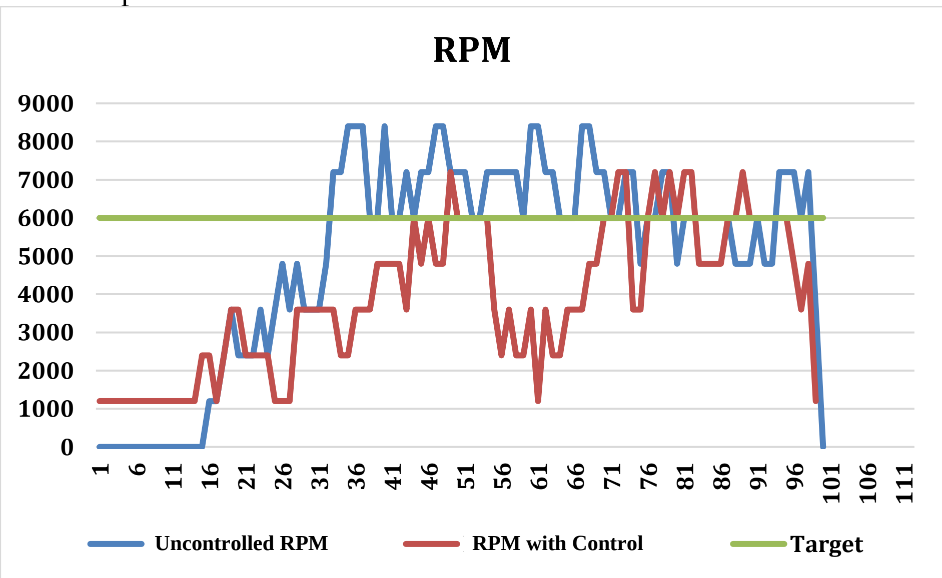


Figure 9. Comparison Graph of RPM Values at Set Point 6000 RPM
Source: Personal Documents

Dynamic testing at a set point of 6000 RPM shows that without control, the engine experiences speed instability with fluctuating RPM values, disproportionate throttle, and high fuel consumption (14.5 mL), so the system is considered inefficient. In contrast, the use of Fuzzy Logic control provides more optimal performance with stable RPM graphs, smooth and adaptive throttle movements, fast speed response, and more efficient fuel consumption (12.8 mL), thus improving RPM stability, system response, and fuel efficiency compared to the system without control.

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

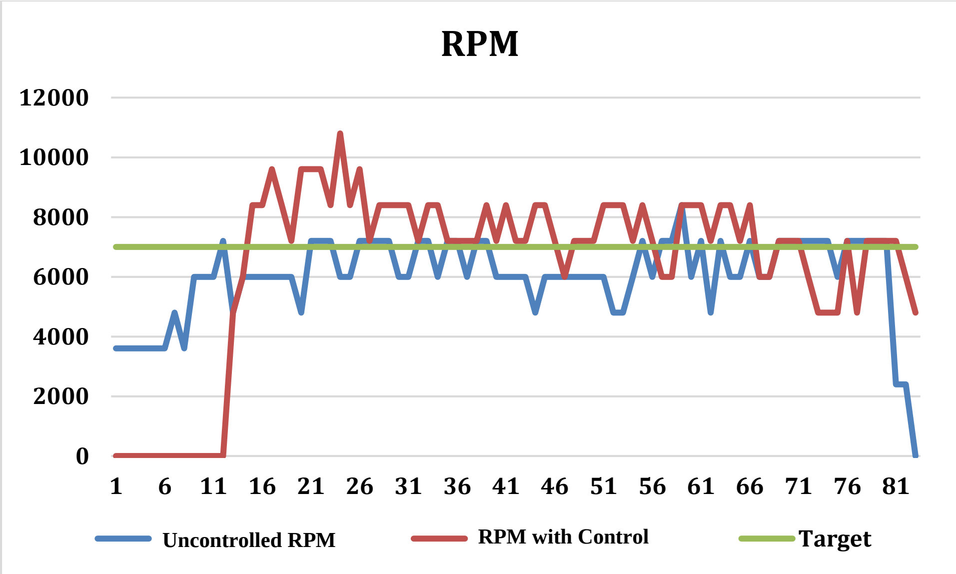


Figure 10. Comparison Graph of RPM Values at Set Point 7000 RPM
Source: Personal Documents

Testing at a set point of 7000 RPM with Fuzzy Logic control shows that the system is able to work stably and efficiently, indicated by the RPM graph that remains close to 7000 RPM without sharp fluctuations, indicating the system's ability to maintain stability even in the presence of disturbances. The throttle works responsively with smooth and consistent adjustments according to actuation needs, while the speed graph shows a steady increase with a smooth curve approaching the set point, thus reflecting the effectiveness of fuzzy control in maintaining the speed of the system. In terms of fuel consumption, the use of 11 mL was recorded, namely from 516.1 mL to 505.1 mL, which indicates better efficiency compared to conditions without control.

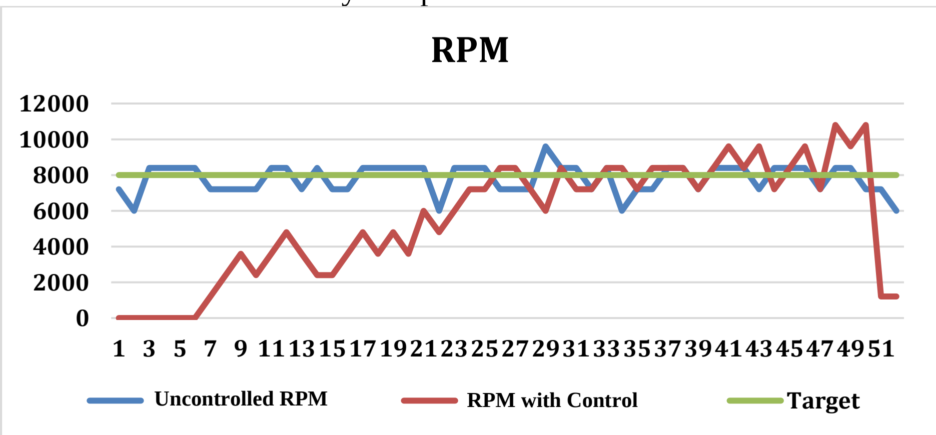


Figure 11. Comparison Graph of RPM Values at Set Point 8000 RPM
Source: Personal Documents

Testing at a set point of 8000 RPM showed significant differences between the system without control and with Fuzzy Logic control. Without control, the RPM was unstable, speed fluctuations occurred, and fuel consumption was more wasteful with a difference of 9.1 mL. In contrast, the use of Fuzzy Logic control made the RPM more stable approaching 8000 RPM, the throttle worked responsively without excessive oscillation, the speed graph was smoother, and fuel consumption was more efficient with a difference of only 5.14 mL, so that engine performance was more optimal.

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

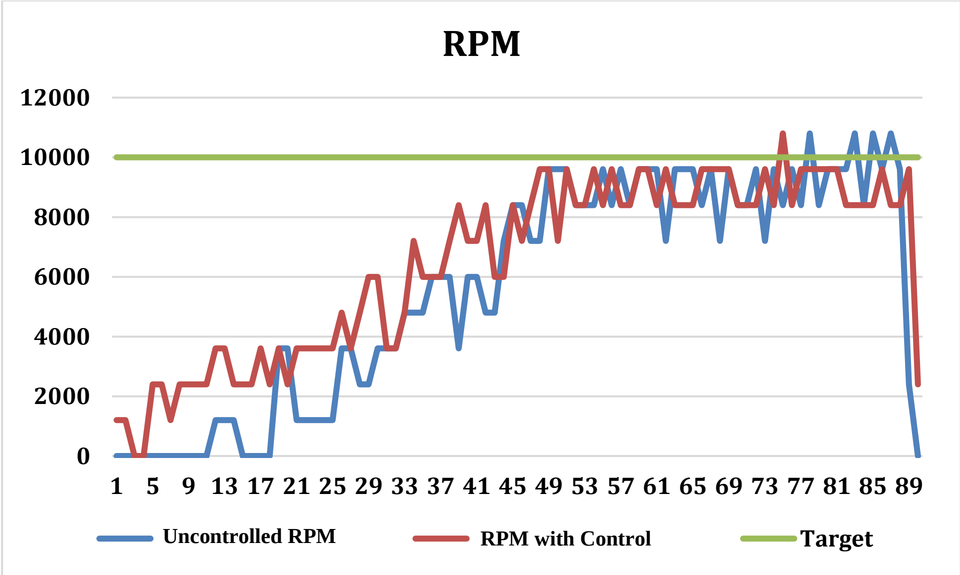


Figure 12. Comparison Graph of RPM Values at Set Point 10000 RPM
Source: Personal Documents

Testing at a set point of 10,000 RPM showed significant differences between the system without control and with Fuzzy Logic control. Without control, the system was unable to achieve engine speed stability, characterized by extreme RPM fluctuations, irregular throttle, unstable speed graphs, and fuel consumption of 19.1 mL which was not commensurate with performance so the system was considered inefficient. In contrast, with Fuzzy Logic control, the system was able to work stably with a consistent RPM at 10,000, a responsive and smooth throttle, fast speeds stable at the set point, and fuel consumption of only 13.5 mL which indicated better energy efficiency and optimal performance.

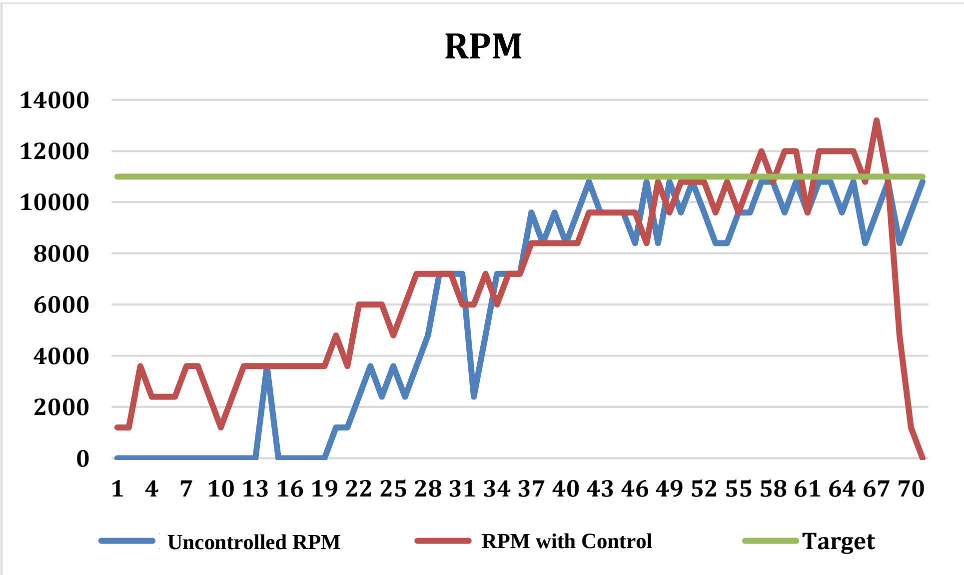


Figure 13. Comparison Graph of RPM Values at Set Point 11000 RPM
Source: Personal Documents

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

Testing at a set point of 11,000 RPM showed significant differences between the uncontrolled system and the one with Fuzzy Logic control. In the uncontrolled system, RPM fluctuated sharply, the throttle was imprecise, the speed was unstable, and fuel consumption reached a difference of 16 mL, indicating the system was inefficient. In contrast, with Fuzzy Logic control, the RPM was able to stabilize near 11,000, the throttle responded smoothly and adaptively, the speed increased and maintained consistently, and fuel consumption was more efficient with a difference of 13.1 mL. This proves that Fuzzy Logic control is able to improve the stability, responsiveness, and efficiency of the system as a whole.

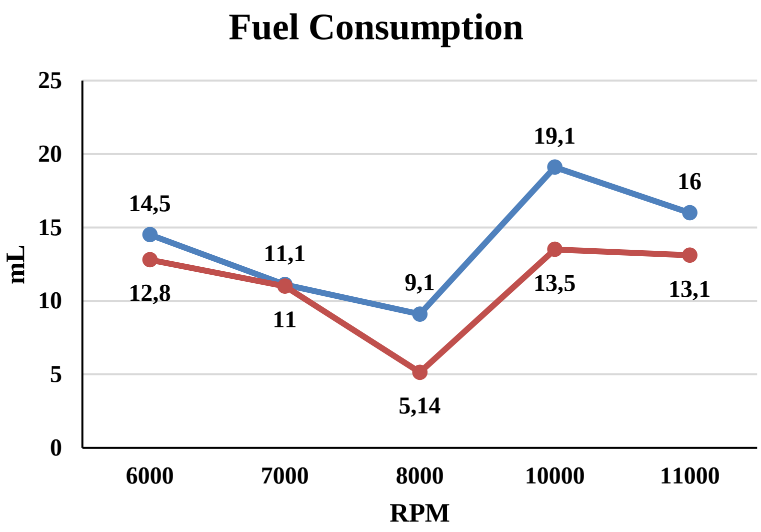


Figure 14. Fuel Consumption Comparison Graph
Source: Personal Documents

Based on the graph, the implementation of the control system is proven to increase fuel efficiency. The system without control shows higher consumption at every RPM range with a blue curve, while the system with control is more economical with a red curve, especially at medium to high revs (around 8000 RPM). This shows that the control system helps stabilize engine performance while optimizing performance and reducing overall fuel consumption.

In general, the application of a fuzzy logic controller in this study shows better performance in maintaining the stability of the Internal Combustion Engine (ICE) speed compared to the uncontrolled system. This finding is consistent with the principles of non-linear control theory, where fuzzy logic is considered effective for systems with dynamic characteristics and uncertainty, as it does not require an exact mathematical model of the plant. Unlike linear controllers that assume proportionality between input and output, fuzzy logic relies on rule-based reasoning that adapts to changes in operating conditions, making it highly suitable for the non-linear behavior of ICE under varying loads and wave disturbances.

As a benchmark, the fuzzy controller performance can also be compared conceptually with the conventional PID (Proportional-Integral-Derivative) controller, which is commonly used in industrial motor speed control. PID requires accurate tuning of three parameters (Kp, Ki, Kd) and works optimally on systems with predictable dynamics. However, in highly non-linear systems such as ICE on marine vessels, PID often exhibits limitations, including overshoot and slower response when the load fluctuates significantly. In contrast, the fuzzy logic controller developed in this research shows superior adaptability, smoother throttle response, and more efficient fuel consumption without requiring precise plant modeling. This aligns with findings from previous studies that fuzzy logic is more robust than PID in handling real-time disturbances in non-linear systems.

(cc) BY-SA
Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

CONCLUSION

Based on the results of the design, testing, and analysis, the Internal Combustion Engine (ICE) motor speed control system based on Fuzzy Logic was successfully designed and implemented. This system uses an STM32 microcontroller as a data processor, a photodiode sensor as an actual RPM reader, and a servo motor as a throttle actuator, and is proven to be able to work with a fairly high level of accuracy with an average error of less than 5%. The Fuzzy Logic method allows the system to provide automatic and adaptive control responses to changes in load and dynamic disturbances, thereby increasing the stability of the engine rotation. The test results also show that the application of Fuzzy Logic control makes the RPM more stable, the throttle smoother, and fuel consumption more efficient, especially at medium speeds (8000 RPM), which makes this system efficient and suitable for application in ship engine applications. The main contribution of this research is the clear evidence that fuzzy logic provides more stable control compared to systems without control, achieving an average error below 5% and delivering more efficient fuel consumption across different operating conditions.

For further development, it is recommended that the control system be enhanced by integrating machine learning to generate more optimal and adaptive fuzzy parameters in real time. Furthermore, sensor quality needs to be improved by using high-accuracy RPM sensors and flowmeters that are resistant to extreme temperatures. Further testing is also needed under real-world conditions in open water with varying loads and weather conditions to more comprehensively assess system reliability. Furthermore, the development of a web-based user interface or mobile application that displays speed and fuel consumption data will make the system easier to monitor and control.

ACKNOWLEDGEMENTS

The author would like to express sincere gratitude to Mr. Moejiono, MT. M.Mar.E, Director of the Surabaya Maritime Polytechnic; the supervisors Mr. Edi Kurniawan, SST., M.T. and Mr. Jaka Septian K., S.Si., M.Si.; and Mr. Dirhamsyah, S.E., M.Pd., Head of the DIV TRKK Study Program, for their invaluable guidance and support. Special thanks are also extended to the author's parents, family, and Siti Nawang Arum, S.Pd., for their prayers and encouragement. Appreciation is likewise given to colleagues in the Hybrid Propulsion research group and fellow cadets at the Surabaya Maritime Polytechnic for their support during this research.

REFERENCES

[1] L. Budiyanto and S. Haryadi, “Pengaruh Variabel Putaran (RPM) terhadap Temperatur Gas Buang Mesin Penggerak Utama Type MAN B&W 31990 KW pada Kapal Kontainer,” *Saintara: Jurnal Ilmiah Ilmu-Ilmu Maritim*, vol. 7, no. 2, pp. 38–42, 2023, doi: 10.52475/saintara.v7i2.229.

[2] B. Utomo, “Hubungan Antara Konsumsi Bahan Bakar dengan Berbagai Perubahan Kecepatan pada Motor Diesel Penggerak Kapal,” *Jurnal Rekayasa Mesin*, vol. 15, no. 2, p. 163, 2020, doi: 10.32497/jrm.v15i2.1957.

[3] S. Kirono, E. Diniardi, and R. Adha, “Perencanaan Batang Torak Motor Bensin 4 Langkah 100 Cc,” *SINTEK Jurnal: Jurnal Ilmiah*, pp. 30–38, 2010.

[4] A. Aifiayu and T. Ta'ali, “Sistem Monitoring dan Kontrol Motor AC dengan Fuzzy Logic Controller Berbasis Arduino Uno,” *JTEIN: Jurnal Teknik Elektro Indonesia*, vol. 2, no. 1, pp. 1–5, 2021, doi: 10.24036/jtein.v2i1.102.

[5] A. P. P. Tampubolon, T. B. Sitorus, M. Sabri, T. U. H. S. Ginting Manik, and A. H. Siregar, “Simulasi Perhitungan Performansi Motor Bakar Dengan Menggunakan Program Visual Basic,” *Dinamis*, vol. 3, no. 4, p. 15, 2015, doi: 10.32734/dinamis.v3i4.7009.

[6] Ezenwobodo and S. Samuel, “International Journal of Research Publication and Reviews,” *Int. J. Res. Publ. Rev.*, vol. 4, no. 1, pp. 1806–1812, 2022, doi: 10.55248/gengpi.2023.4149.

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.

[7] K. Rois'Am, B. Sumantri, and A. Wijayanto, "Pengaturan Posisi Motor Servo DC Dengan Metode Fuzzy Logic," *Metode*, Dec. 2019.

[8] D. A. Insantama and B. Suprianto, "Rancang Bangun Kendali Level Air Otomatis Pada Tangki Dengan Servo Valve Berbasis Fuzzy Logic Controller Menggunakan Arduino," *Jurnal Teknik Elektro*, vol. 8, no. 1, pp. 143–151, 2019.

[9] P. Pantai, W. Di, and K. Pacitan, "Perancangan Kapal Trimaran Untuk Penghubung Pantai - Pantai Wisata Di Kabupaten Pacitan," *Jurnal Teknik Perkapalan*, vol. 4, no. 1, pp. 237–245, 2016.

[10] F. E. Maulana and L. Nurpulaela, "Konfigurasi Mikrokontroler Stm32 Untuk Membaca Push Button Dengan Arduino Ide Pada Prototipe Smart Charger Di Pt. Pasifik Satelit Nusantara," *JATI (Jurnal Mahasiswa Teknik Informatika)*, vol. 8, no. 4, pp. 7278–7284, 2024, doi: 10.36040/jati.v8i4.10184.

[11] A. Hunaepi, A. Roihan, and A. Nurtursina, "Perancangan Sistem Kehadiran Pendidik dan Tenaga Kependidikan Berbasis Mikrokontroler ESP32CAM," *Jurnal*, 2021.

[12] R. Sandi *et al.*, "Karakterisasi laju aliran menggunakan beberapa jenis flowmeter dan pengukuran beda tekanan berdasarkan variasi buka katup pada kalibrator aliran," 2022.

[13] A. S. Dwisaputra, F. Yumono, and D. E. Yuliana, "Kontrol Kecepatan Motor Dc Menggunakan Fuzzy Logic Controller Pada Ayunan Bayi," *JASEE J. Appl. Sci. Electr. Eng.*, vol. 2, no. 1, pp. 1–14, 2021, doi: 10.31328/jasee.v2i01.62.

[14] M. A. Ulum and S. I. Haryudo, "Perancangan Sistem Monitoring Kecepatan Putar Motor DC Berbasis Internet Of Things Menggunakan Aplikasi BLYNK," *Jurnal Teknik Elektro*, vol. 9, no. 1, pp. 855–862, 2020.

[15] A. Prafanto, E. Budiman, P. P. Widagdo, G. M. Putra, R. Wardhana, and U. Mulawarman, "Pendeteksi Kehadiran Menggunakan ESP32 Untuk Sistem Pengunci Pintu Otomatis," *Jurnal Teknologi Terapan*, vol. 7, no. 1, 2021.

[16] P. Muliyah, D. Aminatun, S. S. Nasution, T. Hastomo, S. S. W. Sitepu, and Tryana, "Exploring Learners' Autonomy in Online Language-Learning in Stai Sufyan Tsauri Majenang," *Getsempena English Education Journal*, vol. 7, no. 2, pp. 382–394, 2020, doi: 10.46244/geej.v7i2.1164.

[17] F. Parende, I. H. Gunawan, and I. N. Gede, "Analisis Konsumsi Bahan Bakar Motor Bensin Yang Terpasang Pada Sepeda Motor Suzuki Smash 110Cc," *Jurnal Online Poros Teknik Mesin*, vol. 1, no. 1, pp. 1–6, 2013.

Ciptaan disebarluaskan di bawah Lisensi
Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional.