

Effect of Cyclone on Marine Diesel Engine Performance

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Abstract—Small direct-injection (DI) diesel engines remain indispensable for stationary power generation and small marine applications, where improving their output and fuel economy carries real practical value. This study evaluates the effect of modifying an intake manifold using a passive cyclone-type swirl generator on the performance of a marine diesel engine. The research presents a combined numerical and experimental approach to analyze the impact of the cyclone on engine power, torque, brake specific fuel consumption (BSFC), and thermal efficiency. Numerical simulations using Ansys Forte were initially conducted on 27 cyclone geometries to identify optimal turbulent kinetic energy (TKE) generation. Subsequently, experimental testing was performed on a Yanmar TF-85 single-cylinder diesel engine across varying speeds (1400–2200 RPM) and loads (1–3 kW). The numerical results indicated that the 110560-cyclone model generated the highest TKE (+11.20%) despite a slight reduction in mass flow. Experimental findings revealed that the cyclone significantly enhanced power and torque at low-to-medium speeds (1400–1800 RPM). Notably, at 1800 RPM, the optimal cyclone reduced BSFC by up to 20.8% and increased thermal efficiency by 26.3% compared to the standard intake. The enhanced TKE improved air-fuel homogenization, which successfully compensated for the slight volumetric efficiency drop at high speeds, providing practical evidence for intake-side swirl enhancement as an affordable route to improved marine engine performance.

Keywords—Brake Specific Fuel Consumption, Cyclone, Diesel Engine, Engine Performance, Intake Manifold, Swirl.

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I. INTRODUCTION

Marine diesel engines are integral to global trade and local economies, yet they contribute significantly to exhaust emissions. The International Maritime Organization (IMO) has implemented stringent emission standards alongside targeting a 40% reduction in greenhouse gas emissions by 2030 [1]. Concurrently, small direct-injection (DI) diesel engines remain the workhorse of the developing world, powering generator sets and light marine craft where ruggedness and fuel economy are paramount [2]. The Yanmar TF 85 MH, a single-cylinder DI unit, is a familiar sight in Indonesian fishing harbors. Users continuously seek simple, affordable ways to coax more torque and power out of these engines while keeping fuel consumption—which dominates operational costs—in check [3], [4]. Since costly redesigns of the combustion system are rarely an option for such modest engines, attention naturally turns toward the intake side, where a well-chosen modification can improve combustion at its source.

The underlying logic is straightforward: better mixing of air and fuel yields more complete combustion, releasing more of the fuel's energy as useful work, which directly results in higher torque, higher power, and lower specific fuel consumption [5]. In-cylinder air motion—swirl in particular—is the lever that controls that mixing,

breaking up the fuel spray, spreading it through the available oxygen, and hastening the formation of a combustible mixture [6]. Small high-speed DI engines are known to benefit from high intake swirl ratios, especially at part load [7].

Researchers have pursued this goal along several avenues. Guide vanes, grooved and helical runners, throttling plates, and swirl generators of various shapes have all been fitted to intake manifolds to raise turbulence and swirl [8], [9]. Experimental studies confirm the payoff: swirl-generator manifolds have been found to raise engine torque and improve brake-specific fuel consumption relative to standard manifolds, while also reducing hydrocarbon emissions [5], [10]. The magnitude of the gain, however, is sensitive to both the device geometry and the engine's operating regime [11].

The cyclone-type swirl generator is a particularly attractive solution because its helical vane geometry produces a concentrated, cyclonic rotational core with a relatively simple, passive structure. Recent characterization of axial cyclone geometries has clarified how inlet velocity and vane proportions dictate the flow pattern and the associated pressure penalty [12], [13]. Meanwhile, the Yanmar TF 85 MH itself has become a recurring test platform for performance and combustion research [14], [15], making it a natural candidate for a dedicated study of intake-side swirl enhancement.

Despite this breadth of work, comprehensive studies combining both numerical simulation and direct experimental evidence for a cyclone-type swirl generator applied to the Yanmar TF 85 MH are scarce. This study fills that gap by investigating how the cyclone device reshapes the engine's torque, brake power, and fuel consumption across its operating range. By integrating a 3D computational fluid dynamics (CFD) study with physical bench testing, this research provides the real-world validation needed to establish cyclone-driven

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intake swirl as a viable, low-cost intervention for optimizing marine DI diesel engines.

TABLE 1.
PRINCIPAL SPECIFICATIONS OF THE YANMAR TF 85 MH TEST ENGINE

Parameter	Specification
Model	Yanmar TF 85 MH
Type	Single-cylinder, 4-stroke, DI
Cooling system	Water-cooled
Bore × stroke	85 mm × 87 mm
Displacement	≈ 0.493 L
Compression ratio	≈ 18 : 1
Rated output	8.5 HP @ 2200 rpm (continuous)
Loading	Coupled to generator / load bank

II. METHOD

A. Test Engine and Instrumentation

The experiments were performed on a Yanmar TF 85 MH single-cylinder, four-stroke, water-cooled DI diesel engine, whose specifications are listed in Table 1. The engine was coupled to an electric generator serving as the load bank, in line with its normal service as a genset prime mover or small marine generator. A dynamometer and instrument panel provided readings of rotational speed, voltage, and current, while fuel consumption was measured volumetrically using a graduated burette and a stopwatch.

B. Cyclone Design and Simulation

The swirl generator is a passive cyclone-type device comprising curved helical vanes housed in a short cylindrical body sized to match the intake manifold bore. Its design was based on geometrical variations in twist angle (30, 45, 60 degrees), vane height (5, 8, 11 mm), and vane length (30, 40, 50 mm), resulting in 27 cyclone variations. Before physical fabrication, the designs were simulated transiently for the intake stroke using Ansys Forte to evaluate Turbulent Kinetic Energy (TKE) and mass flow characteristics [16], [17]. The optimal design from the simulation was then manufactured via 3D printing and installed upstream of the port intake.

C. Experimental Procedure and Data Treatment

Testing followed a comparative design: the engine was first run with the standard intake manifold to establish a baseline, then with the cyclone-fitted manifold under identical conditions using B40 fuel. Engine speed varied from 1400 to 2200 rpm. Engine load systematically varied at 1 kW, 2 kW, and 3 kW. At each set point, the engine was allowed to reach a steady thermal state before data were recorded.

From the recorded electrical output, speed, and fuel-flow data, Brake Power (P) in kW was calculated by extracting the alternator's electrical output, accounting for transmission efficiency. Engine torque (T) in Nm and

Brake Specific Fuel Consumption (BSFC) were computed as follows:

$$P = \frac{2\pi NT}{60000} \text{ kW} \quad (1)$$

$$BSFC = \frac{\dot{m}_f}{P} \text{ g/kWh} \quad (2)$$

where N is the engine speed (rpm), T the engine torque (Nm), and $\dot{m}_f$ the fuel mass flow rate. Experimental IMEP results were also validated against numerical IMEP data using the Willans line method to account for Friction Mean Effective Pressure (FMEP).

III. RESULTS AND DISCUSSION

A. Cyclone Selection via Numerical Simulation

The numerical simulation results of 28 models (1 baseline + 27 cyclones) at 2000 RPM revealed opposing fluid mechanic phenomena between air turbulence intensity and mass flow capacity. Almost all cyclone geometries increased TKE. The 110560 cyclone model recorded the highest surge in turbulent energy, reaching 3,673,445.98 cm²/s² (+11.20% compared to baseline). High TKE indicates massive swirl formation, which breaks down injection particles rapidly for better fuel-air homogeneity. Conversely, the addition of the cyclone introduced airflow resistance, with the 110560 model experiencing the highest mass flow reduction of 4.12%.

B. Engine Power and Torque Analysis

Under partial loading (1 kW and 2 kW), the cyclone significantly increased engine power and torque, particularly at lower speeds (1400 RPM). For a 1 kW load, the 110530 cyclone model produced 0.565 kW of power, a 70.3% increase from the baseline (0.332 kW). This indicates that the cyclone effectively improved the combustion process at lower speeds. Torque followed a similar trend; at a 3 kW load and 1400 RPM, baseline torque was 11.330 Nm, which increased to 12.462 Nm (110530) and 12.417 Nm (110560).

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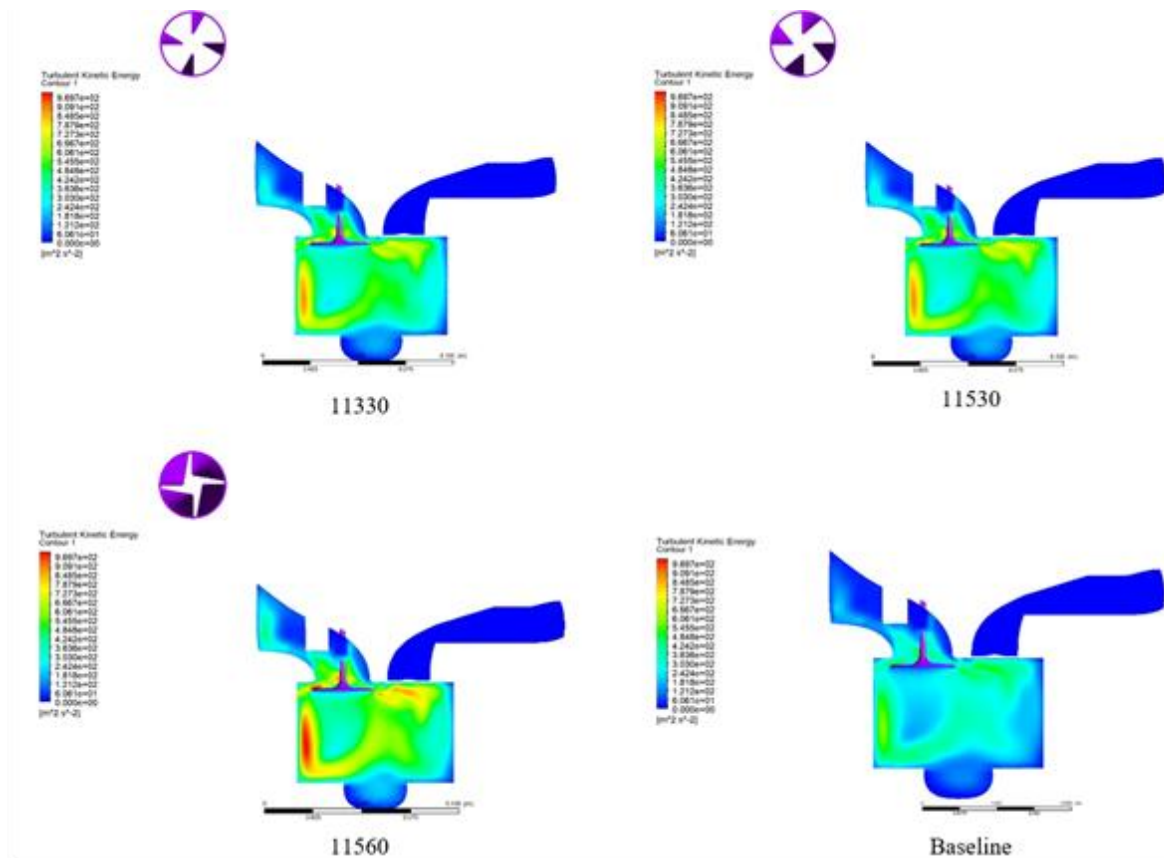


Figure. 1. Turbulent Kinetic Energy contour comparison between cyclone variations and baseline.

However, at high speeds (2000-2200 RPM), the air flow resistance caused by the cyclone guide vanes began to affect volumetric efficiency. Consequently, several cyclone models experienced slight power and torque deficits compared to the baseline. Despite this, the 110560 model demonstrated a superior aerodynamic configuration, successfully mitigating the restriction and slightly outperforming the baseline power and torque at 2200 RPM under a 3 kW load (+0.8%).

C. Specific Fuel Consumption (BSFC)

The application of the cyclone demonstrated notable improvements in fuel efficiency. At 1800 RPM, a stable operating condition for this engine, the cyclone maximized the quality of air-fuel mixing.

The 110560 specimen showed the best performance. At the highest simulated load at 1800 RPM, the BSFC dropped to 280.77 g/kWh compared to the baseline's 354.72 g/kWh. This equates to a fuel consumption saving of up to 20.8%. Even at 2200 RPM, where pressure drop influence is higher, the optimal cyclone model still managed a 5.9% reduction in BSFC compared to the standard intake.

D. Thermal Efficiency

Thermal efficiency, the inverse parameter of SFC, measures the success ratio of converting combustion heat energy into actual mechanical energy.

The results align with the BSFC data. At 1800 RPM under high load, the baseline thermal efficiency was 25.37%. Utilizing the 110560 cyclone elevated the thermal efficiency to 32.05%, representing a relative increase of 26.3%. The enhanced TKE facilitated a more uniform flame propagation and homogeneous mixture, ensuring that a higher percentage of combustion heat was converted into mechanical thrust rather than being lost through the exhaust or cylinder walls.

E. Validation and Comprehensive

Analysis Experimental IMEP compared with numerical IMEP showed a variance of less than 5%, sharing identical trends at high loads for 1600, 1800, and 2000 RPM. The comprehensive analysis confirms that while physical cyclone geometries (taller and longer vanes with higher twist angles) induce a pressure drop that slightly reduces mass flow (up to 4.12%), the resulting massive increase in TKE (+11.20%) overcompensates for this volumetric loss. The enhanced turbulence ensures superior thermodynamic extraction from the fuel, maintaining or increasing mechanical output while drastically lowering fuel consumption.

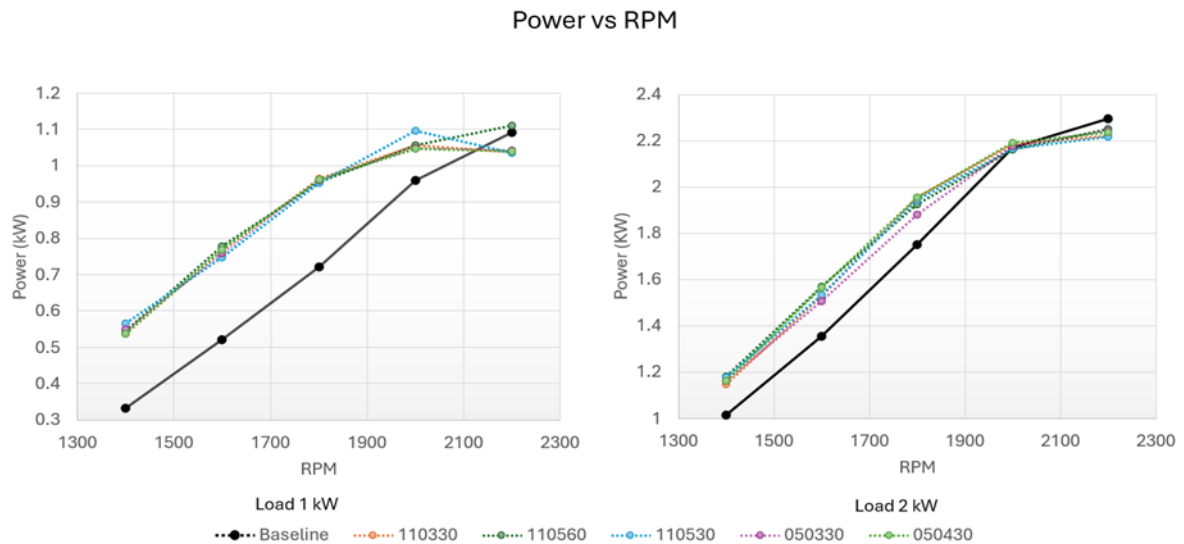


Figure. 2. Comparison of Specific Fuel Consumption with and without cyclone variations.

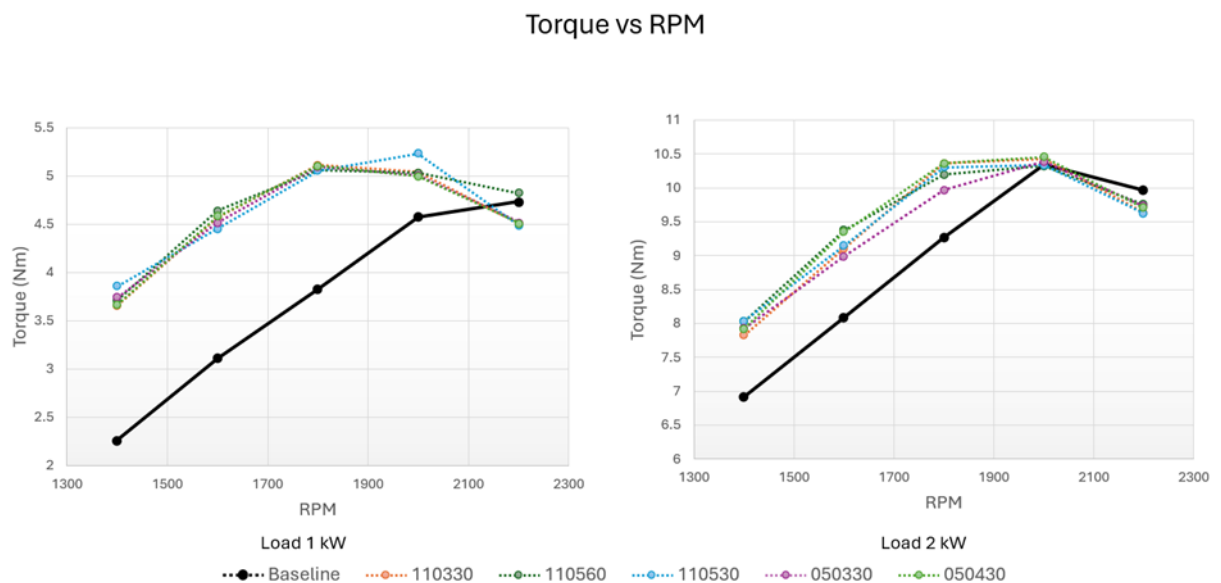


Figure. 3 Comparison of Thermal Efficiency with and without cyclone variations.

IV. CONCLUSION

Modifying the intake manifold using a cyclone device significantly affects the performance of marine diesel engines. At low to medium speeds (1400–1800 RPM), the cyclone robustly increases power and torque (up to a 10% increase at heavy loads) due to highly turbulent air enhancing the air-fuel mixture. While high speeds (2200 RPM) introduced slight volumetric flow restrictions due to pressure drop, the optimal 110560 cyclone model still maintained superior performance over the baseline. Furthermore, the enhanced Turbulent Kinetic Energy (TKE) generated by the cyclone homogenized the combustion process, leading to a substantial decrease in Brake Specific Fuel Consumption (up to 20.8% reduction) and an increase in thermal efficiency (up to 26.3% enhancement). The optimal design (11 mm vane height, 50 mm length, 60 degrees

twist angle) provides the best balance between fluid flow retention and combustion optimization for marine applications.

DECLARATION OF AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used Claude (Opus 4.8, Anthropic) to refine the English-language expression, clarity, and academic phrasing of the text, and Grammarly to assist with grammar, spelling, and punctuation. These tools were used solely for language enhancement and did not contribute to the study's conceptualization, methodology, data analysis, or interpretation of results. After using these tools, the author(s) carefully reviewed and edited the manuscript and take full responsibility for the content and integrity of the publication.

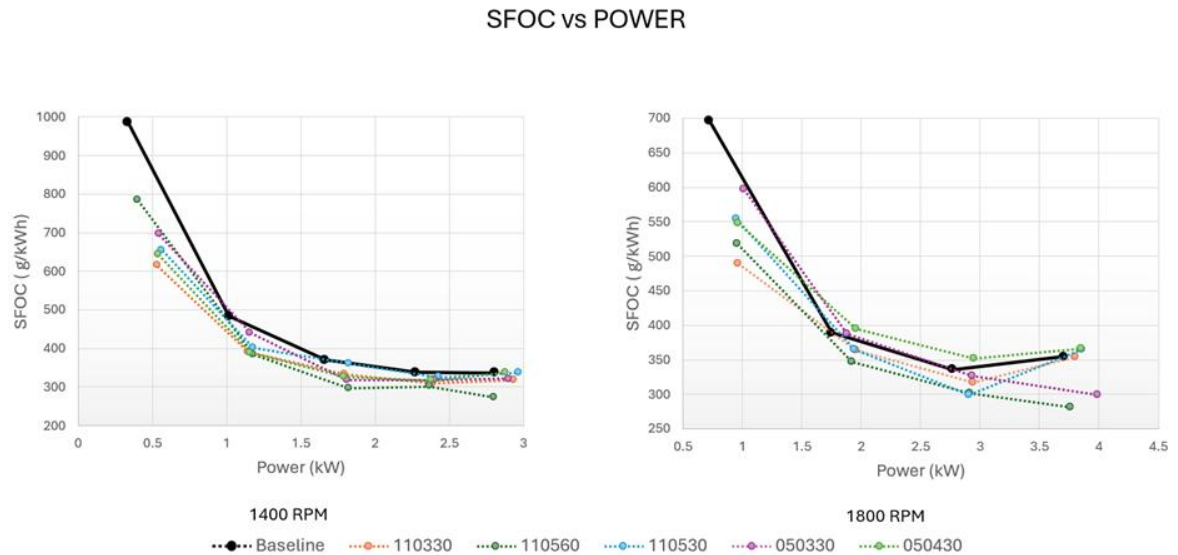


Figure. 4. Comparison of Specific Fuel Consumption with and without cyclone variations.

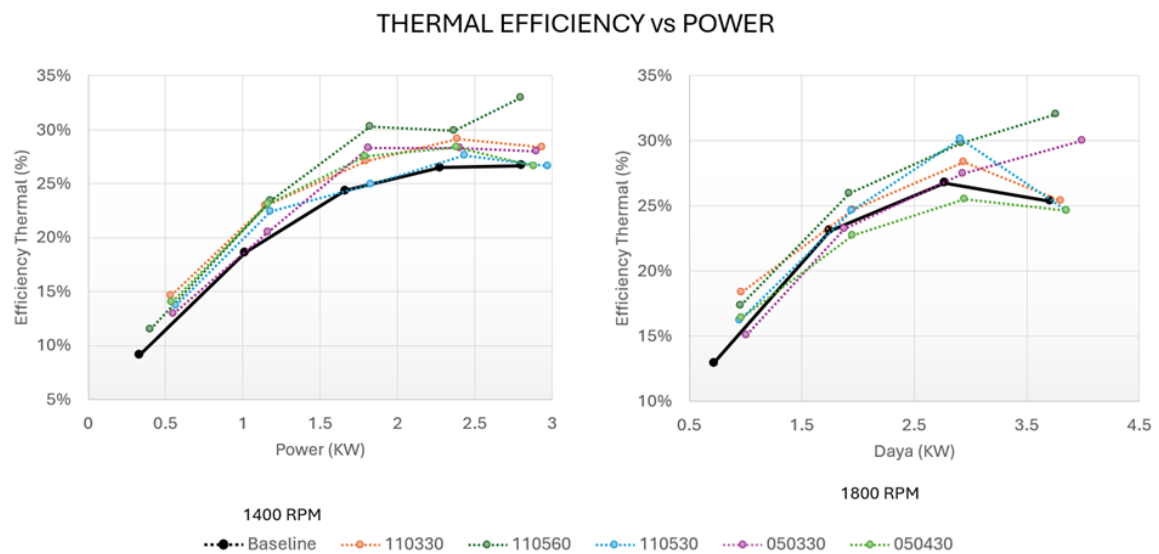


Figure. 5. Comparison of Thermal Efficiency with and without cyclone variations.

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