CIMAC CONGRESS 25
ZURICH, MAY 19 – 23, 2025

2025 | 101

Development of CPGC M450DF-Clean, Efficient, High-Powered Medium-Speed Dual Fuel Series Engines

Dual Fuel / Gas / Diesel

Yali Song, China Shipbuilding Power Engineering Institute CO., Ltd

Junfeng Cheng, China Shipbuilding Power Engineering Institute CO., Ltd.
Teng Liu, China Shipbuilding Power Engineering Institute CO., Ltd.

This paper has been presented and published at the 31st CIMAC World Congress 2025 in Zürich, Switzerland. The CIMAC Congress is held every three years, each time in a different member country. The Congress program centres around the presentation of Technical Papers on engine research and development, application engineering on the original equipment side and engine operation and maintenance on the end-user side. The themes of the 2025 event included Digitalization & Connectivity for different applications, System Integration & Hybridization, Electrification & Fuel Cells Development, Emission Reduction Technologies, Conventional and New Fuels, Dual Fuel Engines, Lubricants, Product Development of Gas and Diesel Engines, Components & Tribology, Turbochargers, Controls & Automation, Engine Thermondynamis, Simulation Technologies as well as Basic Research & Advanced Engineering. For further information please visit https://www.cimac.com.

ABSTRACT

The M450DF engine developed by China Shipbuilding Power Group is a remarkable achievement. The 1150kW~1200kW per cylinder with large cylinder diameter of 450mm and rated speed of 600 rpm demonstrate its powerful performance.

The dual-fuel functionality, capable of switching between diesel and LNG fuels, offers great flexibility and meets the stringent IMO Tier III emission requirements in gas mode, highlighting its environmental friendliness. The consideration of design protection for pure diesel series engines in the development process is a thoughtful addition.

The availability of V-type and L-type configurations in the M450 series engine expands its application range to land-based power generation and marine propulsion and power generation. The power range of 6.0 to 24MW provides a wide range of options for different uses.

The engine's characteristics such as the high-reliability mechanical main fuel system, intake air pre-mixed gas design, U-Flow cylinder head intake and exhaust design, and compact integrated intake chamber design not only make it structurally compact and easy to maintain but also enhance its standardization. The dual-fuel mode switching flexibility, high-performance turbocharging system, independently controllable electronic control system, and high-performance fuel system contribute to its competitiveness in terms of performance, fuel efficiency, and emissions.

Moreover, the consideration of future fuels and preparation for upcoming emissions regulations show the forward-thinking nature of the M450 series engine, ensuring its adaptability and longevity in the evolving industrial landscape.

1 INTRODUCTION

In response to increasingly stringent environmental protection regulations, dual-fuel (LNG & diesel) engines, have emerged as the future of global ship power development due to their clean and eco-friendly characteristics. China Shipbuilding Power (Group) Co., Ltd. (CPGC) has initiated the development of a new dual-fuel medium-speed engine family with a cylinder bore diameter of 450mm. The engine series includes versions ranging from 6 to 20 cylinders, available in both in-line and V-type configurations, with a power range from 6900 kW to 24000 kW. These engines are designed to meet power requirements for marine applications, offshore platforms, and land-based power stations while significantly reducing emissions, aligning with the global marine industry's green and low-carbon development trend.

Following successful tests on a full-scale 450 mm bore single-cylinder engine in 2023, CPGC launched the first full-scale 8ML450DF prototype—an in-line multi-cylinder engine—for testing at the end of 2024.

2 MAIN TECHNICAL SPECIFICATIONS

The 450 series engine is engineered for high reliability and durability while adhering to stringent low-emission requirements. It complies with TIER II standards in diesel mode and TIER III standards in gas mode, achieving high thermal efficiency with fuel consumption rates of ≤183 g/kWh in diesel mode and gas consumption rates of ≤7400 kJ/kWh in gas mode.

Through the advanced design of generalized components, this engine offers enhanced market competitiveness. The first 450 engineering prototype is illustrated in Figure 1, and Table 1 provides detailed technical specifications.

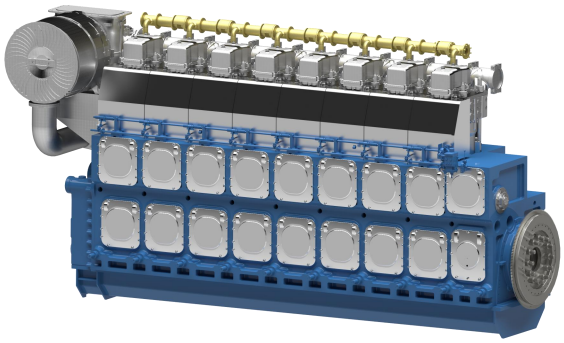

Figure 1. 8ML450DF engine

Table 1. Main technical specifications

Item	Unit	Features
Bore diameter	mm	450
Stroke	mm	600
Nominal speed	rpm	600
Cylinder numbers and arrangement	-	6-9 in-line, 12-20 V-type
Power per Cyl.	kW	1150 (in gas mode)
Fuel type	-	HFO/ MDO +GAS
BMEP	bar	24.1
Pmax	bar	240
Fuel consumption	g/kWh	⩽183
Fuel gas consumption	kJ/kWh	⩽7400
Emission level		Diesel mode : TIER II Gas mode : TIER III

3 MAIN TECHNICAL FEATURES

The design process of the M450 series engine thoroughly considered key factors such as reliability, maintainability, safety, and environmental adaptability. These factors crucially impact the engine's performance, service life, and customer satisfaction.

3.1 Fuel system

3.1.1 Main fuel system

During fuel mode operation, the M450 engine operates with a PLN (Pump-Line-Nozzle) mechanical fuel injection system developed by CPGC (see Figure 2). This highly reliable system ensures stable engine operation. With a rail pressure of 1600 bar, the fuel injected into the cylinder burns more completely and efficiently, reducing fuel consumption and enhancing overall high engine performance.

Figure 2. Main fuel injection system

3.1.2 Gas admission valve

In gas mode operation, the M450 engine utilizes electrically actuated Gas Admission Valves (GAV), as shown in Figure 3. Each cylinder requires one GAV, ensuring proper gas quantity and allowing gas flow compensation for each cylinder.

The M450 engine uses Micro Pilot Injection (MPI) to ignite the fuel gas during gas mode operation (see Figure 4). The electronically controlled MPI system features an 1800 bar pressure common rail, with a minimum injection quantity of 1% of MCR fuel, ensuring successful gas ignition while reducing emissions.

Figure 3. Gas admission valve

3.1.3 Micro pilot injection

The M450 engine uses micro pilot injection to ignite the fuel gas during gas mode, shown in Figure 4. The electronically controlled MPI system has 1800bar pressure common rail and meanwhile its minimum injection quantity reaches to 1% of MCR fuel, ensuring successful ignition of gas while reducing emissions.

Figure 4. Micro pilot injector

3.2 Electronic control system

The electronic control system developed by CPGC (concept shown in Figure 5) is another critical component in the M450 series engine. Utilizing advanced electronic control technology, this system enables precise parameter control, improving engine performance and reducing emissions for enhanced environmental friendliness.

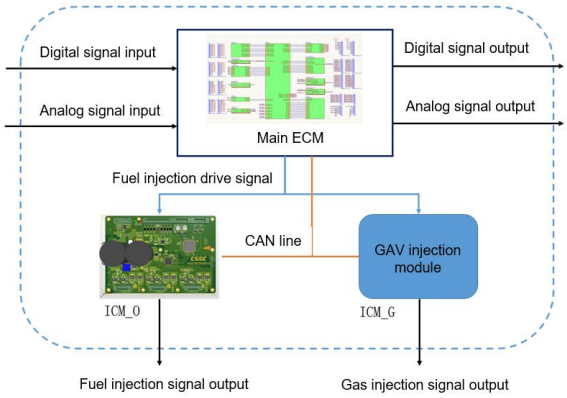

Figure 5. Electronic control system

3.3 The compact U-Flow cylinder head

The compact U-Flow intake and exhaust design design is a unique feature of the M450 series engine's cylinder head. These two features play a key role in improving the engine performance and efficiency.

This design (see Figure 6) facilitates smooth air entry into the cylinder and aids in effective exhaust gas discharge and ensures high combustion efficiency.

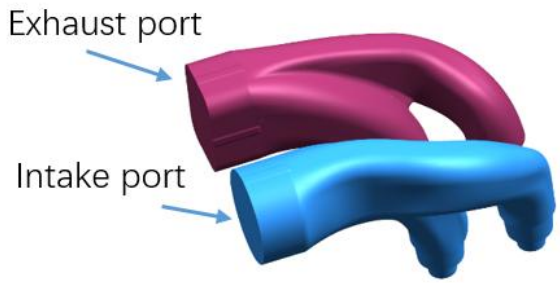

Figure 6. U-Flow intake and exhaust ports

3.4 Cylinder liner

The replaceable cylinder liner and detachable water jacket (see Figure 7) simplify maintenance and significantly enhance serviceability, contributing to reduced downtime and maintenance costs.

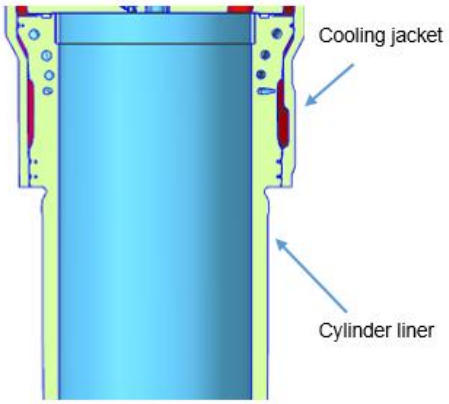

Figure 7. Cooling jacket and cylinder liner

3.5 Turbocharger

The turbocharger, a crucial part of the engine's turbocharging system, provides the required high boost pressure, thereby improving engine performance and efficiency. For the 450 series engine, a high-pressure ratio (5.53) and high-efficiency turbocharger has been selected (see Figure 8).

Figure 8. Turbocharger

In addition, the two engine layouts with turbochargers on the free end and the driving end of the engine provide greater flexibility for the M450 series engines allowing them to easily meet diverse applications requirements.

4 INTEGRATED PUMPS

An engine advanced design concept integrates high and low-temperature water pumps, lubricating oil pumps, micro-pilot injection high-pressure pumps, and the lubricating oil filter into a single unit. This integration makes the engine more compact, efficient, and easier to maintain, offering an improved solution for various application scenarios.

5 GENERALIZED DESIGN

The generalization coefficient refers to the interchangeability and compatibility between different parts or components. Increasing this coefficient allows designers to reduce model-specific or configuration-specific parts, thereby lowering production costs, simplifying supply chain management, and enhancing maintenance and replacement convenience. The 450 series medium-speed engines encompass numerous variant design categories, presenting a significant challenge to designers. When dealing with changes in cylinder numbers and fuel types, increasing the "generalization" coefficient of parts becomes particularly crucial. This engine series employs a common design for parts across multiple models, reducing manufacturing costs and improving maintenance convenience. This design concept helps lower operating costs and enhance engine durability and reliability, ultimately providing greater economic benefits to users. Table 2 details the generalized design classification of 450 series engines.

Table 2. Generalized design classification

Parts	Different fuels (diesel and diesel &LNG duel fuel engine)	Variable number of cylinders (6-9 and 12-20 cylinders)
Crankcase	Completely universal	One type for in-line and one type for V-type.
Crankshaft	Completely universal	The basic dimensions of the individual crank throws are the same.
Piston	Skirts are same; Piston crown shapes and ring land heigts differ	Completely universal
Connecting rod	Length differs, big end and small end are the same.	Completely universal
Cylinder liner	Blanks are same; Different heights of protective rings	Completely universal
Cylinder head	Blanks are the same; machining parts differ.	Completely universal
Camshaft	Blanks are the same, outline differs	Completely universal
ECU	Independent controller for micro-pilot injection in dual fuel engines	Designed to accommodate up to 20 cylinders in control module channel.

6 THE FULL-SIZE SINGLE-CYLINDER ENGINE

By the end of 2023, a full-size prototype single-cylinder engine (SCE) was constructed and began an extensive testing program. Figure 9 illustrates

the single-cylinder engine test platform, and Table 3 outlines its basic parameters.

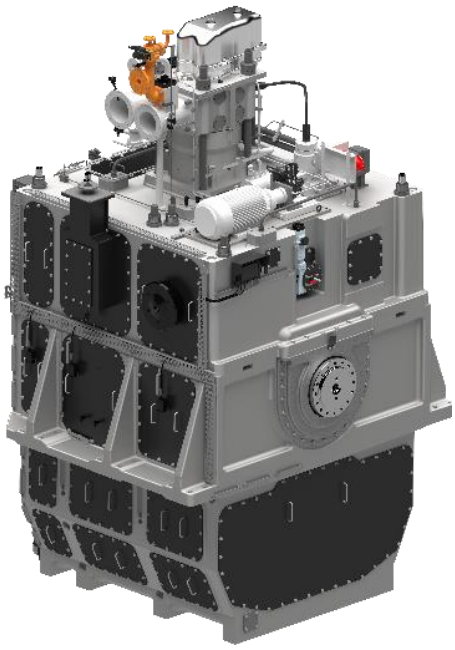

Figure 9. Single-cylinder engine

Table 3. Single-cylinder engine specification

Cylinder bore	450 mm
Design protection range of cylinder bore	320-450mm
Stroke	600 mm
Rated speed	600 r/min
Maximum designed combustion pressure	30 MPa;
Design protection coverage range of single-cylinder power	600 kW - 1300 kW
Mean effective pressure	⩾2.41Mpa
Applicable fuels	Light diesel oil, biodiesel, LNG

The SCE platform enables the following main test functions:

- New fuel testing: Various fuel development tests, including fuel system function tests and performance tests.
- Emission performance testing: Measurements of engine emission performance, such as particulate matter and nitrogen oxide emissions, to ensure compliance.
- Performance testing Evaluation of various engine performance parameters, including power, torque, and fuel consumption rate.
- Reliability testing: Durability, high and low temperature, and vibration tests on various engine components to assess their reliability and durability.
- Fault diagnosis and simulation: Simulation of various engine faults and abnormal situations, providing relevant diagnostic information for accurate fault analysis and localization.
- Optimization and improvement: Feedback on engine performance and reliability to facilitate optimization and operational improvements.

7 CONCLUSIONS

The 450 series engines offer low emissions, high efficiency, and exceptional reliability, underscored by forward-looking design concepts and strong market competitiveness. Key features include:

- Common design across multiple models: Reduces manufacturing costs and improves maintenance convenience, leading to lower operating costs and enhanced durability and reliability.
- Future-proofing: Consideration of necessary boundary conditions for future fuels and upcoming emission legislation during the R&D process, ensuring adaptability to future market needs and strong market competitiveness.
- Long life cycle: Reliable and durable characteristics provide users with long-term, stable services.
- Versatility: Powerful performance and various application scenarios have garnered wide market recognition.

In summary, the 450 series engine's low emissions, high efficiency, reliability, and durability, combined with its forward-looking design and strong market competitiveness, position it as a standout product in the shipbuilding industry.