CIMAC CONGRESS 25
ZURICH, MAY 19 – 23, 2025

2025 | 517

SCE920 - Key enabler for the roll-out of validated new technologies to largest engine sizes

New Engine Concepts & Systems

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ABSTRACT

For many decades, the approach towards the validation of technologies and their adoption on the portfolio of large two-stroke low-speed propulsion engines consisted in a sequence of steps: following the initial verification of a technology prototype on a (rather small) multi-cylinder lab engine, the concept was refined, and a first industrialised version was established to the first commercial engine. This first engine featuring the new technology, in most cases of about the same size as the lab engine, was then extensively optimised and tested up to the obtention of type approval and then directly installed on a ship. Based on the experience acquired in these first steps, the technology was then often scaled to the (larger) engine sizes in the product portfolio. However, this scaling was realised without testing on equivalently sized lab engines and the first application on even the largest engine sizes involved commercial engines, with corresponding distinct first-time-right requirements.

Obviously, this approach is associated with non-negligible risk, together with correspondingly high efforts and costs. In view of the continuously increasing demands for marine propulsion technologies, this proves to be more and more challenging as we are operating at the limits of applicability of various key technologies. The need for technological step changes imposed by the IMO’s ambition towards decarbonisation acted as additional motivation for considerable adjustments of the development approach. First milestones reached in this upgrade were the addition of two further multi-cylinder lab engines in order to be able to allocate dedicated test platforms to each of the main future fuel types, and, specifically, the SCE520. This single-cylinder engine, with a bore size similar to all the multi-cylinder test engines, allows the fast and efficient transfer of concepts and technologies to the respective platforms.

Realising such large low-speed two-stroke single-cylinder engines is associated with considerably different challenges compared with the high- or medium speed segments, where such engines have been used successfully for many years. To name only a few, the distinct dynamics associated with the high stroke-to-bore ratio and the uniflow scavenging principle require carefully elaborated solutions for controlling engine vibrations and ensuring air and exhaust flow management representative of multi-cylinder product configurations.

There have been different examples in recent years of the traditional scaling approach reaching its limits, specifically in the areas of combustion technology and piston running. This triggered extensive validation and optimisation campaigns on production engines of the largest bore size, with significant cost impact. WinGD therefore decided to invest in a largest bore single-cylinder engine, the SCE920. It involves many features of the proven X92-B and X92DF portfolio engines, and its realisation profited from the experience gained in the earlier development of the SCE520.

The SCE920 has already been applied for various tests with multiple fuels: Following initial tests in diesel operation, it has been used to explore the limits of the low-pressure DF-engine technology. It also plays a major role in the development of WinGD’s methanol technology, which was initially tested for the first time on a 500mm bore laboratory test engine, then immediately applied on the SCE920, before it is directly transferred to a 10X92DF-M engine for commercial application.

This testing of new technologies on the same bore size for the first time allows the direct rollout on largest bore engines. This opens unprecedented opportunities to faster address relevant markets with validated technologies. The SCE920 is also providing capacity for addressing any issues arising from operation of largest bore engines in the field, as well as for the further optimisation of technologies and products.

1 INTRODUCTION

For many years, WinGD has used various methods to validate new technologies in their laboratories, including the Spray Combustion Chamber (SCC), test rigs and a multi-cylinder (MCE) laboratory engine [1]. The SCC has proven to be ideal for initial investigations of combustion behaviour, such as testing of new fuels or injection components. Test rigs are used to assess the performance and the endurance behaviour of new components or systems, while the MCE lab engine allows the validation of new technologies under realistic engine conditions.

Based on the findings from lab testing, a new technology was refined, and a first industrialised version was developed for a commercial engine, typically about the same size as the MCE lab engine, i.e., with a bore of approximately 50 cm. This first engine featuring the new technology was then extensively optimised and tested until type approval was obtained, after which it was directly installed in a ship.

Based on the experience gained in these initial steps, the technology was then often scaled to larger engine sizes within the product portfolio. However, this scaling was carried out without testing on equivalently sized lab engines. The first application on even the largest engine sizes involved commercial engines, which came with distinct first-time-right requirements.

Obviously, this approach is associated with non-negligible risks, along with correspondingly high efforts and costs. Given the continuously rising demands for marine propulsion technologies, this has become increasingly challenging as we operate at the limits of applicability for various key technologies. The need for significant technological advancements, driven by the IMO's (International Maritime Organization) ambition towards decarbonization, has further motivated considerable adjustments to our development approach. The first milestones achieved in this upgrade include the addition of two multi-cylinder lab engines, allowing us to allocate dedicated test platforms for each of the main future fuel types, as well as the single-cylinder engine (SCE) SCE520 with a cylinder bore of 520 mm.

In recent years, there have been various examples of the traditional scaling approach for large bore engines reaching its limits, particularly in the areas of combustion technology and piston running. This has triggered extensive validation and optimization campaigns on production engines of the largest bore size, resulting in significant cost impacts. Consequently, WinGD decided to invest in an additional single-cylinder engine representative for the upper end of the bore size spectrum, the SCE920. A multi-cylinder lab engine of this size was deemed impractical due to high manufacturing and operating costs.

Realizing such a large low-speed two-stroke single-cylinder engine presents considerably different challenges compared to the high- or medium-speed segments, where similar engines have been successfully used for many years. To name just a few, the distinct dynamics associated with the high stroke-to-bore ratio and the uniflow scavenging principle require carefully developed solutions for controlling engine vibrations and ensuring effective air and exhaust flow management, representative of multi-cylinder product configurations. This paper describes how the technical requirements were integrated into the SCE920 design, with a strong focus on the aforementioned technical challenges.

2 INTERNATIONAL PROJECT SETUP

Shortly after the successful start of WinGD's first single-cylinder engine, the SCE520 – based on the portfolio engines X52 and X52DF – discussions about developing a large SCE began. Following the final decision to proceed, the project was officially launched in December 2021.

Thanks to the extensive experience gained during the development of the SCE520, combined with the availability of proven components and systems from the portfolio engines X92-B and X92DF, the SCE920 was developed and manufactured in just 24 months, with the first start a few days before Christmas 2023.

Another reason for the short development time was that the development team was largely the same as for the SCE520 project. It comprised experts from WinGD Switzerland and CSPI (China Shipbuilding Power Engineering Institute Co. Ltd), with dedicated project managers in both companies.

3 REQUIREMENTS

The general purpose of a lab engine is on one hand the validation of new technologies before their introduction on commercial engines, and on the other hand to explore new methods, concepts and extreme parameters that may be introduced in the coming years. Additionally, a lab engine provides testing capacity to address any issues arising from the operation of large bore engines in the field, as well as for the further optimization of technologies and products.

Based on the above, a lab engine in general, and the SCE920 in particular, must be designed to be as flexible as possible to meet future demands. One of the most important requirements is that this engine can operate with various fuels. It was developed from the outset as a dual-fuel (DF) engine, capable of functioning as a traditional diesel engine as well as in a low-pressure gas mode. Additionally, certain precautions were taken to facilitate a conversion to methanol and ammonia operation in the near future.

The principal engine parameters selected for the introduction are identical to those of the commercial engines X92-B and X92DF. This approach allowed the use of many existing structural components, helping to keep the development time short. Since the behaviour of an SCE differs slightly from that of an MCE, utilizing known parameters facilitated the adjustment of the SCE to align with the measured performance data of the well-proven customer engines. The layout of the SCE920 was based on principal parameters that are considerably higher than those of today's commercial engines. Below, the Table 1 presents both the introduction and layout parameters.

Table 1: Principal parameters (introduction; layout figures in brackets)
BMEP: Brake Mean Effective Pressure

	SCE920 diesel	SCE920 DF
Bore B [mm]	920	920
Stroke S [mm]	3468	3468
S/B ratio [-]	3.77	3.77
Power / cyl. @ R1 [kW]	6450 (8000)	5320 (5870)
Speed R3 - R1 [rpm]	70 - 80	70 - 80
BMEP [bar]	21.0 (26.0)	17.3 (19.1)
P max [bar]	200 (250)	200 (250)

If required in the future, the SCE920 must be capable of operating with principal parameters even higher than the layout figures shown in Table 1, but with a reduced bore size, for example, 820 mm, to avoid overloading the base structure.

The scavenging system must be designed to withstand pressures of up to 10 bar and to be easily adaptable to variable scavenging conditions, such as temperature, air humidity, and back pressure. Additionally, interfaces for exhaust gas abatement systems, such as Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR), need to be prepared.

An integral part of the SCE920 project was the adoption of WinGD's Variable Compression Ratio (VCR) system, based on the designs of smaller engines [2] [3]. The VCR system allows the adjustment of the compression ratio (CR) to meet actual requirements for optimal performance and reliability. For example, in WinGD's dual-fuel gas engine, it enables a higher CR in diesel mode and a lower CR in gas mode.

Thanks to the relatively simple construction of a SCE, it is possible to test new components and systems with reasonable effort. Typical activities on a lab engine include for example exploring the potential of new piston running concepts and validating new fuel injection systems.

4 SCE920 DEVELOPMENT

4.1 Component layout

As mentioned in Chapter 2, significant experience was gained during the development of the first two-stroke single-cylinder engine, the SCE520. While many components from portfolio engines can also be used for an SCE, certain areas require special attention. Most of these special solutions are necessary because an SCE has a considerably different dynamic behaviour compared to an MCE. Challenges include higher external forces and moments, less uniform engine speed over one revolution, and greater pressure fluctuations.

As with any lab engine, the SCE920 had to be designed for a wide range of applications and significantly higher loads (see also Chapter 3). However, the goal was to base the design as closely as possible on the portfolio engines X92-B and X92DF. On the one hand, the development time was relatively short, which did not allow for specific development efforts on all components. On the other hand, special manufacturing tools with unacceptably long lead times would be necessary for certain key components, such as the bearing shells.

One main difference between a test engine and a commercial marine engine is the expected running hours per year and the overall lifetime. Whereas an X92-B engine installed in a container vessel typically accumulates about 6,000 hours per year over a lifetime of up to 20 years, a test engine is expected to have a lifetime of 10 years with approximately 600 hours of running time per year. Additionally, some components that are subject to testing are replaced regularly, resulting in an even shorter lifetime. All of this allows for exceeding the well-known limits for portfolio engines to a certain extent.

In the following chapters, it is described in detail how the challenges and limitations described above were considered in the design and layout of some of the main components. A 3D representation of the CAD assembly is shown in Figure 1.

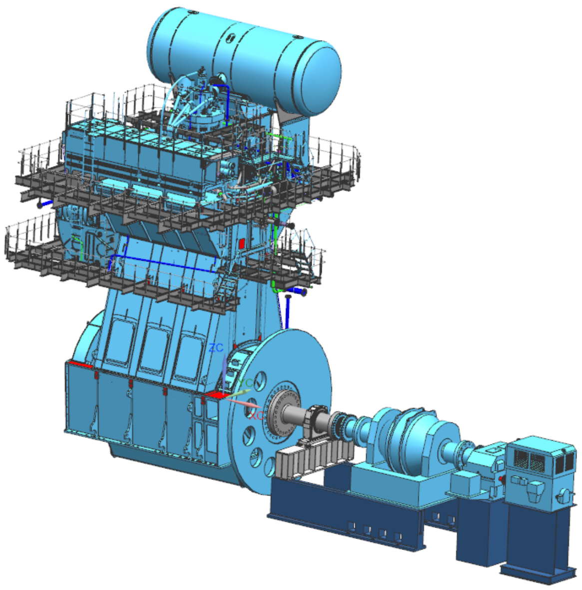

Figure 1: 3D representation of the SCE920, with the water brake, gear box, and e-motor on the right side

4.2 Engine dynamics and running gear

As mentioned in chapter 1, the development of the SCE presents unique challenges, particularly concerning the running gear. One of the primary issues is managing external forces and moments to prevent damage to the engine foundation and excessive vibrations in and around the test bed. Another challenge is maintaining the comparability of SCE results with MCE, for which a speed fluctuation target of ± 7% has been set.

To address the external forces and moments, a three-cylinder crank train was selected, implemented as in the SCE520 with a 120° 'firing order'. A crankshaft version with a 180° crank distribution was also considered as a viable alternative to limit the dynamics; however, it was ultimately discarded in the early design phase due to its static unbalance, which makes it unmanufacturable. The crankshaft design is based on the X92-B, utilizing the existing FCV1-L cranks and the standard material M60.6, with all crank pins featuring holes. Figure 2 below shows 3D views of the SCE920 crankshaft.

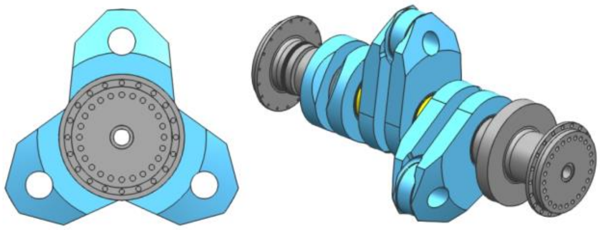

Figure 2: Crankshaft with 120° crank distribution

Table 2 below shows the external forces and moments of two SCE920 variants, both with the 120° crank distribution, in comparison with two cylinder configurations of the X92-B. SCE920 V1 follows the concept of the SCE520, with connecting rods and crossheads for all three cylinders, whereas SCE920 V2 represents the solution where connecting rods and crossheads are omitted for cylinders #1 and #3. Since the foundation has a poor load-bearing capacity in the horizontal shear direction, V2 has finally been selected; additionally, V2 offers lower manufacturing costs due to the absence of connecting rods and crossheads. However, an adapted foundation is necessary to handle the significantly larger external forces compared to the X92-B.

Table 2: External forces and moments
F = force, M = moment
h = horizontal, v = vertical
1, 2, 4 = order

	SCE920 V1	SCE920 V2	6X92-B	8X92-B
F1v [kN]	669	2569	0	16
F1h [kN]	0	199	0	16
F2v [kN]	358	1267	0	6
F4v [kN]	25	88	0	47
M1v [kNm]	9570	0	0	1308
M1h [kNm]	4670	0	0	1154
M2v [kNm]	2621	0	6906	315
M4v [kNm]	182	0	479	547

To meet the speed fluctuation requirements, a large tuning wheel on the driving end and a large flywheel on the free end were chosen, providing a total inertia of over 300,000 kgm² and a total weight of approximately 55 tons. Experience from the SCE520 development indicates that, with the standard flywheel and no tuning wheel, speed fluctuations of up to ± 20% can be expected.

The commercial X92-B engine, which served as basis, is the only WinGD engine with two different cylinder distances. The bigger one, measuring

1664 mm, was selected in the early design phase for the SCE920 because it offers a main bearing width of 440 mm, compared to 420 mm for the shorter cylinder distance, and the main bearing journal diameter measures 1120 mm instead of 1060 mm. This results in a stiffer crankshaft and main bearings with a higher load capacity compared to the smaller cylinder distance. The selection of the standard X92-B main bearing, featuring a white metal layer, was confirmed by Elasto-Hydro-Dynamic (EHD) simulation, considering the higher firing pressure. Main bearings are less loaded in the SCE since only one cylinder fires, whereas in the MCE, neighbouring cylinders can also be under high pressure, adding additional load to the main bearing between the two loaded cylinders.

The crank pin bearing uses AlSn40 material with the same dimensions as the X92-B. Unlike the series solution, the connecting rod has a trapezoidal shape with a machined cavity for better load distribution to the crank pin bearing, ensuring acceptable bearing loads even under the highest cylinder firing pressures. The crosshead bearing size was increased to a diameter of 1000 mm (X92-B: 920 mm) and a width of 998 mm (X92-B: 900 mm), with the material remaining unchanged as white metal, as AlSn40 bearings of these dimensions cannot be manufactured. Additionally, the conrod shaft diameter was increased to ensure sufficient safety against buckling.

The thrust bearing design remains the same as that of the X92-B, but with reduced clearance to axially fix the crankshaft.

4.3 Fuel injection and servo oil system

The commercial X92-B and X92DF engines feature WinGD's proprietary Injection Control Unit (ICU) to precisely control the timing and quantity of injected liquid fuel. The ICU is mounted directly on the fuel rail inside the rail unit box and enables individual control of the three conventional fuel injection valves per cylinder. Hydraulic simulations were performed to assess its usability on the SCE920, which has significantly higher cylinder power and, consequently, a greater injected fuel quantity per cycle. Fortunately, this was confirmed, requiring only a minor adaptation to the filling bore.

The changes to the exhaust valve drive are more significant. To accommodate the increased maximum cylinder pressures of the SCE920 compared to the commercial 92 cm bore engine variants, it was necessary to increase the servo oil pressure from slightly above 200 bar to 300 bar. As a result, the so-called Valve Control Unit (VCU) required some reinforcements and adaptations.

Some adaptation to the characteristics of a single-cylinder engine was also necessary for both the fuel and servo oil rails: a considerable increase in volume compared to the per-cylinder volume of a commercial engine. This increase was required to limit pressure fluctuations in the rails – caused by fuel injection and exhaust valve operation – to a level similar to that of commercial engines, ensuring comparable operating behaviour. Simply increasing the rail diameter was not possible, as the existing expensive machining tools for drilling the bore had to be used. Based on calculations, the fuel rail volume is determined to be 48 litres, while the servo oil rail volume is 120 litres. After determining the rail volumes, the design must balance available installation space and manufacturing capabilities. The calculated dimensions are listed in Table 3, and the selected arrangement is shown in Figure 3.

Table 3: Rail design parameters

	Fuel rail	Servo oil rail
Volume (l)	48	120
Inner diameter [mm]	70	145
Length [m]	12.5	7.3

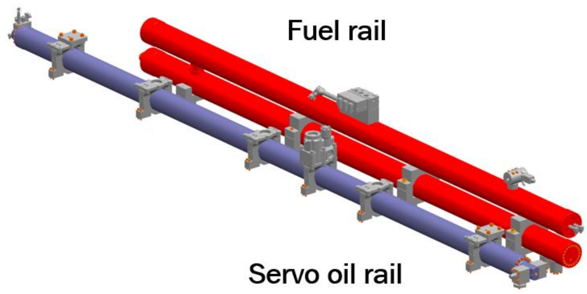

Figure 3: Fuel and servo oil rails

The solution for the fuel and servo oil supply is basically the same as that for the SCE520. In contrast to the commercial engines, where the respective pumps are driven from the crankshaft via a set of gear wheels, a solution with an e-motor drive has been selected. This allows more flexible operation of the pumps, and the expensive gear wheels could be omitted. Naturally, the number of fuel pumps and the size of the servo oil pumps had to be adapted to the higher power of the SCE920 compared to the SCE520. See Figure 4.

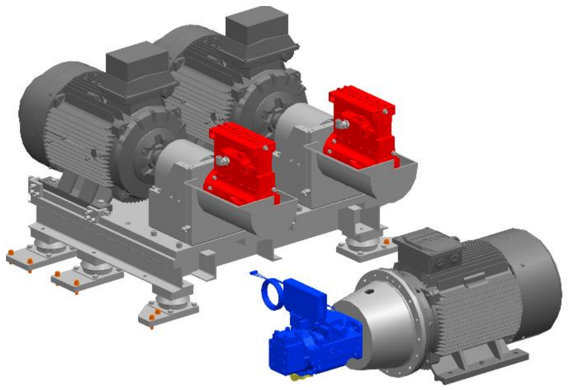

Figure 4: Fuel (red) and servo oil pumps (blue) with e-motor

Based on the design parameters, one-dimensional simulation calculations were conducted for the servo oil system and the fuel injection system.

For the 100% engine load case, the pressure curves for fuel rail and servo oil rail are shown in Figure 5 and Figure 6 below. Calculations show that if the single-cylinder power is 6450 kW, the fuel rail pressure drop is 7.3 %, and at 8000 kW, it increases to 8.9 %. The servo oil rail pressure drop is 10.7 %. These values are comparable to those of commercial multi-cylinder engines and therefore fall within the SCE920 specification.

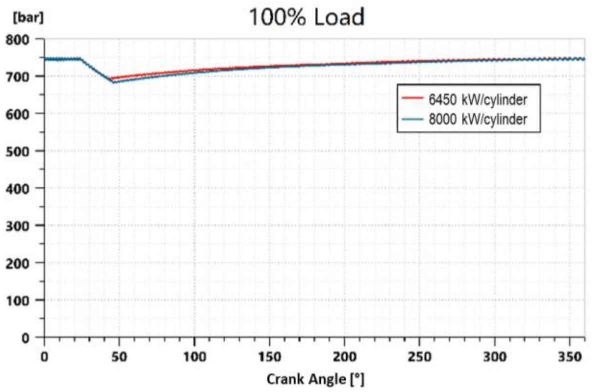

Figure 5: Fuel rail pressure curve

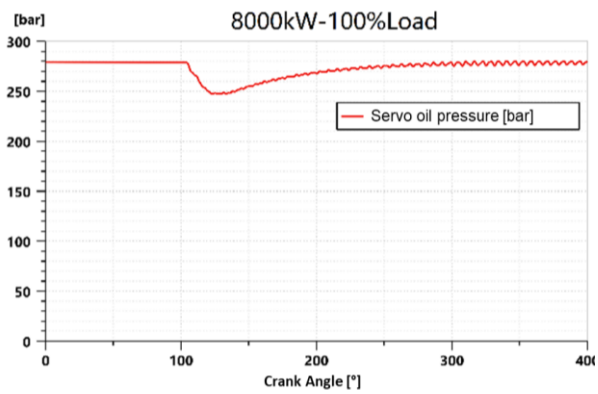

Figure 6: Servo oil rail pressure curve

4.4 Scavenge system

The cylinder jackets of WinGD's commercial engines are always made of grey cast iron as it offers the best compromise between manufacturing friendliness, cost, and required stiffness. A cast construction is also used for the SCE920, whereas the cylinder jackets of other test engines were made from welded construction due to the one-time production. The procurement of a top plate being over 300 mm thick, and the challenges associated with the welding of such very thick steel plates were seen as too big. Therefore, the proven casting technology was ultimately selected.

To limit pressure fluctuations in the scavenge air receiver and the exhaust manifold, their relative volumes are significantly larger compared to the respective commercial engines, X92-B and X92DF. With the selected designs, the targeted pressure fluctuations of the commercial engine – 0.1 to 0.15 bar for the scavenge air receiver and 0.2 to 0.3 bar for the exhaust manifold – can be achieved. The scavenge air receiver is designed in two parts along the entire length of the cylinder jacket and is bolted to the cylinder jacket similar to commercial engines. The exhaust manifold is positioned as usual but features an enlarged diameter and extends over the length of three cylinders. See Figure 7.

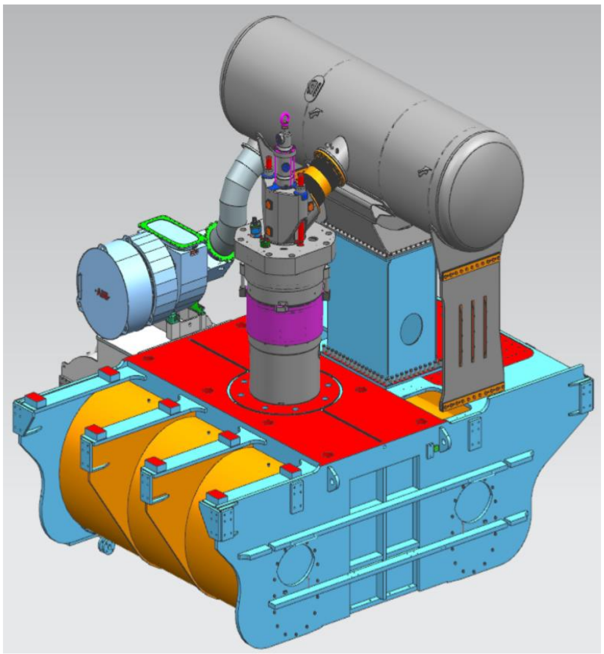

Figure 7: Cast cylinder jacket with attached scavenge air receiver on fuel and exhaust side; size-adjusted exhaust manifold

4.5 Super-charging system

The design of the supercharging system is one of the core tasks in the development of the SCE920 which shall be operated in the future with different fuel types at various rating points and conditions. The design must balance the total cost of the equipment, operational energy consumption, and the expected performance of the supercharging system. It must also meet the requirements for ratings of up to 8,000 kW. Additionally, a high degree of flexibility is required to allow the operation of the single-cylinder engine in different modes, such as cold start or transient load variation, without any hardware modifications during testing.

The concept diagram of the supercharging system for the SCE920 is shown in Figure 8. The supercharging system is capable of quickly switching between operation with the turbocharger only and operation with the turbocharger combined with an Electric Charging Blower (ECB). Several shut-off and adjusting valves are implemented in the supercharging system. On the one hand, they allow an easy adaptation to different test scenarios. On the other hand, they help to protect the turbocharger against overspeed and surging. For instance, a Cylinder Bypass Valve (CBV) is provided to create a flow path between the scavenge air receiver and the exhaust manifold, maintaining airflow to the compressor during sudden engine stops, which occur frequently in a test engine.

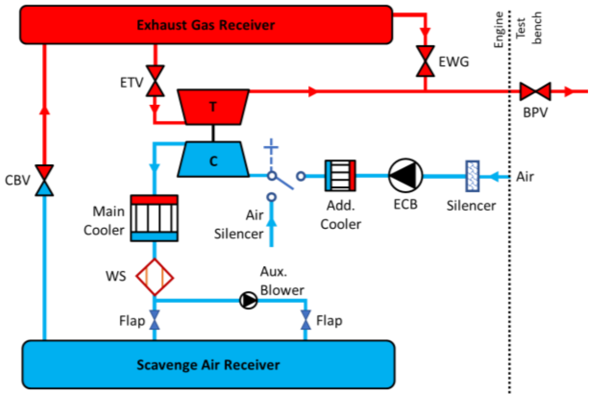

Figure 8: Concept diagram of the super-charging system
CBV: Cylinder Bypass Valve
ETV: Exhaust Throttle Valve
EWG: Exhaust Waste Gate
BPV: Back Pressure Valve
ECB: Electric Charging Blower
WS: Water Separator

4.6 Combustion chamber components

The combustion chamber components are very similar to those of the commercial X92-B and X92DF engines. Most adaptations were necessary due to the higher maximum firing pressure of the SCE920 test engine. The changes are relatively minor, as the reduced safety margin due to the increased firing pressure can be accepted in many areas due to the limited running hours of a test engine, as described in chapter 4.1.

Those adaptations are as follows:

- The cylinder cover features a thicker and larger flange, which is adapted to the larger cylinder cover studs (8 times M125 instead of M110).
- The exhaust valve cage is fixed with larger studs (2 times M110 instead M100). Additionally, it has an adapted valve drive for the higher servo oil pressure of nominal 300 bar, compared to 200 bar of the commercial engines.
- The outer shape of the cylinder liner remains unchanged; however, the scavenge ports and the anti-polishing ring have been modified to accommodate a wider range of compression ratios.

A cross-section view of the combustion chamber components (diesel version) is shown in Figure 9.

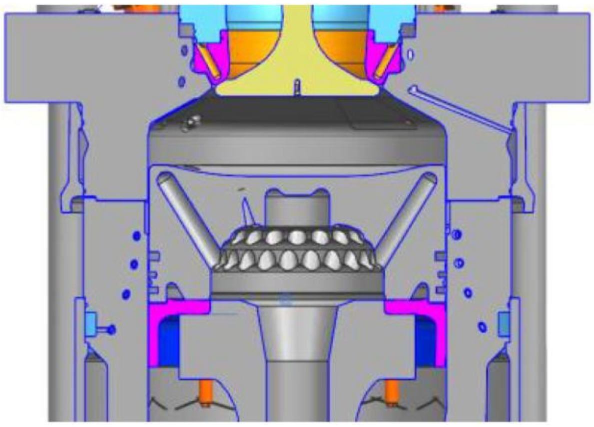

Figure 9: Cross-section of combustion chamber components

4.7 Engine structure

The engine structure design is fundamentally based on the multi-cylinder X92-B, utilizing the same steel plate thicknesses and steel cast girders. Despite the significantly increased firing pressure, a Finite Element (FE) analysis showed that the loads on the weld seams, steel plates and girders are within acceptable levels as the structure of the middle section, with its firing cylinder, is supported by the column and bedplate of the neighbouring sections. See Figure 10.

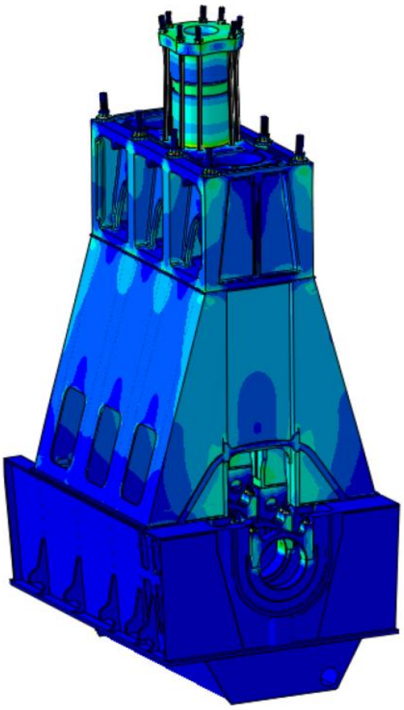

Figure 10: FE model of column and bedplate (load case: cylinder cover bolts, main bearing bolts and tie rods tightened)

Some adaptations were necessary at both ends of the bedplate and column as the standard flywheel and the turning gear were moved to the free end, while a large tuning wheel is installed on the driving end.

4.8 Starting and braking

WinGD's commercial two-stroke marine engines are equipped with an air starting system. Compressed air at a pressure level of approximately 30 bar is injected into each cylinder through electronically actuated valves. This is sufficient to overcome the resistance torque caused by the friction of the bearings, piston rings and gear wheels, as well as the shafting and propeller of the vessel.

However, for single-cylinder engines, the imbalance caused by gravity is significant. Without external forces, the rotating and moving parts of the engine will automatically return to a position 120° away from top dead centre (second cylinder). For a pneumatic starting system, this position is far from ideal. Either a very powerful starting air system would be needed to overcome the maximum torque of up to 630 kNm caused by the imbalance; or the crankshaft would need to be positioned in a more favourable position using the turning gear before each engine start. These options were discarded, and considering cost, flexible starting, technical maturity, and testing requirements, an e-motor-driven starting system was specifically designed, as illustrated in Figure 11. A conventional water brake is used to absorb the produced power, just as in the test bed operation of commercial engines. A clutch is provided to disconnect the gearbox and the e-motor from the drivetrain during SCE920 operation.

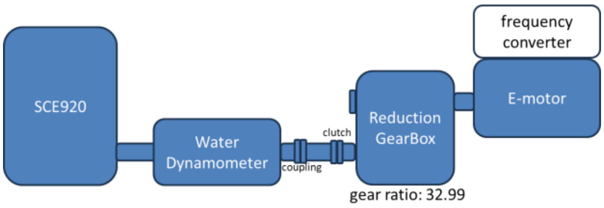

Figure 11: Schematic of drivetrain with water brake, gear box and electro-starter-motor

During the starting sequence, the e-motor, controlled by a frequency converter, is brought to the ignition speed of 45 rpm within approximately 60 seconds. The engine's electronic control system keeps the exhaust valve open until the ignition speed is reached, minimizing total resistance torque; the water brake operates at 'no load.' Once the ignition speed is reached, the exhaust valve begins to open and close, and shortly afterwards, fuel is injected into the cylinder. The clutch is disengaged to prevent damage to the gearbox or e-motor.

4.9 VCR

WinGD's design concept for a Variable Compression Ratio (VCR) system was presented to experts at the CIMAC Congress 2019 in Vancouver, Canada [2], and the latest update will be introduced during the CIMAC Congress 2025 in Zürich, Switzerland [3]. Therefore, the description in this paper is intentionally kept brief.

A VCR system allows to adjust the position of the piston during engine operation to vary the compression ratio (CR). The CR directly influences the combustion behaviour and the thermal efficiency of the engine. With a VCR, the best possible CR can be selected for various conditions, such as gas or diesel mode operation, for different engine loads, or varying ambient conditions.

WinGD's VCR system continuously adjusts the CR using a hydraulic piston located in the crosshead pin, which moves the piston rod vertically. See Figure 12. The hydraulic chamber in the crosshead pin is supplied with system oil via a separate knee lever. By adjusting the oil feed rate, the piston can be moved upwards or held in position. If the oil supply is reduced, the piston gradually moves downwards due to a small, intentional leakage rate from the hydraulic chamber.

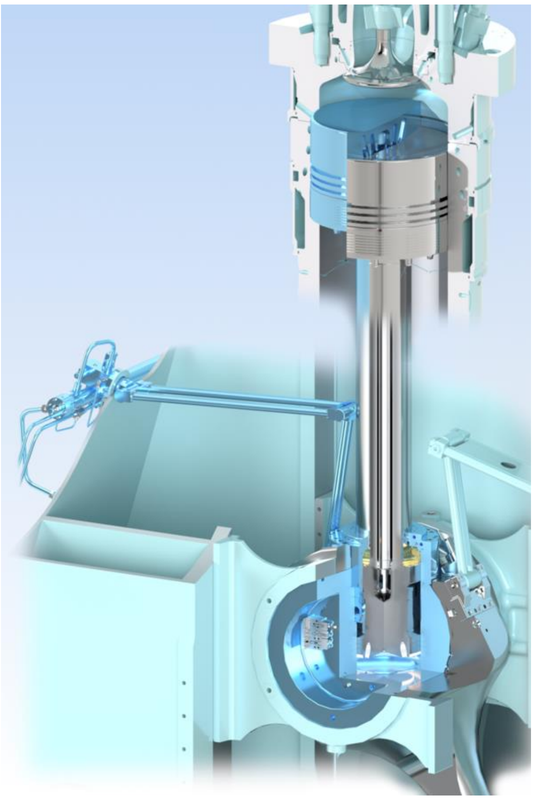

Figure 12: 3D view of the VCR system

The CR is automatically adjusted by the engine control system WiCE (WinGD integrated Control Electronics). The ‘stepless’ control allows the optimization of the performance at part load without compromising the efficiency at high or full load.

The first VCR systems were developed for the X62DF and X62DF-S engines, followed by the X72DF. A field test on a RT-flex50DF has been ongoing since late 2024, and in January 2025 the very first WinGD engine equipped with a VCR system, a 6X62DF-2.1, has successfully passed its Type Approval Test (TAT) at the Japanese engine builder MESDU. The VCR developed for the SCE920 will be tested in mid-2025, and with minor modifications it can be applied later to the commercial X92DF engines.

5 TESTING EXPERIENCE

5.1 Diesel and gas operation

After the initial start at the end of 2023 and the completion of the commissioning of the engine and its ancillary systems, the first testing phase focused on diesel operation at a maximum BMEP of 21.0 bar, corresponding to the R1 rating point of the X92-B. This initial testing was crucial to tune the SCE920 as closely as possible to the X92-B engine and to identify the inevitable differences between the SCE and MCE. After several weeks of intensive testing, the SCE920 was converted to the gas DF version, and the same tuning optimization was done as for the diesel version. This initial testing is essential for establishing a solid foundation for subsequent tests. Figure 13 shows the SCE920 on the testbed at engine builder CMD (CSSC-MES Diesel Co., Ltd.) in Shanghai, China.

Figure 13: The SCE920 on its testbed

The measurements confirmed that the layout of the SCE920 was correctly done. As expected, speed fluctuations are more pronounced in the single-cylinder engine compared to the corresponding multi-cylinder engine. The measured fluctuation on the SCE920 was in the range of ± 5 rpm, which is within the targeted limit of ± 7 %, whereas it is negligible on the X92-B and X92DF engines. Other fluctuations, such as dynamic fuel command, servo oil pressure, and scavenge air pressure are also more pronounced on the SCE920, as shown in Figure 14. However, all of these parameters are well within the specified limits and do not negatively affect the performance of the SCE.

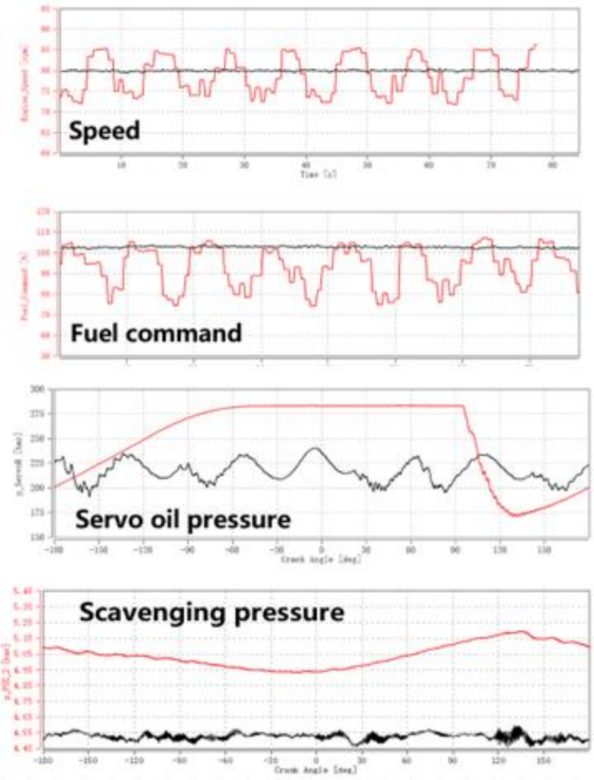

Figure 14: Comparison of fluctuations between multi-cylinder (black) and single-cylinder (red) engines

The fuel rail pressure directly affects the driving characteristic of the ICU and consequently the behaviour of the fuel injection valves. Therefore, significant attention during the SCE920 testing was given to examining the fluctuation characteristics of the fuel rail during the injection phase. The experimental data for a representative load condition is shown in Figure 15. The pressure curves of the three fuel injection valves demonstrate that the fuel injection pressure can be kept almost constant throughout the entire injection phase, while the pressure in the fuel rail drops by approximately 12 %. The corresponding curves for a commercial X92-B engine are very similar.

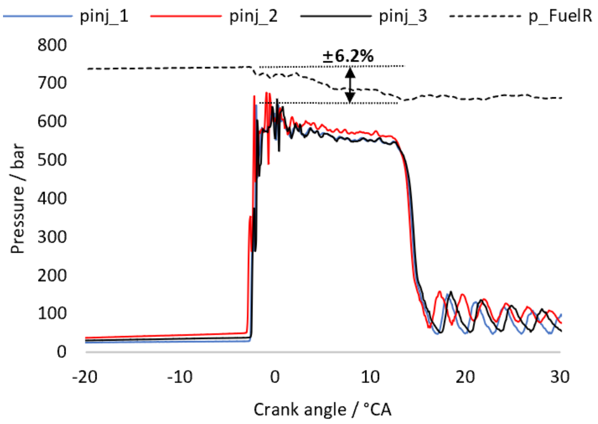

Figure 15: Injection pressure and fuel rail pressure curves

After the initial tests in diesel and gas mode, the SCE920 was ready for its first full-scale testing campaign, as described in the next chapter.

5.2 Methanol operation

In 2021, WinGD began developing new fuel injection systems for ammonia and methanol, as described in two separate papers [4] [5]. Today, both fuels are primarily produced from fossil raw materials. However, if they are produced in a CO_2-neutral manner in the future, they could help to transition the marine sector toward climate neutrality.

The first commercial order for a methanol engine happened to have a 92 cm bore size – a 10X92DF-M. Therefore, the SCE920 was the perfect fit for testing the new technology before its implementation on the first customer engine. A dedicated test rig was also established to validate the main components of the methanol injection system in a cost-efficient manner before the operation on the SCE920 began.

The methanol conversion of the SCE920 began in mid-2024, following a development and manufacturing period of approximately six months. Methanol operation then commenced in early October 2024. The main objectives of these tests were:

- Conducting performance and hydraulic measurements to confirm or refine simulation results
- Validate the control system and making necessary corrections
- Assessing the safety concept (e.g., the purging of the entire methanol system)
- Gaining initial insights into the reliability of the methanol injection system in real engine operation

During testing, the SCE920 quickly achieved 100% load in methanol mode with stable combustion and highly promising performance. The methanol energy share was approximately 95%, as predicted, with a minimum injection duration of the ICU system, which is used to pilot the methanol combustion. The test results demonstrate that the ICU design can precisely inject both the smallest fuel amounts for pilot injection in methanol mode – even at low engine loads – and large fuel amounts in diesel mode.

Figure 16 below compares the cylinder pressure and heat release curves between diesel and methanol modes at full engine load. The methanol curve shows a faster heat release rate compared to the diesel curve. This, along with lower compression and firing pressures, indicates the superior efficiency of the methanol mode.

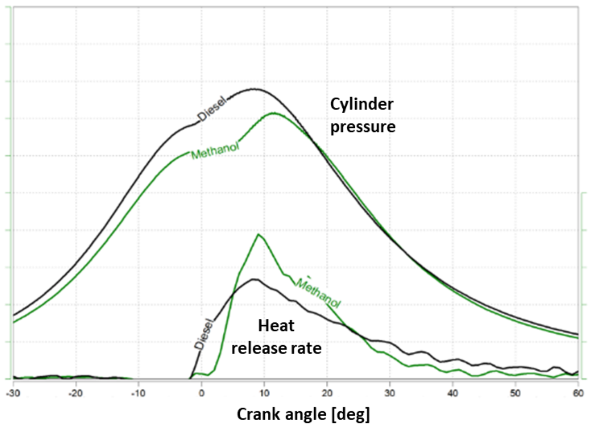

Figure 16: Comparison of cylinder pressure and heat release curves for diesel (black) and methanol (green) modes

The exhaust gas temperatures in methanol mode are significantly lower than in diesel mode, ranging from -30°C to -60°C (see Figure 17). This reduction is due to the better engine efficiency in methanol operation.

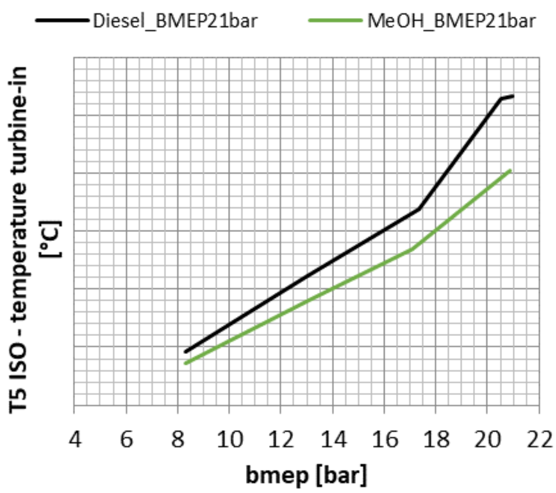

Figure 17: Comparison of the exhaust gas temperatures before turbocharger turbine between diesel (black) and methanol (green) mode

After about two months of methanol operation on the SCE920, prototype testing of the 10X92DF-M began at CMD. Since extensive testing had already been conducted on the SCE920 – including nozzle tip pre-selection, pilot fuel parameter optimization, and tuning of injection and exhaust valve timing – the 10X92DF-M test program could be relatively short. Over approximately two months, the findings from the SCE920 were largely confirmed, culminating in the successful completion of the Factory Acceptance Test and the Type Approval Test.

5.3 Testing outlook

As explained in the previous chapter, testing of the first 10X92DF-M proceeded very smoothly and successfully. However, optimizing a new technology is an ongoing process. In the weeks after finalizing this paper, additional tests are planned to gain a deeper understanding of the methanol fuel injection system and combustion process. This will help to further optimize not only the X92DF-M engines but also methanol engines of other bore sizes which are already in WinGD's order book.

The next major test phase will focus on the X92DF gas engine. By equipping the SCE920 with the newly developed VCR (see Chapter 4.9), WinGD's Exhaust Gas Recirculation (EGR) system, known as 'iCER' (intelligent Control by Exhaust Recycling) [6], and other optimized components, the goal is to explore further optimizations of the X-DF, particularly in reducing methane slip and improving fuel consumption in both gas and diesel operation.

Further tests will explore the limits of diesel, gas, and methanol engines – for example, by increasing the Brake Mean Effective Pressure (BMEP); introducing the ammonia fuel injection system to the largest engine sizes, and validating solutions for issues encountered in the field.

6 CONCLUSIONS

After identifying the need for a large test engine, the SCE920 was developed and manufactured in just 24 months, thanks to the experience gained during the earlier development of the SCE520 and the close cooperation between WinGD and the engine builder CMD. The demand for a large engine test platform arose primarily from the fact that typical test engines have bore sizes around 520 mm, but certain technical challenges become significantly more pronounced in large-bore engines with bore sizes exceeding 800 mm.

During the first test campaign, the SCE920 was initially commissioned and then tuned to perform as similarly as possible to the respective commercial engines, the X92-B and X92DF. After a few months, this initial phase was successfully concluded and the SCE920 war ready for its real purpose.

In the summer of 2024, the SCE920 was prepared for its first full-scale test campaign by being converted into a methanol test engine. The newly developed methanol injection system, which had already undergone extensive testing on a dedicated test rig, was then tested on the SCE920 before its first installation on a customer engine, a 10X92DF-M. The short and smooth testing of WinGD’s first commercial methanol engine impressively demonstrates the advantage of having an equally sized test platform for the validation of a new technology before its market introduction.

Further tests of the methanol concept are planned for the first quarter of 2025 to fine-tune and optimize the system. Afterwards, the newly developed VCR system for the 920 mm bore engines will be installed on the SCE920. Upon validation, it will simplify testing activities by enabling the compression ratio to be adjusted during engine operation, a process that typically requires several hours.

The testing possibilities for the coming years are manifold and have not yet been explored in detail. It is expected that the ammonia fuel injection system will be validated on the SCE920 once it is developed for the largest bore WinGD engines. Other new components, systems or technologies will also undergo validation on the SCE920 once they reach the appropriate maturity level.

If in future any issues arise from the operation of large engines in the field, WinGD will have a test tool available that allows a fast and cost-efficient root cause analysis and the validation of countermeasures before their implementation on customer engines.

7 ABBREVIATIONS

BMEP: Brake Mean Effective Pressure

BPV: Back Pressure Valve

CBV: Cylinder Bypass Valve

CMD: CSSC-MES Diesel Co., Ltd.

CR: Compression Ratio

CSPI: China Shipbuilding Power Engineering Institute Co. Ltd

DF: Dual Fuel

ECB: Electric Charging Blower

EGR: Exhaust Gas Recirculation

EHD: Elasto Hydro-Dynamic (simulation)

ETV: Exhaust Throttle Valve

EWG: Exhaust Waste Gate

FE: Finite Element (analysis)

iCER: intelligent Control by Exhaust Recycling

ICU: Injection Control Unit

IMO: International Maritime Organization

LNG: Liquified Natural Gas

MCE: Multi-Cylinder Engine

SCC: Spray Combustion Chamber

SCE: Single-Cylinder Engine

SCR: Selective Catalytic Reduction

VCR: Variable Compression Ratio

VCU: Valve Control Unit

WiCE: WinGD integrated Control Electronics

WS: Water Separator

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