Efficient propulsion for seagoing vessels

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1 Introduction

Efficient propulsion can be defined as to consume minimum amount of fuel and oil for a defined ship speed and cruising distance. At the same time, the ship shall generate minimum emissions such as CO_2, NOx, SOx and combustion particles.
The following parties are involved in this process:

- Shipyard / ship designer as responsible party for the hull shape e.g. power need for a defined ship speed.
- Engine designer as responsible party for the efficiency of the power generating machinery.
- Propulsor designer as responsible party of propulsor equipment.

These parties must respect a good economy when proposing efficiency improvements.

2 The electronically controller RT-flex common rail engine

Instead of the usual mechanically-controlled fuel injection pumps and exhaust valve drives of Wärtsilä RTA engines, the RT-flex engine has an electronically-controlled common-rail system in which fuel oil and servo oil are delivered at regulated pressures to rail pipes arranged in a rail unit along the side of the cylinders. Heated fuel is delivered. Ready for injection, at pressures up to 1000 bar. Servo oil is drawn from the engine lubrication system through an automatic self-cleaning fine filter and delivered at pressures up to 200 bar.
Fuel injections and exhaust valve operation are controlled by individual control units for each cylinder. The control units are directly mounted on the single-piece rail pipes and are controlled using servo oil through Wärtsilä electro-hydraulic rail valves.
Fuel oil and servo oil are supplied to the common-rail system from the very compact supply unit mounted on the side of the engine. The supply unit is driven through gearing from the crankshaft and is equipped with a number of fuel supply pumps, the number of pumps depending upon the number of engine cylinders and power output. The fuel supply pumps make several strokes during each crankshaft revolution owing to the drive gear ratio. Fuel delivery volume and rail pressure are regulated through suction control of the fuel supply pumps. The servo oil pumps are also incorporated in the supply unit.
All RT-flex functions are governed by the Wärtsilä Engine Control System (WECS) which triggers the electro-hydraulic rail valves for the respective functions. The master input comes from the crank angle sensor which delivers the absolute crank position. WECS communicates directly with the ship's machinery control system.
Reliability and safety has the utmost priority in the RT-flex system. There is also extensive duplication in the system for redundancy, in the supply pumps, main delivery pipes, crank angle sensor, electronic control units, etc.
By allowing injection pressures and timing to be optimised at all loads, RT-flex common rail engines offer reduced fuel consumption below 90% engine load compared with conventional camshaft type engines.
The RT-flex system gives important benefits in environmental compliance. The most obvious is the smokeless operation of RT-flex engines at all engine speeds. The flexibility of the RT-flex system allows a low NOx operating mode with 15 – 20% reduced NOx emissions.
RT-flex engines are able to run very stable at very low speeds, slower then camshaft-type engines. They can run without smoking at 10 – 12% nominal speed. This is made possible by a precise control of injection, optimised injection pressure, optimised valve timing and shutting off individual injectors at low speeds.

3 Waste heat recovery for reduction of fuel consumption and emissions

Waste heat recovery is the only technology commercially available today that provides both lower fuel consumption and lower exhaust gas emissions, including CO_2 and NOx. With today's modern low-speed engines having an excellent thermal efficiency of up to 50%, there is still 50% of the fuel input energy not put to productive use. Improved utilisation of fuel energy results in both lower fuel costs and lower emissions. The high-efficiency WHR plant can recover more then 11% of the engine shaft power. Exhaust gas energy is recovered and applied in both a steam turbine and exhaust-gas power turbine to generate electrical power, equivalent to more then 11% of engine power. The electrical power can be employed either in a shaft motor to aid propulsion or in supplying shipboard services.

The high-efficiency WHR plant consists of a dual-pressure economiser, a multiple-stage dual-pressure steam turbine, a power turbine, an alternator driven by both the steam turbine and the power turbine and a shaft motor/alternator system.

The power turbine uses a part of the exhaust gas steam from the diesel engine before turbochargers to generate shaft power which can be added to the steam turbine driving the generator.

The exhaust gas economiser consists of a high-pressure part with HP evaporator and superheating section and a low pressure part with LP evaporator and superhating section. The pressure in the high pressure steam drum is about 9.5 barg and about 3.5 barg in the low pressure steam drum. The economiser outlet temperature is not les then 160°C to avoid sulphur corrosion and excessive fouling in the economiser outlet. Saturated steam is drawn from the HP steam drum for ship service.

A dual-pressure steam turbine running at about 6750 rpm is used. The high pressure side works at about 8 – 9 barg inlet pressure. The low pressure side works at about 3 – 3.5 barg inlet pressure. The condenser pressure is 0.065 bar. A speed-reduction gear between steam turbine and generator reduces the turbine speed to 1800 rpm generator speed.

The power turbine uses a part of the exhaust gas stream before turbochargers (about 10%) from the diesel engine to generate shaft power which can be added to the steam turbine driving the generator. The turbine is a derivative of a well-proven model of turbocharger turbine. The torque of the power turbine is fed to the steam turbine rotor through a reduction gear and an overrunning clutch.

The shaft motor/alternator is of the low-speed type, directly mounted in the propeller shaft line. It operates on variable electrical supply frequency. A frequency control system controls the frequency to and from the electrical supply. The system operates on 6’600 V. It is arranged to operate either as a motor or an alternator. In the motor mode, it uses surplus electric power generated by the turbogenerator to support propulsion. The motor function is also used as a booster to increase ship speed if needed. In the alternator mode, it generates electric power for ship service in case the engine load is low and the turbogenerator does not generate enough power.

The payback time of the complete high efficient WHR plant is expected to be less the 5 years, depending on heavy fuel price.

4 The electronically controlled Wärtsilä Puls cylinder lubricating system

The Wärtsilä Puls Cylinder Lubricating system enables a much lower lubricating oil feed rate than previous systems while improving the distribution of cylinder lubricating oil on the running surface of the cylinder liner.

The Puls Lubricating System features precise, electronic control of feed rate and timing with full flexibility in settings. It involves the spraying of cylinder lubricating oil as jets on to the liner surface from a single row of quills arranged around the liner, each quill having a number nozzle holes. The oil jets are individually directed to separate, evenly distributed points on the liner surface. There is no atomisation and no loss of lubricating oil to the scavenge air.

5 The Wärtsilä Tip Rake Propeller and Efficiency Rudder

With the Wärtsilä Tip Rake Propeller an efficiency gain of 2 – 3% is possible while reducing at the same time the pressure pulses by about 10%.

The Wärtsilä Efficiency Rudder developed in co-operation with Becker Marine Systems consists mainly of a rudder bulb and an asymmetric rudder profile. It reduces the drag and therefore improves the efficiency by about 5%. It also reduces rudder cavitation due to better alignment of the flow behind the propeller.

Heinrich Schmid was born 1947 in Winterthur, Switzerland. He joined the Sulzer Diesel Division in 1973 and worked in several positions in the two-stroke Diesel Engine Division. Today he is General Manager for Application Development for Wärtsilä two-stroke engines