JOURNAL OF MARITIME RESEARCH

Vol XXIII. No. I (2026) pp 243–246

ISSN: 1697-4840, www.jmr.unican.es

Application of Hybrid Turbochargers Onboard Ships

Hare Ram Hare[1,*], Vikash Sinha[2], Nakshatra Sah[3], Anushka Bhardwaj[4]

ARTICLE INFO

Article history:
Received 30 Apr 2025;
in revised from 01 Aug 2025;
accepted 30 Aug 2025.

Keywords:
Hybrid turbochargers, alternator, auxiliary blowers, lower fuel consumption.

ABSTRACT

As all global industries are pushing towards net zero emissions, sustainable energy production plays a vital role. In the maritime domain, hybrid turbochargers can help in achieving this objective. Hybrid turbochargers are waste heat recovery devices that utilize the exhaust gas from the main propulsion engine to rotate the turbine and on the other end of the turbine shaft, there is an alternator. This reduces the fuel oil consumption of the auxiliary engines which are the prime movers for the alternators as now some portion of the electricity requirements is served by the turbo alternator. Also, it eradicates the use of auxiliary blowers that have to be used for the starting of the engines. Therefore, the use of hybrid turbochargers leads to lower fuel consumption, lesser cost of electricity generation and lower emission levels.

1. Introduction.

Electricity usage and generation on ships is essential for powering various systems and ensuring safe and efficient operations. Ships employ a combination of generators, often fueled by diesel or gas turbines, to produce electrical energy. This electricity is used for propulsion, lighting, navigation, communication, refrigeration and many other applications. Advanced ships may also integrate renewable energy sources like solar panels and wind turbines to reduce fuel consumption and emissions [1-4].

[1]Assistant Professor, Department of Marine Engineering, Indian Maritime University, Mumbai Port Campus, Email: hareram@imu.ac.in.

[2]Faculty, Mechanical Engineering, Department of Marine Engineering, Indian Maritime University, Mumbai Port Campus, Email: vikashsinha.mpc.ctf@imu.ac.in.

[3]Cadet, B.Tech (Marine Engineering), Department of Marine Engineering, Indian Maritime University, Mumbai Port Campus, Email: nakshatrasah63@gmail.com.

[4]Cadet, B.Tech (Marine Engineering), Department of Marine Engineering, Indian Maritime University, Mumbai Port Campus, Email: anushkabhardwaj1809@gmail.com.

[*]Corresponding author: Hare Ram Hare. E-mail Address: hareram@imu.ac.in.

2. Electricity generation onboard ships.

Electricity on ships can be generated through various methods, depending on the size, type of ship, and its specific requirements. Here are the primary ways in which electricity is generated on ships:

- **Diesel Generators**: Diesel generators are the most common and versatile method for electricity generation on ships. They run on diesel fuel and can range in size and number depending on the ship's power needs.

- **Gas Turbines**: Large and fast vessels, such as cruise ships, may use gas turbines for electricity generation. Gas turbines provide high power to weight ratios and are suitable for ships that require significant electrical power.

- **Shaft generators**: These utilize the rotation of the propeller shaft to generate electricity. They save fuel, reduce emissions, and efficiently supply power, often alongside traditional generators. This technology is common in vessels with high power demands, like large container ships, enhancing energy efficiency and environmental sustainability.

- **Batteries**: Energy storage systems, including lithium-ion batteries, are becoming more common on ships. They store excess electricity and can supply power during peak demand or in case of generator failure.

The choice of electricity generation method depends on factors such as the ship's size, intended use, regulatory requirements, and environmental considerations. Efficient electricity management systems help ensure that power is distributed appropriately to various onboard systems, including propulsion, navigation, lighting, communication, and more.

2.1. Fuel consumption in electricity generation.

The amount of fuel consumed by a ship for electricity generation can vary widely depending on several factors, including the type of ship, its size, the efficiency of the power generation systems, and the power demand. However, taking an approximate for a container ship (large, typically over 10,000 TEU):

Fuel consumption for electricity generation:

- Approximately 1.5 to 2.5 metric tons of heavy fuel oil (HFO) per hour at cruising speeds.
- Specific fuel consumption (SFOC): Around 150-250 grams of fuel per kWh of electricity generated.

In compliance with MARPOL Annex VI, Very Low Sulfur Fuel Oil (VLSFO) is preferred over HFO for emission control. The cost of VLSO is around $600-$700 per metric tonne. For a voyage of one month, in a ship with an 80,000 kW main engine and 3000 kVA electrical capacity;

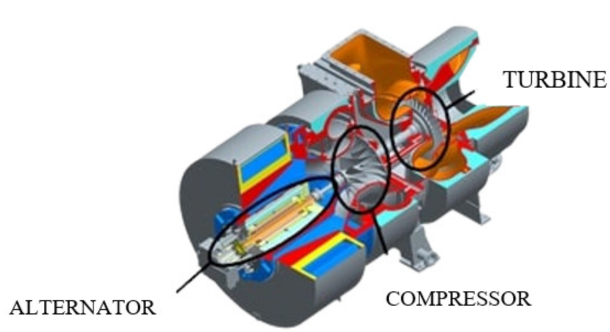
Fuel consumed per day= $(0.2\times3000\times24)/1000 = 14.4$ tonnes.

Cost of fuel consumed per month = $(14.4\times650\times30)=$ \$280,800.

3. Hybrid turbochargers.

Hybrid turbochargers as shown in Figure 1 are advanced engine components designed to improve the efficiency and performance of internal combustion engines. They combine traditional turbocharging technology with electrical or mechanical assist systems. The hybrid turbocharger can recover waste heat and energy, reducing turbo lag, enhancing engine response, and increasing overall fuel efficiency. This technology is especially relevant for reducing emissions and improving power delivery in vehicles and marine applications.

Figure 1: Hybrid Turbocharger.



Source: motorship.com.

The revolution energy of the turbocharger rotor on the diesel engine is used for compression of the combustion air. The hybrid turbocharger, consisting of a turbocharger rotor connected to a motor-generator for directly converting part of the above mentioned revolution energy into electric power, possesses the following features:

(a) Neither additional power turbine and its accessory equipment nor any piping thereto is necessary, requiring almost no excess space.

(b) Utilizing its function as an electric motor, the performance of the turbocharger system can be improved especially at part load (with the two cycle engine it can substitute for the auxiliary blower).

(c) Owing to that there is no pressure loss in the exhaust gas line and that energy conversion is carried out in the turbine of the turbocharger, high turbine efficiency can be achieved.

3.1. Requirements for setting up hybrid turbochargers.

For a hybrid turbocharger, three basic things required are:

1. Conventional turbocharger with extended shaft to accommodate alternator at blower end.
2. A specially designed very compact alternator to run at very high speed of around 9000 rpm.
3. A cooling system for an alternator as heat generated will be more due to its compact size for a given rpm.

3.2. Working of hybrid turbocharger.

The working is similar to any other generator; the only difference here is the prime mover which is the turbocharger itself. The speed of the prime mover governs the voltage and frequency of the generator. An initial DC power is provided so that the required output voltage and frequency can be achieved. At 9500 KW, the hybrid system can generate about 756 KW which is enough to take up the full sea load of a normal-sized merchant vessel.

3.3. Developments so far.

Mitsubishi Heavy Industries and Calnetix have collaborated for the implementation of this technology. Mitsubishi Heavy Industries, Ltd. (MHI), the leading marine equipment manufacturer was looking for next generation of energy recovery systems that can enable the company to generate a significant amount of power from the engine's exhaust energy onboard marine vessels while remaining compliant with international rules and regulations concerning the marine environment. Calnetix designed and built a high-speed permanent magnet (PM) motor generator that fits inside the silencer of MHI's existing hybrid turbocharger, resulting in a very small footprint that is a mere 313 millimetres longer than its conventional counterpart [4]. By diverting a small portion of the engine exhaust gas that would normally be dedicated entirely to the marine turbocharger, the hybrid turbocharger has the capability to provide all the auxiliary power necessary for the average ship and potential for saving thousands of dollars in fuel cost per day. When the ship is at cruising speed, the integrated Magnaforce™ generator, driven by the marine turbocharger rotor shaft, produces electrical power equivalent to up to five percent of the main engine output. During slow steaming, by acting as a motor, the permanent magnet machine's turbo assist capabilities enhance the performance of the main engine. For hybrid turbocharger installation, the motor generator was optimally designed to match the turbocharger shaft speed and also to be fully compatible with Calnetix high-frequency power electronic drives.

3.4. Challenges with the use of hybrid turbochargers.

There are various challenges that arise when hybrid turbochargers are incorporated with the main propulsion engine for generating electricity, which can be stated as:

- **Requirement of the constant speed**: Electricity generation requires the prime mover to rotate the rotor of the alternator at a constant speed. As the exhaust from the main engine can vary at different speeds, it will become difficult to run the turbine at a constant RPM.
- **Reduction of the speed of rotation by turbocharger**: The maximum speed by which 60 Hz electricity can be produced is 3600 RPM (when the alternator has 2 Poles) but the turbocharger usually runs on an RPM much higher than this (~12000-15000 RPM).
- **Balancing of the rotating masses**: Balancing plays an important role in maintaining the clearances between the turbine blades and the casing, if they are not proper then the turbocharger will merely act as a blower.

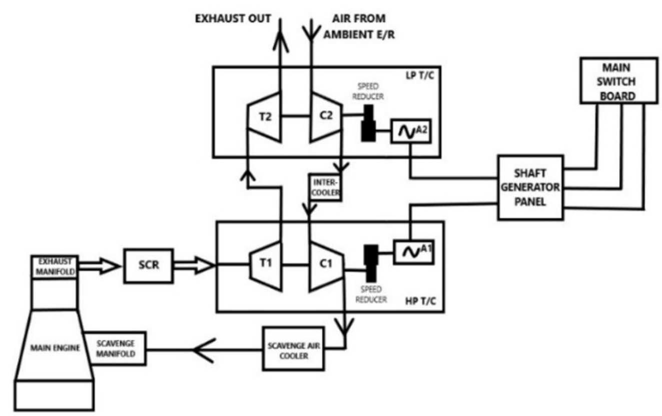
Addressing these challenges and finding solutions for them becomes crucial in order to ensure the proper working of hybrid turbochargers and the effective generation of electricity.

4. Proposed installation.

As we have seen, there are several challenges we have to overcome for efficiently generating electricity with the help of turbochargers, we intend to propose an installation which will not only overcome the existing challenges but also will provide some other advantages to the existing system. We intend to modify the installation as shown in the Figure 2. The proposed installation comprises the combination of two turbochargers. The exhaust gas from the exhaust manifold after passing through the SCR enters the first turbine (T1) which will act as the prime mover and rotate the shaft which in turn will rotate the compressor (C1) and alternator (A1). Exhaust gas after coming out from T1 will enter the turbine (T2) where it will help T2 to act as the prime mover and rotate the compressor (C2) and alternator (A2). In this way, the compressor will be able to supply charge air to scavenge manifold for combustion and the alternator will be able to generate electricity. This generated electricity is then passed through the Shaft Generator Panel (SGP) in order to remove ripples before the electricity is given to the Main Switch Board (MSB).

The above-mentioned working is illustrated, when the main engine is already running. But when the engine is not running, we can still use this arrangement in an efficient manner. This time we can give external supply to the alternator from MSB which will now act as a motor and drive the compressor as well as the turbine. The compressor will take ambient air from the engine room and supply it to the charge air cooler after being passed through both the compressor as well as the intercooler present in between both the compressors. The pressure of exhaust gas entering T1 is more than that T2. So, it will be apt to call the Turbocharger with T1 as the High-Pressure Turbocharger (HP T/C) and the turbocharger with T2 as the Low-Pressure Turbocharger (LP T/C). This installation is also incorporated with speed reducers before the alternator in order to reduce the high-speed rotation generated by the turbine in both turbochargers [10-12]

Figure 2: Proposed Installation.



Source: Authors.

4.1. Benefits from the proposed installation.

Following are the benefits we can achieve from the proposed installation:

- It helps to limit the use of auxiliary engines to ports as the electricity consumption during the sea leg of the voyage can be catered by the hybrid turbocharger(s).
- Since, the proposed installation uses multi-staging of turbochargers, it improves the power generation as well as the charge air density of the scavenge air. High density charge implies that more oxygen is available which eventually leads to more efficient combustion.
- The need for an auxiliary blower is eliminated as the generator can act as a motor when provided with the external source of electricity from the MSB and rotate the shaft of the compressor to draw in the ambient engine room air for the time being when the exhaust gas is not available.
- High speed of the turbine can be reduced with the help of speed reducers so that appropriate speed can be given to the alternator for the generator of the electricity.

4.2. Possible challenges in the proposed installation.

Following are some of the challenges that might be encountered while the implementation of the proposed model:

4.2.1. Possible increase in NO_X emissions.

The downside of this is that more availability of oxygen leads to high temperatures in the combustion chamber which eventually increases NO_X. As the charged air density going to the scavenge manifold will be high, the supplied amount of oxygen for the combustion will be more which can result in high temperature in the combustion chambers due to which the nitrogen present in the fuel can break and result in the formation of NO_X. But this challenge can be easily overcome by an efficient SCR unit or a catalytic converter.

4.2.2. Tackling the need for constant speed.

The constant speed requirement can be tackled by only operating the hybrid turbochargers when the main engine is running at either HALF AHEAD or FULL AHEAD rpm. For reducing the turbocharger speed at the alternator end, two sets of speed reducers (reduction gears) can be used, one for each speed. Rest of the time the alternator can be isolated and the turbocharger can be run similar to a conventional one and electricity supply during that time would be catered by the diesel generators.

4.2.3. Efficient cooling of the alternator.

The alternator would employ air and water cooling. Fresh water from the LT circuit of the central cooling system would be circulated in a radiator grid. Air from a fan would blow over the grid to the alternator and provide cooling effect; the fresh water would be cooled by seawater and re-circulated again.

Conclusions.

The purpose of this technical paper is to benefit the maritime sector by replacing the current Diesel Generator which consumes HFO or diesel oil for its operation and is acting as a source of harmful emissions, with an alternative method that will not only reduce the consumption of fuel oil but also reduces the harmful emission as it will be completely based on waste heat recovery principle that will be benefitting the shipping companies while complying with all the rules and regulations in a very efficient manner.

References.

1. Calnetix Technologies. (n.d.). Hybrid turbocharger system for ships. https://www.calnetix.com/case-studies/hybrid-turbocharger-system-ships.
2. Mitsubishi Heavy Industries. (2014). Hybrid turbocharger system for marine engines. https://www.mhi.co.jp/technology/review/pdf/e441/e441049.pdf.
3. European Commission. (n.d.). Reducing emissions from the shipping sector. https://climate.ec.europa.eu/eu-action/transport/reducing-emissions-shipping-sector_en.
4. Calnetix Technologies. (n.d.). Hybrid turbocharger system for ships [Video]. YouTube. https://www.youtube.com/watch?v=OcG68TxMIxs.
5. Ship & Bunker. (n.d.). Bunker fuel prices. https://shipandbunker.com/prices.
6. Marine Insight. (2019). Hybrid turbocharger for marine engines: Maritime technology innovation. https://www.marineinsight.com/main-engine/hybrid-turbocharger-for-marine-engines-maritime-technology-innovation/.
7. Wärtsilä. (n.d.). Reduction gear (gearbox). https://www.wartsila.com/encyclopedia/term/reduction-gear-gearbox.
8. Maritime Page. (n.d.). Fuel consumption: How much fuel cargo ship uses. https://maritimepage.com/fuel-consumption-how-much-fuel-cargo-ship-use/.
9. Altosole, M., Figari, M., & Vettori, M. (2021). Hybrid turbocharging systems for marine diesel engines: Performance and energy efficiency analysis. Journal of Marine Science and Engineering, 9(3), 321. https://doi.org/10.3390/jmse9030321.
10. DieselNet. (n.d.). Turbochargers. https://dieselnet.com/tech/air_turbocharger.php.
11. Marine Engineering. (n.d.). Marine alternator maintenance guide. http://www.marineeto.we.bs/2020/11/06/marine-alternator-maintenance-guide/.
12. Nyborg-Mawent. (n.d.). Auxiliary blowers. https://www.nyborg-mawent.com/en/products/other-ventilation-equipment/auxiliary-blowers/.