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Maritime sector has always been influencing the global economy. Shipping facilitates the bulk transportation of raw material, oil and gas products, food and manufactured goods across international borders. Shipping is truly global in nature and it can easily be said that without shipping, the intercontinental trade of commodities would come to a standstill.

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HYBRID PROPULSION SYSTEM

Gaurav Kumar
Shubham Thakur

Abstract
Regional and global air pollution from marine transportation is a growing concern. In descending the sources of such pollution, researchers have now become more interested in tracking where along the total fuel life cycle, these emissions occur.

Mechanical power and electric power work together in the propulsion train optimizing the propulsion efficiency for ships with a flexible power demand. The combination of mechanical power by dual fuel engine and electrical power by electrical motors through hydrogen fuel cells delivers propulsion power, providing the right amount of power and torque to the propeller in each operation mode.

**Dual fuel engine**- The dual fuel engine is an excellent solution for fulfilling IMO TIER 3 NOX as well as the increasingly stringent Sulphur fuel caps. The dual fuel engine uses both gas-oil mixture and natural gas as fuel. That adds to the security of energy supply. The thermal efficiency of dual fuel engine is 36%, so that the availability of gas at a price 10% less than that of fuel oil make it worthy for consideration.

**Hydrogen fuel cells**-A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (proton exchange membrane) cell uses hydrogen gas and oxygen gas as fuel. The product of the reaction in the cell are water, electricity and heat.

Our Hybrid propulsion systems include a dual fuel engine, hydrogen fuel cell and electric motor ,typically allowing the diesel , gasoline or LPG engine to do the heavy work when needed , and allow the electric system to respond to lighter loads such as low-speed cruising or providing power for lights and electronics.

Using these two in connected manner we get one of the most efficient propulsion systems.

**Key word:** Hybrid propulsion, Dual fuel engine, Hydrogen fuel cells.

1. **DUAL-FUEL ENGINE:**

A dual-fuel engine is an engine designed to burn predominantly natural gas but with a small percentage of diesel as a pilot fuel to start ignition. The engines operate on a cross between the diesel and the Otto cycle. In operation, a natural gas–air mixture is admitted to the cylinder during the intake stroke, then compressed during the compression stroke. At the top of the compression stroke the pilot diesel fuel is admitted and ignites spontaneously, igniting the gas–air mixture to create the power expansion. Care has to be taken to avoid spontaneous ignition of the natural gas–air mixture, but with careful design the engine can operate at close to the compression conditions of a diesel engine, with a high-power output and high efficiency, yet with the emissions close to those of a gas-fired spark-ignition engine. However, efficiency tends to fall, and emissions of unburned hydrocarbons and carbon monoxide rise at part load.
Typical dual-fuel engines operate with between 1% and 15% diesel fuel. Since a dual-fuel engine must be equipped with diesel injectors, exactly as if it were a diesel engine, a dual-fuel engine can also burn 100% diesel if necessary, though with the penalty of much higher emissions.

Diesel engines can operate with much higher compression ratios than spark ignition engines and this allows them to achieve higher efficiencies. The large disparity in efficiency between a spark ignition engine and a diesel engine has prompted engine developers to search for a way of achieving the efficiency of a diesel engine in spark ignition engine. This is the origin of the dual-fuel engine which has been the most successful of these hybrids.

A gas metering control unit is used to control the gas mass flow rate. The gas flow rate provides a similar linear relationship to the power output as for the diesel level. This enables the diesel and gas power produced to be calculated and the engine to be protected against overload. The diesel side of their engine is powered by a mechanical injection system which is connected to an electric actuator. The figure provides a schematic view of the system.

In dual fuel mode, this diesel controller is still responsible for the actual speed/power control. An additional control loop then controls the optimum gas quantity. This enables the diesel injection system to respond dynamically to rapid fluctuations or step changes. If the load is disconnected, the engine can quickly be switched back to pure diesel operation. This prevents the diesel level from falling below the minimum required for combustion and thus causing misfires.

1.1. Further Improvements:

A total energy system implies on-site power generation in which the energy input from either liquid fuel (diesel engines) or a combination of gaseous and liquid fuels (dual-fuel engines) is maximized by recovering the waste heat from the generating process. By so doing the overall thermal efficiency of generation may be raised from 37% to about 80%.
1.2. **Advantages:**

1. LPG-powered engines guarantee the lowest unburned hydrocarbons emissions (-95% compared to 2-stroke engines and –42% compared to 4-stroke gasoline engines / -92% and –34% compared to LPG engines).
2. Dual fuel engine results in high CO2 savings and high variable cost savings.
3. A power station based on multiple dual-fuel engines in parallel offers high flexibility, both in fuel use and in output. This increases the reliability of power supply.
4. The key advantage of dual-fuel engines – which typically primarily use liquefied natural gas (LNG) but can also run on heavy fuel oil or marine diesel oil – is that their owners can select the most economical fuel under different conditions.

2. **HYDROGEN FUEL CELL:**

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A PEM (Proton Exchange Membrane) cell uses hydrogen gas (H₂) and oxygen gas (O₂) as fuel. The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-product.

2.1. **How does it work:**

Pressurized hydrogen gas (H₂) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When an H₂ molecule comes in contact with the platinum on the catalyst, it splits into two H⁺ ions and two electrons (e⁻). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

Meanwhile, on the cathode side of the fuel cell, oxygen gas (O₂) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H⁺ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H₂O).
All these reactions occur in a so-called cell stack. The expertise then also involves the setup of a complete system around core component that is the cell stack.

The stack will be embedded in a module including fuel, water and air management, coolant control hardware and software. This module will then be integrated in a complete system to be used in different applications.

Due to the high energetic content of hydrogen and high efficiency of fuel cells (55%), this great technology can be used in many applications like transport (cars, buses, forklifts, etc.) and backup power to produce electricity during a failure of the electricity grid.

2.2. **Advantages:**

- By converting chemical potential energy directly into electrical energy, fuel cells avoid the “thermal bottleneck” (a consequence of the 2nd law of thermodynamics) and are thus inherently more efficient than combustion engines, which must first convert chemical potential energy into heat, and then mechanical work.
- Direct emissions from a fuel cell vehicle are just water and a little heat. This is a huge improvement over the internal combustion engine’s litany of greenhouse gases.
- Fuel cells have no moving parts. They are thus much more reliable than traditional engines.
- Hydrogen can be produced in an environmentally friendly manner, while oil extraction and refining are very damaging.

3. **HYBRID PROPULSION SYSTEM:**

Mechanic and electric power work together in the propulsion train, optimizing the propulsion efficiency for ships with a flexible power demand. The combination of mechanical power, delivered by dual fuel engine, and electrical power by hydrogen fuel cell. Delivers propulsion power, which assures the ship a broad operational capability, providing the right amount of power and torque to the propeller in each operation mode. Whereas a diesel-mechanic propulsion system is designed according to its maximum power demand, which, for example, is fixed for a tanker or cargo vessel according to the most hours of the operation profile, a
hybrid propulsion plant is better prepared for changes in operation during the vessel’s trip or even the vessel’s life.

Hybrid propulsion systems can be differentiated between configurations, where the diesel engines and the E-motors work in parallel on the propeller (CODLAD), or where either the diesel engine or the E-machines are used (CODLOD).

Hybrid-electric systems include dual fuel engine and hydrogen fuel cell to run electric motors typically allowing the diesel, gasoline or LPG engine to do the heavy work when needed, and charge the electric system and allow it to respond to lighter loads such as low-speed cruising or providing power for lights and electronics.

The advantages of all-electric or parallel-electric boats are the reductions in pollution, noise, vibration, and potentially, cost.

In a parallel hybrid system, both the dual fuel engine and the electric motor can provide power to the propeller.

Figure 1. Electric Drive System
3.1. **Advantages of hybrid propulsion system:**

- Flexible use and highest efficiency.
- The propeller can be driven by the diesel/LPG engine, and / or by the electric motor, resulting in a highly redundant and reliable propulsion system.
- Part-load in a conventional system.
- Part-load in an electrical system.
- In hybrid mode, the engine and the propeller can operate with variable rpm (combination mode) and the network frequency and voltage are fixed and stable.
- Reduced plant operating costs due to the possibility to operate the main engines and auxiliary gensets in a range where the required amount of power is provided by a combination of engines which run near or at their optimal loading with their minimal specific fuel oil consumption.
- As a result of high plant efficiency over a wide range of operation modes, not only fuel oil consumption is lower, but fuel related emissions like SOX and CO2 are also reduced. Further pollutants are reduced as there is less incomplete combustion that intensively occurs in the low-loaded engines.
- In E-mode with variable-speed E-motors less noise is caused and pressure side cavitation on the propeller is reduced, as it can be operated at an optimal speed / pitch ratio. Propeller speed and pitch can be controlled independently. Additionally, the underwater noise signature can be reduced. This especially offers benefits at slow speed sailing.
- Depending on the operational modes of the vessel the main engines and the auxiliary engines run less hours per year and, when in operation, on higher loads. Both lead to less required maintenance.
- Large variation of operation modes appropriate for a flexible power demand, for slow speed operation up to boosting. This results in an optimal overall plant operational capability with fast system responses and a high plant flexibility.
- While mechanical optimization is often determined by one or a few operational modes, the electrical drive capability tremendously increases flexibility. “Off-designs” for hybrid propulsion systems are fewer compared to pure mechanical system designs.
3.2. Disadvantages of hybrid propulsion system:

- Lower overall energy efficiency for ships running at full-rated speed all the time due to losses.
- Higher initial capital cost.
- Different and improved training for ship’s crew as the system is completely different from mechanical system and involves major automation.

4. CONCLUSION:

In recent years, the concept of a hybrid drive, especially for inland vessels, has been developed. The hybrid propulsion system can be beneficial from both economic and ecological point of view. It can be a onetime investment. The advantage of hybrid propulsion is particularly visible when the ship is operating at a low speed. Moreover, the major benefit resulting from hybrid propulsion in electric mode was significantly reduced noise pollution. It may be essential factor for urban or environmentally protected areas. The Hybrid propulsion system showed that there is possible to lower operating costs due to lower fuel consumption. However relative benefit resulting from using hybrid propulsion is strongly dependant on the specific aspect of route (i.e., speed limits, current) and vessel speed. If the combustion engine works for most of the time at optimum load (80% of full power), then the fuel savings are minimal. However, if the travel includes different power demands, resulting i.e., from speed limits, then the fuel savings can reach up to 40%. Addition to that use of hydrogen fuel cells for providing the electrical power makes it more environment friendly. This technology can be used as an upgradation in existing technology.

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