Prime Mover – Are there alternatives to the diesel engine?

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In 1903 the first diesel engine driven vessel – the Russian inland water tanker "Vandal"- entered into service. She was equipped with three diesel engines of 120 hp each. Nowadays about 97 % of the seagoing vessels have diesel engines as prime mover and for power generation. The power of the largest engines is above 100.000 hp. The main advantage is the low specific fuel consumption and the ability to burn heavy fuel oil. The small space requirements for the engines and the bunker fuel as well as the reasonable specific price are also promoting this propulsion system. Two stroke engines have the additional advantage that no gearbox is needed. However, the boundary conditions in the maritime industry are changing and the question "Are there alternatives to the diesel engine?" has to be investigated permanently.
In Order to compare the overall efficiency of a prime mover following main parameters have to be taken into consideration:

- Investment costs of propulsion plant
- Fuel consumption at full load and part load
- Space requirements and weight
- Space requirements of bunkerfuel
- Costs and handling of fuel
- Maintenance costs
- Reliability, Operability
- Environmental aspects

The theoretical efficiency of reciprocating engines is mainly depending on the compression ratio while the gas turbine process is depending on the maximum temperature. Since this temperature is limited for gas and steam turbines as long as steel is used for turbine blades the efficiency of the diesel engines will be higher. However, the diesel engines are producing more NOx emissions due to the temporary very high temperatures after ignition.
In the last 30 Years steam turbines plants with 70 bar pressure, 560°C maximum temperature and intermediate superheating have been developed. Steam turbines plants have the advantage to burn nearly every kind of fuel, low maintenance costs and a low noise and vibration level. However, the efficiency of these plants is not exceeding 35% and at present fuel prices there is no chance that a steam turbine will be installed. In addition to these economical facts there is only limited crew who have operational experience with steam turbines. These plants also need more space so that the engine room is larger compared to diesel plants and consequently there is less room for cargo.
Stronger environment legislation might boost combined gas/steam turbine plants which reach a thermal efficiency between 40 and 47% for large plants. The diesel engine reaches values in the range of 50 % for engines above 10 MW. The combined cycle gas/steam turbine with electric propulsion motors was introduced on some passenger vessels. Low exhaust gas emission and a low noise and vibration level are the main advantages for this type of vessel in particular when they operate in environmental sensitive areas. The disadvantage is that "clean fuels" have to be used which are presently about 80% more expensive than heavy fuel oil. As long as it is allowed to burn heavy fuel oil at sea, this economical disadvantage can not be compensated.
Four submarines of the German navy have been equipped with fuel cells for power generation. They are operating with hydrogen and oxygen on very low temperatures and an efficiency above 60%. The main advantage is the extremely low noise level, these boots are hard to detect. If other fuels than hydrogen or methanol are used a reformer plant is needed, which is rather complex and decreases efficiency of the plant. By using diesel oil the fuel cells efficiency is below the values of diesel engines. Presently the specific installation costs for fuel cells are 20 times higher than the costs for a diesel plant.
As a matter of fact nearly all newbuildings currently ordered are equipped with diesel engines except some niche products like high speed crafts and navy vessels where gas turbines are installed. On LNG (liquefied natural gas) carriers the steam turbine was dominating till 2003 because the boil off gas can be burned without major modifications in the steam boilers. New dual fuel engines have been developed as well as reliquefaction plants. The dual fuel engines have a lower efficiency than pure diesel engines. The exhaust gas emissions – in particular NOx - are much lower. By using these technologies the transport costs of LNG can

be reduced by 10 to 15 %. As a consequence only a few LNG carriers have been ordered with steam turbine plants in the last three years.
The influence of the availability of fuels is of major importance for the future development of ship propulsion plants. The reserve/production ratio of oil is in the range of 40 years, gas reserves will last for about 60 years. The energy prices will rise because consumption increases in particular in the largest countries of the world by population China and India.
Nearly all liquid and gaseous fuels can be used in diesel engines. However, the coal reserves are much higher (+200 years). Burning coal dust or coal slurry in diesel engines has not proved to be an alternative. The wear rates of liners and rings have been not acceptable. In case that coal will come back as fuel for seagoing vessels the reintroduction of steam plants might happen.
Nuclear power is not an alternative because the majority of countries will not allow that these ships enter their ports. The potential of solar and wind energy is not sufficient to be used as prime mover. However, these natural resources can be used as efficiency booster like the “sky sails” technology.
Seaborne transport is the most efficient way to transport goods and the diesel engine is the most efficient prime mover. It seems that at least for the next 20 years this will remain.

Hans Jacob Gätjens started his professional career as Marine Engineer. After that he obtained his doctor's degree on Diesel engines and worked with the shipyard HDW in Kiel, where he became head of the project department for merchant vessels before he joined Germanischer Lloyd as director of the machinery division. He then became managing director of Marine Service, a company providing marine consulting services based in Hamburg. He is currently Chief Executive for Central Europe of Bureau Veritas.