POWERING ACADEMIC RESEARCH --

Hulls, Propulsion Equipment, Vibration & Underwater Noise.

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Abstract-

The global shipping industry stands at critical crossroads, grappling with existential question of survival amidst a landscape shaped by technology, regulations, geopolitics, and climate change. Amidst these multifaceted challenges, academic research emerges as a beacon of hope, offering innovative solutions to navigate the turbulent waters ahead. This paper delves into the pivotal role of academic research in advancing sustainability within the maritime sector, focusing on hull design, propulsion equipment, vibrations, and underwater noise.

Through a comprehensive review of literature and case studies, this study elucidates how cutting-edge research in hull optimization, propulsion system efficiency, vibration reduction techniques contributes to enhancing the environmental performance and operational efficiency of vessels. Furthermore, it examines the synergistic interplay between technological innovation, regulatory frameworks, geopolitical dynamics, and climate imperatives in shaping the future trajectory of global shipping.

By shedding light on the symbiotic relationship between academic research and the maritime industry, this paper underscores the transformative potential of collaborative endeavours in driving sustainable practices amidst the evolving global challenges. Ultimately, it posits that academic research serves as both a torchbearer of hope and a catalyst for change, offering actionable insights to steer the maritime industry towards a brighter and more sustainable future.

Keywords-

Hydrogen ; Methanol ; Antifouling ; Hydrodynamic ; Hybrid system ; Streamlined

Emerging Proplusion Equipments

Methanol -

Green Methanol (CH_3OH) produced from renewable sources is an attractive marine fuel option due to its low carbon intensity. An engine using green methanol can even provide carbon-neutral propulsion.

Methanol inclusion in the IMO's Interim Guidelines for Low Flash Point Fuels was passed in November 2020. It may be used onboard ships as fuel for internal combustion engines or as a fuel source for fuel cell operation.

MAN has developed the 'ME-LGI' concept for high-pressure injection of liquid low flashpoint fuels such as methanol. This involves a relatively low fuel supply pressure, and all high-pressure pumping is done within the injector. Fuel injection is accomplished by a booster fuel injection valve that raises the injection pressure to 550-600 bar. The first application of this concept was in methanol-burning Dual Fuel (DF) engines on several methanol carriers. As methanol is a liquid at ambient temperature, the existing liquid fuel infrastructure may also be leveraged for the supply of methanol with limited conversion. As a liquid fuel, only minor modifications are needed to existing systems/infrastructure used for conventional marine fuels. The modifications are mainly concerning the low flash point of methanol. Hence less funds will be required for the vessel owners to propel the ships using methanol by minor modifications in the existing two stroke IC engine . Keeping the zero carbon policy into consideration , MAN has developed world's first two-stroke dual-fuel engine named MAN B&W ME-LGIM which can run on both methanol as well as conventional fuels . Specifically designed to meet the needs of the maritime industry, it is a versatile and scalable solution that is suited to a wide range of vessel types. Simple handling, storage, and bunkering of methanol, combined with relatively simple auxiliary systems and the potential to be carbon-neutral, makes it an attractive option for meeting decarbonization targets. The engine works with even better efficiency compared to our conventional fuel engines. Switching between methanol and fuel oil is seamless and thereby supports reliable and continuous operation of the engine.

Fig-1 MAN B&W ME-LGIM

Overlooking this transition towards green and environmentally sustainable shipping , the leading maritime trade giant MAERSK has placed and order of 19 vessels propelled by green methanol in pursuit of achieving the zero emission dream of the company .Following this , many other companies are also taking the same path

Large scale production of green methanol is a biggest challenge for which various countries as well as companies are heavily investing in infrastructure for the same. If the production capacity is increased , it will make this green fuel more cost effective . one other drawback that can raise concern is Methanol's specific energy of 19,700 kJ/kg is much lower than that of LNG and conventional liquid fuels.

For the same energy content, methanol requires about 2.54 times more storage volume than conventional fuels which needs to be addressed

Hydrogen -

Hydrogen fuel cells operate by creating electricity through a chemical reaction. Each fuel cell consists of a negative electrode called an anode and a positive electrode called a cathode. The electricity is produced at these electrodes, facilitated by an electrolyte that carries electrically charged particles between them, along with a catalyst to accelerate the reactions. While hydrogen serves as the primary fuel, oxygen is also required for the fuel cell to function. It has minimal environmental impact, as the combination of hydrogen and oxygen produces water as a by-product , therefore entirely free of carbon emissions. Because fuel cells utilize an electro-chemical reaction rather than combustion, they can achieve higher efficiencies compared to traditional energy production methods. This efficiency can be further enhanced by combined heat and power generators, which utilize waste heat from the cell for heating or cooling applications.

While single fuel cells do not produce a large amount of electricity, they are combined into stacks to generate sufficient power for their intended use, whether it's for small digital devices or large power plants. Unlike batteries, fuel cells do not require recharging and can continuously generate electricity as long as the fuel source, in this case, hydrogen, is provided. With an anode, cathode, and an electrolyte membrane, fuel cells have no moving

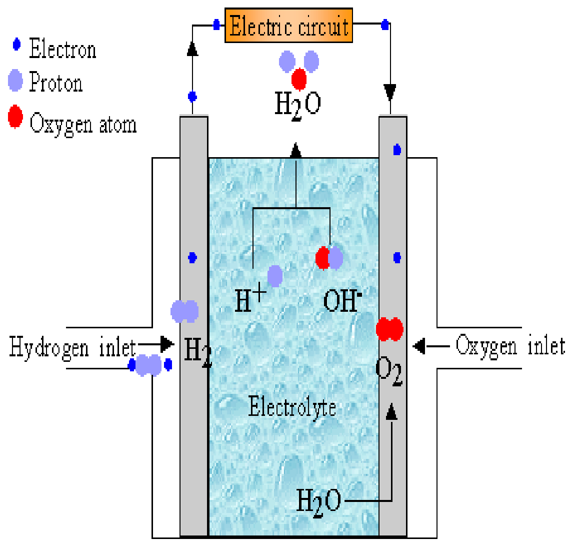

Fig-1.2 Hydrogen fuel cell

parts, making them both quiet in operation and highly reliable. Additionally, hydrogen can be directly burned in internal combustion engines aboard ships, similar to conventional fossil fuels such as diesel or gasoline.

Hydrogen can be produced through various methods such as steam methane reforming (SMR), electrolysis, and biomass gasification. Onboard ships, hydrogen gas is stored in high-pressure tanks or cryogenic tanks.

<u>Hulls and Ship Vessel</u>

The ship's watertight enclosure is crucial for safeguarding the cargo, machinery, and accommodation spaces from weather, flooding, and structural damage. An advancement in ship hull materials is the adoption of fiber-reinforced composites like carbon fiber and fiberglass, renowned for being lighter and stronger than traditional steel.

CAD Software-

Employing CAD software for ship hull design has tremendously impacted the shipbuilding industry. The 3D representation created using CAD tools allows for precise modeling of hull

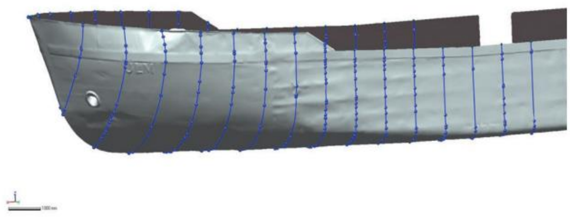

Fig-1.4 Cross-sections taken at pre-defined locations

surfaces, essential for subsequent design and calculations such as hydrodynamics, stability, and tank definition. B-spline curves and surfaces serve as the basis for representing the ship hull's curves and surfaces within the CAD software, offering flexibility in achieving the intended hull shape.

Laser Scanning-

When it comes to measuring ship hulls for hydrodynamic simulations, the preference for surface-based measurements arises due to the complexity and deformation of the original shape in some cases. Methods such as terrestrial laser scanning (TLS) and close-range photogrammetry are continuously evolving for comprehensive data acquisition, particularly capturing the entire vessel's body out of the water. For research analysis purposes, the use of scanners like Surphaser 400 and Faro Focus 3D 120S, along with Geomagic DesignX software for meshing the cleaned, co-registered, and resampled point clouds, can be instrumental.Additionally, modifications aimed at reducing the ship's resistance and consequently fuel consumption are worth considering.

Antifouling coating-

The hull of the ship is coated with antifouling paint to prevent the growth of marine life such as algae, mussels, and barnacles. This type of paint typically contains copper and zinc, which are effective but have toxic effects on marine organisms. To address this issue, the US Office of Naval Research has been funding research into developing environmentally friendly alternatives for over 20 years. The goal is to create coatings that do not harm marine life but still prevent organisms from adhering to the ship's surface. One promising solution involves using a biocompatible polymer called PEG in fouling-release coatings. This polymer forms a slippery surface that prevents biofilms and proteins from sticking without harming marine life.

While this alternative shows potential, there is a need to overcome challenges in transitioning from traditional antifouling paints to this new coating. Additionally, it is important to find a solution that is both nontoxic and cost-effective to replace the current toxic substances in marine paints.

These materials use zwitterions, molecules with equal numbers of positively and negatively charged groups, attached to polymer chains in alternating patterns to build a strong, stable water layer that prevents organisms from adhering to a surface, thus inhibiting biological growth.

Fundamentally, zwitterionic materials represent a shift in paradigm for antifouling solutions.

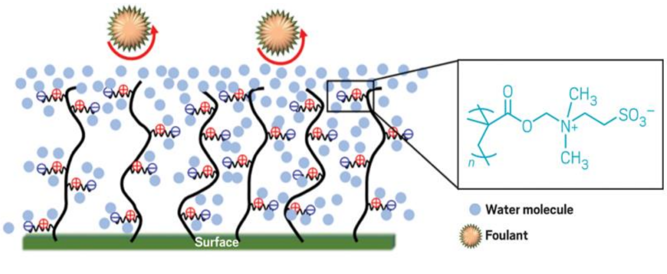

Fig-1.3 Poly(sulfobetaine methacrylate), a zwitterionic material

Rather than killing organisms or using shear forces to push them off, zwitterionic coatings make ship hulls effectively invisible. After years of trial and error, the commercialization of these materials is in sight, Jiang says. The new materials' benefits go beyond blocking the necessary organisms. Hydrogels used in antifouling for ship hulls create a slippery surface that prevents marine organisms from adhering. They work by releasing water or other substances to form a barrier, reducing friction and fouling accumulation. This eco-friendly approach minimizes the need for toxic chemicals and improves ship efficiency by reducing drag, leading to lower fuel consumption and maintenance costs.

Vibration and Underwater noises

Mechanical disturbances and the transmission of sound waves through water cause vibrations and underwater sounds in the sea. These vibrations can originate from sources such as ships, marine machinery, and underwater construction activities, potentially impacting marine life and ecosystems.

To address these concerns, quiet ship design incorporates advanced hull shapes, propeller designs, and insulation materials to reduce vibration and underwater noise.

Quiet ship design -

It advanced hull shapes, propeller designs, and insulation materials to minimize vibration and underwater noise. By optimizing structural integrity and propulsion systems, such designs reduce disturbances that could otherwise impact marine environments and wildlife, enhancing overall acoustic stealth and environmental sustainability.

Advanced propulsion systems-

Such as electric and hybrid engines, reduce vibration and underwater noise by operating more smoothly and efficiently compared to traditional diesel engines. They produce fewer mechanical vibrations and eliminate noisy components like gearboxes, contributing to quieter and environmentally friendly marine operations

Hull shape optimization -

This reduces vibration and underwater noise by minimizing hydrodynamic drag and turbulence. Streamlined hulls experience smoother water flow, reducing the forces that cause vibrations. This design also lowers cavitation risk around propellers, which decreases noise generated by collapsing bubbles. Overall, it enhances acoustic stealth and environmental sustainability in marine environments.

Active noise control systems reduce vibration and underwater noise by emitting precise anti-noise waves that cancel out undesirable noise frequencies generated by ship machinery. By actively interfering with and neutralizing noise waves, these systems significantly lower overall noise levels in marine environments, enhancing acoustic comfort and environmental sustainability..

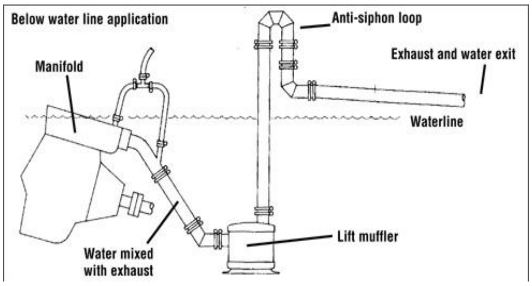

Fig-1.5 Exhaust system

Underwater exhaust systems direct engine exhaust gases away from the ship's hull, reducing underwater noise caused by turbulent exhaust discharge. By minimizing disturbance to water flow around the hull and propeller, these systems contribute to quieter marine environments and mitigate acoustic pollution, benefiting marine life.

Vibration control mounts are used to reduce vibration and underwater noise by isolating machinery and equipment from the ship's structure. These mounts are typically made of materials like rubber or elastomers and are designed to absorb and dampen vibrations generated by engines, propulsion systems, and other mechanical components.

Hence it is important for each and every generation to enhance and power academic research which would be the strong foundation of a more efficient and environmentally sustainable future of the shipping and related industries and hence benefit the whole mother earth .

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