

NAVIGATING TRANQUILITY: Electric Propulsion and Acoustic Insulation Innovations in Super Yachts

By

Caner Dincol

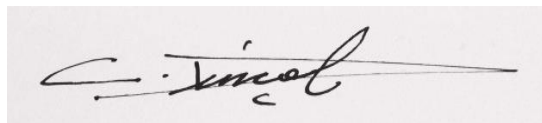
Naval Architect & Marine Surveyor

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Caner Dincol

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I. Abstract:

The following instructions for the selection and installation of electric propulsion systems and acoustic insulation materials for super yachts for pleasure are provided in the hope that they may be useful, but without any guarantee (not even the implied warranty of fitness for a particular purpose).

The purpose of this document is to introduce the procedures for installing the electric motor and acoustic insulation materials based on the presented instructions, attributed to expert application methods according to my intentions.

Please inform the author of any modifications or improvements to be made.

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III. Introduction:

Super yachts for pleasure craft are becoming increasingly popular among boaters, offering a luxurious and comfortable way to explore open waters. With advancements in technology, many yacht owners are now considering the electrification of propulsion systems as a more sustainable and environmentally friendly alternative to traditional diesel engines. Along with the benefits of an electrified propulsion system, the silent operation of electric engines results in a significant reduction of overall noise in the living areas of the yacht. This is achieved by eliminating noise sources that would otherwise require insulation for a comfortable and quiet environment. Consequently, with fewer measures needed for acoustic insulation, enhanced noise reduction can be achieved onboard the yacht.

At LEROTEC SRL, we provide consulting and supervision services for the electrification of propulsion systems for motor and sailing pleasure craft together with sound insulation for yachts. Our team of experts has extensive experience in installing and implementing electric propulsion systems for various types of vessels, ensuring that your yacht is equipped with the most efficient and reliable system available.

A. Importance of Silence and its Effects on Human Beings:

Silence is crucial for human health as it provides a break from noise-induced stress. Research has shown that exposure to constant noise above 85 decibels can lead to issues such as hypertension and sleep disturbance. Incorporating moments of silence, below 30 decibels, into daily life can help reduce stress, improve cognitive function, and promote overall well-being. In medical settings, silence below 40 decibels has been found to aid in pain management, healing, and patient comfort. Recognizing the value of silence and maintaining low decibel levels can significantly benefit both physical and mental health.

B. Background of Sound Pollution in Super Yachts:

Sound pollution in super yachts is a growing concern within the maritime industry, stemming from the increasing popularity of these luxury vessels. The use of powerful engines, onboard entertainment systems, and other mechanical equipment on super yachts generate high levels of noise that can impact the marine environment and onboard comfort. Excessive sound pollution can disturb marine life, disrupt ecosystems, and even violate local noise regulations in certain regions. As super yachts continue to grow in size and complexity, efforts to address and mitigate sound pollution have become essential for ensuring sustainable and responsible yacht operations.

Steel structures, such as those found in super yachts, are known for their high noise conductivity characteristics. This means that sound, whether generated internally or externally, can easily travel through steel materials, leading to the potential for increased noise levels within the structure. To mitigate sound pollution in steel-built vessels like super yachts, various noise reduction techniques and materials can be employed, such as sound insulation, vibration damping materials, and structural design modifications to minimize noise transmission. Additionally, proper maintenance and monitoring of equipment can also help reduce noise levels and improve onboard comfort for passengers and crew members.

IV. Sound Pollution Problems on Super Yachts:

Sound pollution on super yachts can pose several problems, both for those onboard and for the environment:

1. **Disturbance to Guests and Crew:** Excessive noise from engines, machinery, and onboard entertainment systems can cause discomfort and disrupt the tranquility of passengers and crew members, impacting their overall experience on the yacht.
2. **Health and Safety Concerns:** Prolonged exposure to high levels of noise can lead to hearing damage, stress, and fatigue among those onboard. This can compromise the well-being and performance of individuals, affecting their overall health and safety.
3. **Environmental Impact:** Sound pollution from super yachts can disturb marine life, causing stress to aquatic species and interfering with their natural behaviors. This can have long-term consequences on marine ecosystems, disrupting the balance and biodiversity of the surrounding environment.
4. **Regulatory Compliance:** Local regulations and standards often restrict noise levels in maritime settings to protect marine life and maintain quality of life for coastal communities. Failure to comply with these regulations can result in fines, penalties, and reputational damage for super yacht owners and operators.

Addressing sound pollution issues on super yachts requires implementing sound mitigation strategies, using noise-reducing technologies, and ensuring compliance with relevant regulations to protect both onboard occupants and the marine environment.

A. Reasons for Sound Pollution on Super Yachts:

In airborne sound transmission, sound propagates through the air without encountering obstacles, while in structure-borne transmission; sound propagates through the components of the structure system.

Both types of noise are interconnected; for example, noise generated by sounds first travels through the air (airborne noise) and is then transferred through vibration via structural systems (structural noise). These structures vibrate, transmitting the noise throughout all reinforcing elements (bulkheads, longitudinals, bilges, stringers) ultimately reaching the passenger's ear, creating acoustic discomfort.

The UNI EN 12354 standard defines the airborne and structure-borne paths of sound transmission within a building that lead to acoustic discomfort throughout the entire structure. Along with this communication dichotomy, a difference can also be identified between direct transmission and indirect or adjacent transmission. In a specific environment characterized by acoustic discomfort, sound starts from a source and reaches a second environment, considered disturbing or the receiver. As it is transmitted from the disturbing environment to the receiving environment, different paths of propagation are followed.

The main sources of sound pollution on super yachts are the thermal propulsion engines and generator sets, with additional contributions from natural sounds like waves and wind forces. Effectively mitigating sound pollution involves addressing these primary sources of noise. The transfer of propulsion forces from the thermal main engines to the hull structure via the engine feet shock absorbers may not be sufficient to prevent engine noise and vibrations from permeating the hull structure. Because the main task of the engine mount shock absorbers is to transmit the propulsion power to the body shell, without preventing the thermal engine noise and vibrations from spreading as expected. Hence, the substitution of thermal engines with electrically powered alternatives is crucial in reducing combustion-related sounds and vibrations. Enclosing generator sets in acoustically insulated cabins and implementing sound-insulating vibration absorber supports beneath their frames can effectively reduce structure-borne noise transmission through the steel hull.

Additionally, comprehensive insulation of the hull's inner surfaces can prevent both structure-borne and airborne sounds from reaching the living areas of the yacht. Any remaining sounds can be absorbed by integrating specialized sound-absorbing materials into non-structural elements like furniture, ceilings, floors, and doors. Embracing the floating furniture method is also vital in creating a noise-free yacht environment conducive to achieve the comfort of silence.

V. Electric Propulsion System and Acoustic Insulation Innovations:

Even though electrified propulsion systems are gaining popularity due to advancing battery technology, there are significant applications that highlight the most suitable uses of electric propulsion systems. Electrical propulsion offers full control over power distribution between battery packs and generator sets based on navigation needs. In addition to this, electric propulsion systems bring about lower maintenance requirements, sustainability, the use of green energy, and contribute to noise and environmental pollution reduction as positive side effects. There are mainly two types of electrified propulsion systems. Those are parallel and serial systems. For displacement hulls, the most advantageous system is a serial electric propulsion system due to its versatility, manageability and higher efficiency. In general, it is comprised of generator set groups, battery packs, a power management module, and electric propulsion engines. This system provides total power management for functionality optimization, self-protection, and the highest possible efficiency. As a positive side effect, this propulsion system does not create structure borne noise to propagate through hull shell. The advanced acoustic insulation material technology provides totally silent yachts. Due to new sustainable materials, higher durability, total sanitary safety, and higher-performing materials can be obtained.

As stated before, complete sound insulation starts with eliminating sound sources as much as possible and continues with isolating the noise in every isolable area. Thanks to the developments in new technological materials and their combination in panels, this insulation system is successfully applied in living spaces with new furniture materials and assembly methods.

VI. Main Steps for Maintaining Silence on Super Yachts:

Maintaining complete silence and acoustic comfort is a top priority for super yacht owners and guests. This section outlines the main steps yacht designers and builders must take to ensure the highest levels of serenity on board these luxurious vessels.

A. Eliminating the Source of Noise:

The most effective method and starting point to combat noise pollution is to eliminate noise sources as much as possible and replace them with lower noise-emitting alternatives. The intended solution for our scope is the replacement of thermal propulsion engines with electrically-activated engines. As thermal engines have internal combustion and many opposingly moving parts, they are significant emitters of noise, vibration, and even radiation produced by stressed metals. However, electric motors have a rotational movement and no opposingly moving parts, which create less noise and vibration. Simply put, there are no surfaces that are frictionally interacting with each other. For that reason, those electric engines do not produce as much noise in comparison to their traction power as other types of engines.

B. Preventing Noise Propagation through Structures:

The noise can enter the structure through direct contact and/or airborne transmission. Depending on the type of structural material, the noise propagates faster and with less loss of its energy through the structure. As a main step, the noise conduction into the structure should be prevented. Direct contact with noise-emitting sources should be eliminated. Alternatively, the elements to be fitted to the structure should be chosen to be noise and vibration-free.

The silent operation of electric propulsion engines, which have to be mounted on the hull structure, provides a significant advantage for achieving the goal of silent yachts. The thermal engines of the generator sets are mounted on their own frames. They can be fully insulated from the hull structure, as their produced power is conducted through electric cables that do not transmit mechanical forces. Additionally, the generator sets can be located in sound-insulation cabins to reduce the airborne noise from propagating.

C. Preventing Noise Propagation through Airborne Transmission:

Even though the preventive measures above help eliminate structure-borne noise, there can still be residual noise that penetrates the structure. This remaining noise should be stopped from propagating into the living spaces by applying sound insulation on the inner sides of the hull shell. The main idea of sound insulation is to stop noise-emitting surfaces with a barrier and absorb the remaining noise energy using closed-cell insulation materials. The noise propagating through the air moves in every direction, and the sound vibrations tend to make every surface affected by the sound waves vibrate. To prevent sound distribution and echoes of noise, the surfaces that the sound meets must be sound-absorbent, ending with a barrier that stops the sound from propagating structurally to other sections of the yacht. The sound energy is absorbed by the closed-cell acoustic insulation material as it travels through it. For that reason, all steel hull interior surfaces should be covered to eliminate all types of noise.

D. Minimizing Remaining Noise in Living Spaces:

After all the aforementioned prevention methods, there may still be residual noise that could disturb the yacht owner and guests. As a final and comprehensive measure, the furniture and elements of the living spaces, such as ceilings, floors, lockers, non-structural bulkheads, beds, and sofas, should be constructed using sound-insulating and absorbing panels. Additionally, these elements should be mounted to move freely in response to hull torsional movements, a feature known as the "floating furniture system."

The floating furniture system involves mounting furniture on shock absorbers or springs to isolate it from the hull and reduce vibrations or noise. This not only provides additional sound insulation but also enhances the comfort and luxury of the living spaces on the yacht. Choosing materials with sound-insulating properties for the furniture and fixtures can further minimize noise disturbances for the yacht owner and guests. By implementing these final measures, the overall noise levels on the yacht can be significantly reduced, creating a peaceful and enjoyable environment for all on board.

VII. Serial Hybrid Electrified Propulsion System for Super Yachts:

A serial hybrid electrified propulsion system for super yachts combines the benefits of an electric drive system with a traditional power source, such as a diesel generator. In this system, the diesel generator functions as a range extender to charge the batteries that power the electric motors, which in turn drive the propulsion system.

This setup offers several advantages for super yachts, including increased fuel efficiency, reduced emissions, and lower noise levels. The electrified propulsion system allows for silent cruising, making it ideal for eco-conscious owners and providing a more luxurious and peaceful experience for guests on board.

Additionally, the serial hybrid system provides flexibility in power management, allowing for different modes of operation to optimize efficiency based on speed, load, and environmental conditions. Overall, a serial hybrid electrified propulsion system is a cutting-edge solution for super yachts looking to enhance sustainability and performance while maintaining luxury and comfort.

A. Benefits and Applications of Serial Hybrid Systems in Super Yachts:

The serial electric propulsion system offers many advantages for displacement hull yachts. The maintenance-free engines, which do not emit any noise or vibrations, provide significant comfort. Each engine module is rated at max. 1000 kW and additional modules can be added to achieve the necessary power. The propeller shaft can be connected directly to the engine rotor to eliminate the need for a gearbox and reduce mechanical losses.

With varying power requirements, the generator sets can be activated automatically, and any power deficits during passages can be supplemented by battery packs. All power calculations and usage modes will be organized automatically by the power management module. The propeller drivetrain will be protected by thermal fuses in case of rope or chain entanglement or propeller collision with the seabed, ensuring that the fuses open the circuit to stop the propulsion system without causing damage to the entire system.

As the power and torque requests are not directly related to the revolutions per minute of the electric engine, the thermal engines of the generators sets are optimized for their specific revolutions per minute and power output conditions. This ensures that the thermal engines of generators are kept in their best conditions as advised by their producers. This is enabled through the power management module, which allows the generator sets to operate at variable revolutions per minute conditions, while still maintaining working conditions at their optimum level as recommended by the producers.

The electric engines can be operated at specific revolutions per minute. With this unique advantage of electric engines, navigation using auto-pilot on the yacht can be achieved by creating differences in revolutions per minute between the starboard and port engines. This allows for the navigation route to be secured without the need for rudder operation, which can cause significant resistance and oscillating effects. The entire route correction operation will be carried out seamlessly through integration with the power management system and autopilot communication.

The navigational autonomy without running the generator sets of the super yacht is limited by the battery pack power and capacity. However, with the development of battery technology in the future, this navigational autonomy may be improved. Therefore, in the future, without any change to the entire serial hybrid electrical propulsion system, batteries can be replaced to achieve longer navigational autonomy.

The serial hybrid electric propulsion system offers an almost heavy-duty non-stop navigation capability. The propulsion electric motors are thoroughly protected against any possible accidents, completely maintenance-free, and immune to humid and corrosive sea conditions, providing a reliable propulsion system. The power management system will activate the generator sets as necessary. Therefore, in the event of any generator set failure, the reserved generator sets will be ready to maintain the yacht's navigability without sacrificing its cruising speed.

VIII. Conclusion:

The propulsion system and entire sound insulation of a steel hull yacht are totally integrated. The remedial measures of the propulsion system to reduce noise emissions should be supported with innovative insulation materials and installation methods. The electrified propulsion system is not only for maintaining sustainable green energy to navigate yachts, but also for providing silence supported by new noise insulation materials that support overall human health.

IX. References:

I would like to thank to very precious people with whom i consulted to profit their qualified experience and advanced knowledge for preparing my thesis.

Prof. Dott. Branimir Ručojčić'- TEMA Marine Electric-Hybrid Propulsion System.

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Mr. Christian Ferre - Nord Compensati Srl.

Ms. Elena Balleri – 3BMust International.



Caner Dincol

Ing. Navale & Perito Marittimo / Naval Architect & Marine Survey

Lerotec S.R.L.

+39.379 213 7218 (Italia) / info@lerotec.com

Via Andrea Appiani 21 CAP 20900 MONZA (MB) – ITALIA.

P.IVA / Codice Fiscale : 13175790966 / COD. SDI : QULXG4S / Numero REA : MB – 2707093

PEC : lerotec@legalmail.it

www.lerotec.com