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July 2023



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Feel the Vibe?

Mitigating the effects of onboard noise and vibration

By Sara Ventiera

Are you achy? Maybe your back hurts more than normal. Or you're just tired and a bit off balance, and you didn't even go out last night. If these symptoms are suddenly affecting you, there's a chance it's not age or newfound motion sickness. It could be the boat.

Regulators and scientists have been tracking the effects of noise and vibration on the human body for decades. Their findings – which include an increased risk of certain cancers – offer insights into potential health issues that arise from exposure to vibrating heavy machinery.

"Extensive exposure to noise and vibration can cause fatigue and health issues," says Rich Merhige, president of Advanced Mechanical Enterprises in Fort Lauderdale. The more extreme issues that can happen aren't common in yachting, but the industry is not completely in the clear. "For example, I've heard of crew complaining about it when crew quarters are right above the machinery space in the engine room."

Although vibration from rotating machinery tends to cause the more serious issues, just being on a boat in the water vibrates the body at low frequencies. According to the American Bureau of Shipping (ABS), this movement can lead to "motion sickness, body instability, interruptions of task performance, sleep interruption and fatigue, increased health risk aggravated by shock loads due to slam, and reduced human efficiency."

The Basics of Noise and Vibration

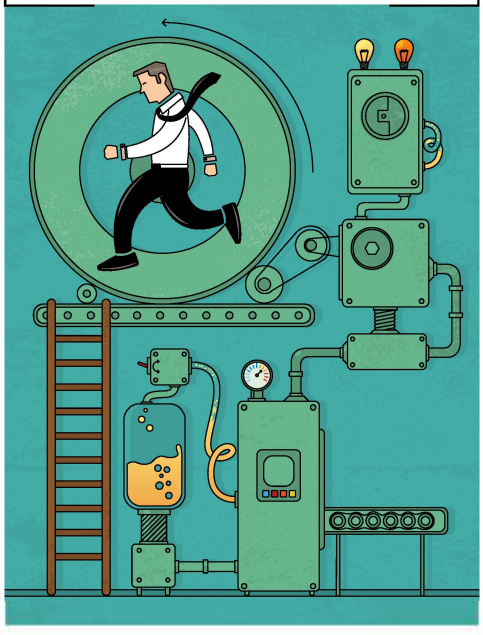
There are two kinds of vibration issues on boats: airborne and structure borne. At the most basic level, airborne vibration is movement you can hear (noise), and structure-borne is movement you feel (vibration).

"Structure-borne vibration is one of the biggest producers of noise and vibration on boats," says Merhige. "Noise can travel and telegraph through a structure, so you can have a noise all the way at the back of the stern and hear it clear as day on the bow if it's transmitting through the structure."

Bill Johnson, owner of Engineering Concepts, has found there's a demarcation point that divides when a vibration is primarily felt or heard – 18 hertz (Hz) or 1,080 cycles per minute (CPM) or revolutions per minute (RPM). On the higher end – over 18 Hz or 1,080 CPM/RPM – is when you'll hear the vibration through high-frequency noise.

The lower end, under 18 Hz/1,080 CPM/RPM, is when you'll detect the vibration in your body. "When you go below that, you're basically into structure-borne stuff," says Johnson. "Your hearing doesn't pick it up."

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This sort of structure-borne vibration occurs when part of a structure vibrates the surrounding air molecules and transmits that movement throughout the entire boat. "Structure-borne noise is a lot worse," says Johnson. "It can transmit much farther than airborne noise, which gets absorbed by the walls, curtains, furniture, and other soft coverings such as carpet."

All vibrations can affect the body; however, these low-frequency vibrations can drive people nuts, especially when exposed for long periods. According to an article in *Air Medical Journal*, vibrations with low frequency and high-amplitude motion between 1 to 100 Hz can cause symptoms such as loss of appetite, interest, adrenergic sweating, salivation, nausea, headaches, fatigue, and vomiting.

"It literally shakes you, like if someone were to shake your body violently for hours on end," says Johnson. "I can't think of anything in the outside world that would compare, other than driving down a bumpy road at a high speed. You're going to feel it physically where your muscles and bones meet but your ears are going to be fine."

Merhige likens the physical sensations to that of an earthquake. Those movements in the earth "generally radiate seismic waves in the frequency range of 0.01 to 10 Hz," according to a paper in *Geophysical Research Letters*.

"I guess it goes back to our caveman instincts," says Merhige. "If something is vibrating at a very low frequency, like a seismic vibration from an earthquake or a volcano, our instincts kick in and we don't like it – it's very uncomfortable."

The *Textbook of Maritime Health* by the Norwegian Centre for Maritime and Diving Medicine has guidelines for equivalent acceleration annoyance for whole-body vibration. Anything above one millimeter per second will create body discomfort. "A really smooth, comfortable running boat is one millimeter per second," says Merhige. "When you start getting to three millimeters per second and up, it becomes noticeable." According to the textbook, more than 2.5 millimeters per second vibrations are classified as "extremely uncomfortable."

Higher-frequency vibration affects comfort, too. Vibrations associated with rotating machinery that range from about 1 to 80 Hz can cause discomfort and reduced human efficiency, claims ABS.

Again, while not common it does exist in yachting. The Danish Maritime Authority has found that long-term, whole-body vibrations may cause joint disorders or diseases, which are



PHOTOGRAPHY: COURTESY OF HEESEN; ILLUSTRATION: MUSTAFAHACALAKI/ISTOCK



Heesen worked closely with Rolls-Royce when building Project Cosmos to address cavitation issues around the propeller design to reduce noise.

especially common in the spine. And people standing on a vibrating foundation for extended periods may feel pain in feet, legs, and back.

According to a European Union directive, exposure to whole-body vibrations must not exceed 1.15 millimeter per second for an eight-hour working day. Remember that falls into the "uncomfortable" category, so if something is shaking to the point where you can feel it, the directive says that you should not be working in those conditions for a full workday. And it says that at 0.5 ("slightly uncomfortable"), you must examine the cause and prevent exposure.

There's a reason the directive has outlined specific guidelines. Studies show that exposure to whole-body vibration can lead to an increased risk of developing musculoskeletal disorder symptoms, peripheral vascular (circulatory), sensorineural (hearing loss) problems, and other diseases. And repetitive exposure to long-term vibration results in a reduction in tactile sensitivity and loss of manual dexterity.

Higher-frequency noise issues are far more common in industrial settings. Newer yachts and those that have been well maintained feature soft-mounted mechanical components to prevent transferring vibration or noise to the hull. Floating floors are used to isolate reverberation and sound. And bulkheads are outfitted with insulation to keep living quarters as quiet as possible.

> All vibrations can affect the body; however, these low-frequency vibrations can really drive people nuts, especially when exposed for long periods.

Many shipbuilders, such as Christensen Shipyards, target a sound level of 60 decibels (dB) in the cabins next to the engine rooms when the engines are running. That is about the equivalent of a vacuum cleaner (60 to 85dB), hair dryer (60 to 95dB), or a normal conversation. According to the U.S. Centers for Disease Control and Prevention, noise above 70dB can start to irritate people and, when exposed to such sounds for an extended period, may start to damage hearing.

In engine rooms, things like squeaky bearings and ventilation fans can produce strong airborne noise frequencies that sound like a whistle and, over time, could impact hearing. Because the sound is annoying, it would likely be noticed and fixed fairly quickly on a yacht.

The Common Culprits

When shipyards cannot figure out how to fix the underlying causes of vibration or noise, captains often turn to experts. While every case is different, the same issues tend to show up.

One of the top sources of vibration and noise is the propellers. While there are several things that can go wrong, often it's a matter of fit. In many cases the propeller isn't properly fitted to the shaft, which causes it to shake and vibrate the entire vessel. "Every boat I've had over the last three years that had a vibration issue was a prop fit issue," says Johnson. "The propeller is actually wiggling on the prop shaft."

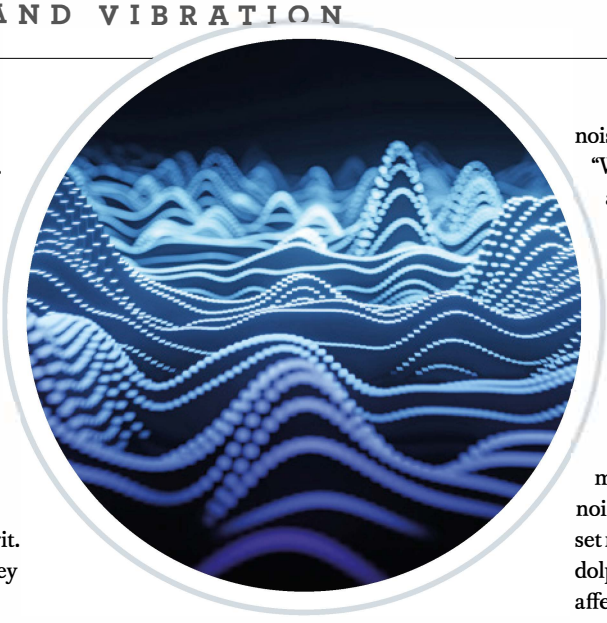
If there's less than 80 percent contact between the propeller bore and the propeller shaft taper, it's going to wiggle. Johnson has found that in cases where it's moving a lot, there's only 40 to 50 percent contact between those two components. This not only increases vibration, but over time (as little as 40 to 50 hours) it will loosen the strut and cause the ports to separate from the hull. "Now you have a problem," says Johnson.

Vibration on the propeller shaft tends to fall under that low-frequency category, the kind that will get under the skin of

everyone on the boat. "It tends to be annoying to people because it's very noticeable," says Merhige.

Another common pathway is the exhaust system. A lot of air and exhaust gas pass through a diesel engine, which essentially operates like a giant air pump. That exhaust typically leaves the engine underwater through a pipe that's isolated from the hull. When there are issues, you get more of that irritating low-frequency vibration. "One of the things that gets me is when people say the vibration goes away at high speeds," says Merhige. "Yeah, it does, because you're not perceiving it as much."

Engine mount issues are also a common culprit. Rubber components only last 10 to 15 years, so they eventually give way. When they do, they tend to emit slightly higher frequency vibrations (but still pretty low), most noticeable when you place your hand below the engine. "The vibration is strong," says Merhige.



PHOTOGRAPHY: FLAVIO COELHO VIA GETTY IMAGES

Finding the Source

Experts have several tools to find the source of problems. Many use accelerometers to measure specific frequencies that can help pinpoint problems. Merhige says he measures vibration on the machines as well as the foundations to see if there's a reduction in performance in the isolators used to tamp down on mechanical vibrations. "You should have an 80- to 85-percent reduction of vibration on isolator mounts," he says.

As technology has improved, so have the diagnostic tools. RINA has started incorporating noise-detecting cameras for hard-to-locate issues. "With a noise camera, you can see the frequency and exactly where the noise is leaking," says Fiorenzo Spadoni of RINA. "It's a matter of quickness of detecting a noise."

Although RINA offers state-of-the-art detection technology, Spadoni says that onboard noise and vibration is not a serious problem for the industry given that comfort is a huge focus. However, he does warn that he sees underwater noise becoming a problem as more ports and regions aim to curb underwater noise pollution. Late last year, the EU Commission set new underwater noise limits to protect whales, dolphins, and other marine species that have been affected by ships.

"This could be a very big challenge for the yachting sector when there are more protected areas, where you have to stay below a certain level, because the vast majority of yacht exhausts go underwater," he says. But as technologies continue to improve and evolve, addressing noise and vibration all around the vessel will get easier. "It will be more achievable than it is today with electric propulsion and other advances."

