

NOISE & VIBRATION DESIGN GUIDANCE
BOW THRUSTERS
(Prepared by Noise Control Engineering, Billerica, MA)

GENERAL

The following rules of thumb should be followed with respect to the location and design of tunnel thrusters.

1. The centerline of the tunnel should be a minimum of one duct diameter above the baseline.
2. The centerline of the tunnel should be a minimum of one duct diameter below the lightest water line.
3. The minimum axial distance from the lower opening edge to the impeller is one duct diameter.
4. The minimum length of the tunnel at centerline is two duct diameters or there is potential for turbulent flow, which also reduces thrust.
5. The hull should be dished downstream of the tunnel opening. The major axis of the dish should be approximately 15 degrees below the horizontal (or follow flow lines) and the angle from the tunnel opening to the edge of the un-dished hull should not exceed 15 degrees (see Figure 9).
6. The radius of the inlet along the hull interface should be 0.05 times the duct diameter.
7. The grill should follow the water streamlines, typically 15 to 20 degrees off the horizontal.
8. The grills themselves should not be flat bar but aerodynamically shaped with rounded leading edges. Grills should take up as little free area as possible. Maximum opening blockage should be 10% to 15%.
9. The axial spacing between the grill and impeller edge should be a minimum of 0.3 times the duct diameter from the impeller.
10. Struts holding the impeller should be faired as much as possible to reduce turbulence, especially when thrusting in a direct where the flow hits the struts before the impeller.
11. Reduce strut cross sectional area as much as possible.
12. Place generous fillets between strut and tunnel wall to reduce vortices.
13. For twin tunnel thrusters, distance between centerlines should be 1.5 duct diameters to 2 diameters for Fixed Pitch Impellers (FP); distance should be as small as possible for Controllable Pitch Impellers (CP).

IMPELLER

1. Increased impeller pitch may produce the same thrust but at a lower rotation rate, which is equivalent to a lower tip speed.
2. Impeller tip speed should be less than 100 fps.
3. A skewed impeller shape has significantly better low frequency performance than one with a radial trailing edge. Skew for "reverse" thrust since this should not harm "ahead" thrust; requires careful hydroacoustic design. For side-by-side tunnels, the skew could be in opposite directions.

NOISE & VIBRATION DESIGN GUIDANCE
BOW THRUSTERS
(Prepared by Noise Control Engineering, Billerica, MA)

4. Consider trade-off between increased tip clearance, which reduces unsteady load at tips that operate in the strut wake, and affect on tip vortex cavitation and thrust performance.
5. Adjust blade pitch distribution to unload tip.
6. Consider odd number of blades, which are susceptible to lower amplitude wake harmonics, therefore generate lower forces.
7. Impeller should have symmetrical blade sections and well rounded edges for equal performance in either direction.

ABATEMENT TECHNIQUES

The best noise control approach is to attack the noise at the source. The source in this case is the impeller. Obviously the best condition is a non-cavitating impeller over the entire operating range. This is seldom achieved. The next best approach is to delay cavitation inception to as high an operating power as possible. Since thrusters are not often operated at full power, but rather at partial power, this approach can definitely improve the acoustic conditions onboard. Often, improvements that delay cavitation inception also improve the thrust developed by the system. The best method to delay cavitation inception is to improve the inflow conditions to provide a uniform inflow into the impeller disc. These methods were described in the preceding section. As discussed previously, once the impeller cavitates, its noise level is proportional to the ratio of cavitating area to the impeller disc area. In this sense all bow thrusters are equally bad actors.

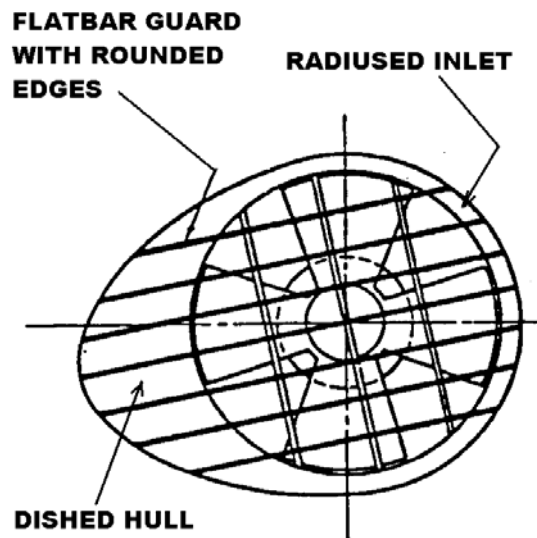


Figure 9: Grill Alignment, from Reference [1]

Low noise impeller designs exist. These typically make use of skewed blades. In some cases, skewing the blade forward may relieve the tip overloading and provide a more uniform loading over the entire blade. The next best non-engineering approach is not to place berths or noise

NOISE & VIBRATION DESIGN GUIDANCE
BOW THRUSTERS
(Prepared by Noise Control Engineering, Billerica, MA)

sensitive compartment within one deck or two compartment longitudinally of the thruster room. Place storage or refrigeration lockers in this area.

SOURCE TREATMENTS

Some thruster vendors are aware of the adverse impact of their system on the vessel and crew. These vendors have carefully considered the hydro-acoustic design or provided built-in acoustic controls. One example is a tunnel thruster that is installed as a double skin tunnel with resilient attachment between the two skins. Studies done by Andresen and Nilsson [2] show that an isolation mounted tunnel with air in the cavity between the two shells can reduce the vibration onboard the vessel. The percentage of air in the cavity is a controlling factor in the performance of this type of treatment. Furthermore, to achieve a high level of vibration reduction, the entire tunnel over its entire length must be resiliently supported. Other vendors claim only an 8 dB reduction in the A-weighted noise for a double wall tunnel with isolators. The cost of these special units needs to be considered against the cost and risk associated with the design and installation of the treatments described in the following sections. Vendors should be able to justify their noise reduction claim with measured noise and vibration data.

Other vendors will supply air injection systems with their thruster. These Prairie type masker systems decouple the wall from the high hydro-dynamic noise induced by the impeller. The air can be injected near the tunnel inlet or near the impeller. This generally takes the form of perforated air emitter pipes located on the perimeter of the duct. This air would be pulled into the thruster, mix with the cavitation, resulting in a gaseous cavitation-ventilation mixture. This mixture would cushion the bubble collapse and thereby reduce the induced vibration and structureborne noise. The additional air would also provide some absorption in the tunnel.

These air systems have provided significant interior noise and underwater noise reductions. Measured noise reduction on one system is 10 dB in the frequency range above 500 Hz. However, these systems also tend to increase the low frequency noise in the range below 100 Hz. This is generally acceptable since the ear is less sensitive at these low frequencies. For instance, a person's perception of a noise level of 92 dB at 80 Hz is the same as a level of 70 dB at 1000 Hz. The amount of reduction achieved by air injection is limited by the potential for other flanking paths for the hydro-acoustic induced noise.

Passive treatments can be employed to reduce the thruster induced noise and vibration. Selection of the optimum approach depends on many non-acoustic factors such as available space, weight constraints, cost and impact on the ship operation. In addition to "source" treatments, two other types are generally classified as treatment of the acoustic path and treatment of the receiver space. Source treatments are those directed at the hydro-acoustic environment. Active noise or vibration cancellation treatments are not yet a proven abatement approach.

PATH TREATMENTS

Only one type of path treatment is generally considered - damping. Noise is carried to adjacent compartments primarily over the structureborne path. Though the airborne noise level in the

NOISE & VIBRATION DESIGN GUIDANCE
BOW THRUSTERS
(Prepared by Noise Control Engineering, Billerica, MA)

bow thruster compartment itself is usually on the order of 100 dB(A) or greater, receiver spaces are rarely adjacent to the thruster compartment. Thus, airborne transmitted noise is usually not a concern. However, if there is a receiver space with a common interface to the thruster room, this interface should be treated with a high transmission loss material, e.g., a limp mass-loaded material sandwiched between compliant layers such as fiberglass.

Damping treatments generally consist of visco-elastic tile material attached to hull plating between the frames. These tiles convert the structureborne energy to heat via a shearing process thereby attenuating the propagation of structureborne energy to the receiver. The effectiveness of this type of treatment depends on the total path length. Damping treatments are typically most effective over the mid- to high-frequencies, the same range over which the source levels are highest. Given the proper amount of damping treatment - that is sufficient path length to the receiver and treatment of all potential structureborne paths by a well designed damping treatment - the received A-weighted noise level may be reduced by 5 to 7 dB, at best. Constrained¹ damping has the potential of reducing noise by 8 to 12 dB, but at a significant weight penalty. Damping on the tunnel wall itself is usually ineffective. This is due to the high inherent impedance of the curved tunnel and its high inherent damping through water loading and the multiple hull connections.

RECEIVER TREATMENTS

"Floating" cabins can be used to mitigate noise in compartments located near a bow or stern thruster. A floating room has finish surfaces connected to the hull through resilient mounts. The gap or void between false deck and structural bulkheads is partly filled with thermal and/or acoustical insulation. This type of treatment attenuates both high structureborne sound and airborne sound. Properly designed and installed, this type of treatment should provide a minimum of 7 dB reduction in the A-weighted noise to a maximum of 20 dB. The most critical parameter in this system is the height of the gap between this deck and the structural deck. The void or gap between the structural and false deck should be between 50 and 100 mm depending on the desired noise reduction. A 100mm gap provides an effective treatment for low frequency noise (which is not usually a problem for bow-thruster induced noise) [3,4].

Damping in the form of special tiles or a resilient underlayment covered by a poured floor can reduce the noise in the receiver compartment by 3 to at most 5 dB. If the deck is not the primary noise radiator, "cladding" treatments can be added to the interior of the bulkheads that control the received noise level. These cladding treatments consist of two layers of a compliant material, typically 50 mm thick 50 kg/m³ density fiberglass, with an intermediate limp mass layer with a surface density of 5 kg/m².

¹ Constrained layer damping has a cover plate, nominally the thickness of the bottom plate, on top of the damping material to provide additional shearing.

NOISE & VIBRATION DESIGN GUIDANCE
BOW THRUSTERS
(Prepared by Noise Control Engineering, Billerica, MA)

References:

1. Raymond Fischer and Leo Boroditsky, "The Future of Shipboard Noise Predictions," International Cooperation on Marine Engineering systems/ SNAME, ICMES 2000, New York, May, 2000.
2. Neal Brown and John Norton, "Thruster Design for Acoustic Positioning Systems," Marine Technology, April 1975 (also presented as SNAME San Diego Section paper, date unknown).
3. NAVSEA DDS 568-1, Thruster Maneuvering Systems, Nov 1987.
4. Raymond Fischer and Leo Boroditsky, SNAME Supplement: Design Guide for Shipboard Airborne Noise Control, NCE Report 99-001, draft submitted via USCG to SNAME, Oct. 1999 (not yet published).