Bollard Pull

A HydroComp Technical Report
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Overview

Bollard pull is a term often used to describe the pulling capability of towing vessels. However, the term "bollard pull" has developed three different meanings, and it is important to know which intended meaning is being used. To help clarify the understanding of bollard pull, let's modify the terms into the following.

- *bollard pull rating* – a theoretical thrust
- *bollard pull thrust* – the actual thrust delivered by the propeller
- *bollard towpull* – the useful pulling thrust

Bollard pull rating

This is the traditional calculated measure of merit that was used as a "rating" for tugboats. It is simply the theoretical thrust achieved at zero speed of advance and full engine RPM. Bollard pull rating is an abstract (and somewhat academic) state that cannot be achieved in real operation. This is due to two things – propellers accelerate water as they spin so they never really see water at zero speed, and engines typically do not reach full RPM at towing speeds (as their propellers are "overloaded" at towing since the pitch is typically sized for a speed higher than the towing speed).

The thrust of a bollard pull rating was convenient to calculate since all you needed was one point from a propeller curve (e.g., KT at J=0) and the engine's rated RPM (with reduction ratio, of course). This calculated thrust – albeit fictional – provided a simple numerical figure to compare one tug's potential thrust against another in a towing scenario.

In HydroComp software, you can calculate the bollard pull rating by entering a nominal zero speed (e.g., 0.1 knots) and selecting the *Bollard (rated RPM)* Service option in PropExpert or *Fixed RPM* Analysis type in NavCad.

Bollard pull thrust

The bollard pull thrust will be calculated using real water velocity, estimates for hull-propulsor interaction coefficients (e.g., wake fraction and thrust deduction), and the true equilibrium engine RPM. A value for water velocity is either a nominal zero speed (e.g., 0.1 knots) if you want a calculation of maximum static thrust, or it could be the real speed at towing (e.g., 3 knots) for an evaluation of what would be expected under these conditions.

Estimates for the hull-propulsor interaction coefficients are usually provided in the calculation software. Fortunately, the sensitivity of these figures is minimal at low speeds, so it is usually unnecessary to consider corrections for things like shallow water or high thrust loading.

The calculation of equilibrium RPM is an iterative process to find the point where the engine can no longer turn the propeller any faster (i.e., the equilibrium torque condition). The shape of the engine's rated power curve affects the calculation, where engines with fuller power at low RPM can provide more torque at towing and therefore more RPM and thrust. Also remember that this is the useable delivered thrust, which is the open-water thrust with the thrust deduction losses. This is the thrust that would be measured with a load cell during an actual bollard test.

In HydroComp software, you can calculate the bollard pull thrust by entering a speed (as described above), defining the engine power curve, and selecting the *Towing* Service option in PropExpert, or *Towing* Analysis type in NavCad.

Bollard towpull

A certain amount of thrust must be used simply to move the vessel. This requires a minor correction to the bollard pull thrust to deduct the boat's own drag from the calculated delivered thrust to determine the net useable thrust. There is no resistance at zero speed, so this is unnecessary if you are considering a nominal zero speed case, but it does measurably affect the useable delivered thrust at real towing speeds.

In HydroComp software, this is calculated and displayed as *Towpull*.

Propeller sizing for towing

Selecting propellers for a bollard condition or towing operation requires compromise. The temptation to select a propeller for nominal zero speed (and its associated small pitch) risks serious performance consequences. With the small pitch optimized for zero speed, the vessel pays a penalty in free-running speed as the governor limits its RPM. Face cavitation and vibration are also more likely as the propeller blade sections near the tip may operate at a negative angle of attack when running at top speed.

In general, the propeller should be selected for a trade-off between the thrust needed at towing speed and the top free-running speed. An increase in one leads to a reduction in the other – increasing pitch makes the free-running operation more efficient, while a reduced pitch improves towing thrust. Therefore, the propeller should be selected for a design speed somewhere between the two. Some typical guidelines are:

1. Typical analysis speeds are 0.1 knots for the bollard pull rating, 3-4 knots for continuous towing, and 9-12 knots at free-run. Of course, these will depend on the characteristics and duty of the vessel.
2. A compromise design speed can be found at the average of the towing and free-running speeds.
3. Design power and RPM is recommended to be 80% to 90% rated power at 100% rated RPM.
4. Use an equilibrium-torque towing analysis to provide attainable delivered thrust and towpull. Evaluate the results, and modify the diameter and pitch as needed to meet any particular requirements, such as to increase towpull or top speed. Remember – improving towpull will reduce top speed, and vice versa.
5. Run the analysis with a suitable towing application cavitation criteria (e.g., Manen).
6. Good towing performance is often found with propellers at about 0.6 P/D ratio.

Efficient bollard operation should produce about 30 pounds of open-water thrust per engine brake horsepower (180 N per BkW).