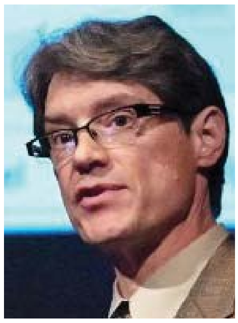
Supplied with kind permission of the ABR Company Ltd, publishers of:
International Tug&OSV
INCORPORATING SALVAGE NEWS

When is bollard pull not really bollard pull?

Donald MacPherson, technical director of US-headquartered performance prediction software company HydroComp, looks at bollard pull – a term he says is often misunderstood and misapplied even by the most seasoned tug industry professionals



► *Donald MacPherson*

One of the worst days that a designer or builder of a tug can have is when the bollard pull test does not meet expectations. After months, even years, of work and anticipation, this is an unwelcome outcome for all involved in the design, construction, or operation of tugs.

So why does this happen? There are principally two reasons: the term 'bollard pull' is misapplied or misunderstood, even by seasoned professionals, and an overly simplistic prediction for bollard pull is used in the design stage.

In this brief article I hope to help clarify the nature of bollard pull, and to describe what makes up a tug's real ability to generate towing thrust.

The term bollard pull describes a very precise function – the static pulling force of a tug when its hawser-line is connected to a fixed position on shore. (The shore-side attachment is called a 'bollard', hence the name for the operation.) In other words, it is the *attainable* towing force on the hawser at *zero vessel speed*. The two terms highlighted in italics are important to properly understanding the scope and limitations of bollard pull.

Anything different from this narrow scope of operation, such as the towing force at any speed other than zero, is not bollard pull. The tug's pulling force across its entire speed range is its 'towpull'.

Figure 1 below illustrates delivered thrust, vessel resistance, and resulting towpull across a speed range for a particular vessel, engine, gearbox, and propeller. The upper curve is the maximum potential delivered thrust, which is the useful force that can be applied to the towed or pushed object. The tug's own resistance is the lower curve, and the difference between the two – that potential force over-and-above the thrust needed to move the vessel itself – is the towpull. The bollard pull point is found on the delivered thrust curve at zero speed (approximately 230kN for this example), and the tug's own free-run top speed (without any additional tow) is where the curves cross (at 13 knots).

"The broad misuse of the term 'bollard pull' to mean 'towpull' too often leads a well-meaning designer to a conclusion that is not fulfilled in service"

Donald MacPherson, technical director, HydroComp

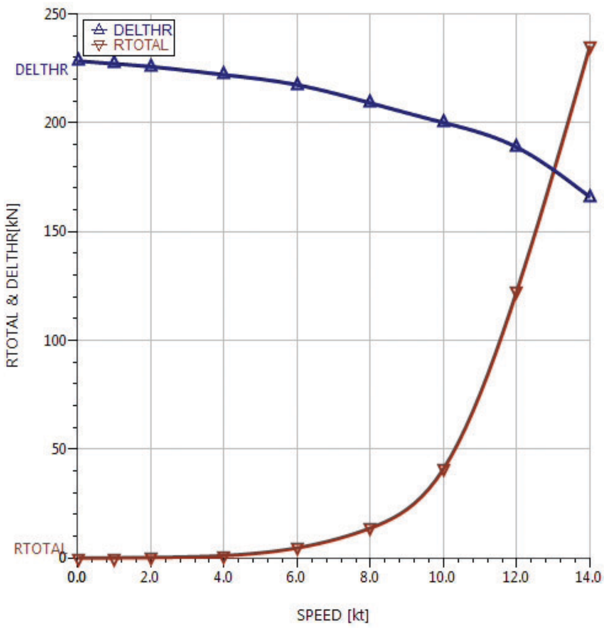
It is important to correctly understand that a statement of the thrust needed to tow an object at some particular speed is not its 'bollard pull' requirement. Figure 1 illustrates the problem that can be caused by this confusion. Say the towing speed for a barge was 6 knots, and one of the many publications or online calculators so titled for 'required bollard pull' predicted 230kN for this speed. This is the thrust requirements at 6 knots, not at the bollard pull specification of zero speed.

The tug described by the plot does indeed comply with a 230kN 'bollard pull' requirement, but it does not produce 230kN of towpull at 6 knots. Rather it is some 5 per cent short. The broad misuse of the term 'bollard pull' to mean 'towpull' too often leads a well-meaning designer to a conclusion that is not fulfilled in service.

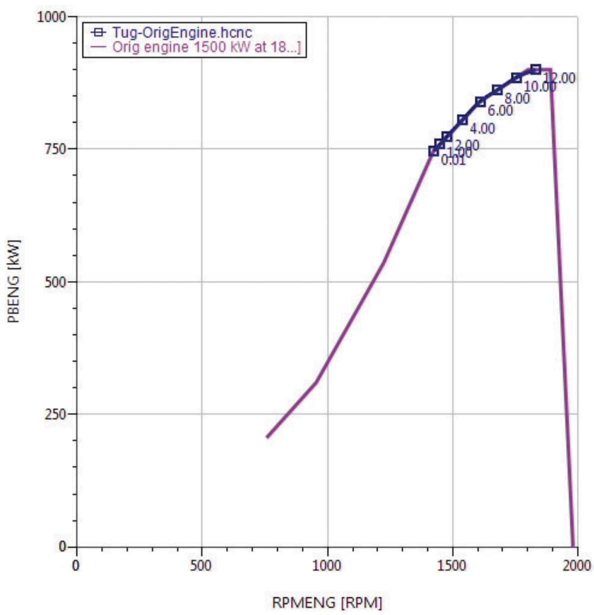
As stated previously, towpull is a system result. It requires that the components be properly matched, particularly the propeller pitch, reduction gear ratio and engine power curve. While most readers will have experience in the importance of proper pitch matching, the shape of the engine's power curve can also be a valuable contributor to optimum towpull.

The plots below (Figures 2a and 2b) are for two engines of identical rated power and rev/min, but with different power curves. In the same way that bollard pull is just a single point on the towpull curve, an engine's rated power and rev/min is also just a single point on the power curve. It is used to describe a capability, but it does not tell the whole story.

An increase in engine power along its



▲ *Figure 1 – Delivered thrust and resistance*



▲ *Figure 2a – Engine power curve*

Supplied with kind permission of the ABR Company Ltd, publishers of:
International Tug&OSV
INCORPORATING SALVAGE NEWS

curve provides more than 10 per cent increase in bollard pull (with a diminishing increase in towpull), as shown in Figure 3. It is easy to see how selection of a suitable engine model with a propeller matched to that engine's power curve is absolutely vital to achieving maximum towpull.

The recipe for generating towpull, and therefore to reliably predict towpull, is composed of three principal parts:

- Propeller thrust at a particular rev/min;
- An engine with the power-making ability to reach that rev/min;
- Interaction between the propeller and hull.

The only method to fully model a system that considers all ingredients is an 'equilibrium torque' calculation. Properly configured commercial propulsion analysis software, such as HydroComp's NavCad and PropExpert software, can provide this calculation.

> *"Unfortunately, it is still a practice in some companies to use simplistic calculations for the prediction of bollard pull, whereby the propeller thrust is calculated at zero boat speed and full rated engine rev/min"*
>
> **Donald MacPherson, technical director, HydroComp**

HydroComp PropElements propeller design and analysis software can further refine towpull predictions for ducted propellers by allowing consideration of the influence of headboxes and inflow disruption on nozzle effectiveness. All of these tools are commercially available and appropriate for any design office.

A systems-based analysis can further reveal another widely held misconception – that bollard pull will always be the highest value of the towpull curve. Not so. Depending on the shape of the engine curve, a propeller with too-high pitch can reduce bollard pull below towpull.

Figure 4 shows the towpull curves for identical systems, except for a small difference in propeller pitch. In this example, an over-pitched propeller will result in a bollard pull test that is some 15 per cent less than its peak towpull.

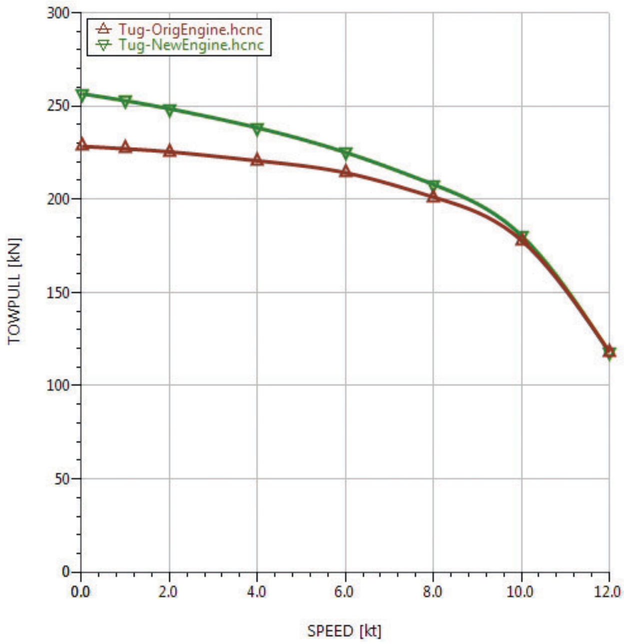
Unfortunately, it is still a practice in some companies to use simplistic calculations for the prediction of bollard pull, whereby the propeller thrust is calculated at zero boat speed and full rated engine rev/min. There is no consideration if the engine has sufficient power to be capable of reaching that rev/min, or any evaluation of the real deliverable towpull.

Furthermore, simplistic calculations do not consider the effect of cavitation breakdown during bollard pull operation. It is critical to use a calculation tool that not only predicts the thrust breakdown on the propeller, but also provides a criteria check for the potential of thrust breakdown on the nozzle of a ducted propeller system. A simplistic calculation can result in too-optimistic prediction of bollard pull, and the measurements from the bollard pull test would greatly fall short of the expectations proposed to the owner or operator by the designer or builder.

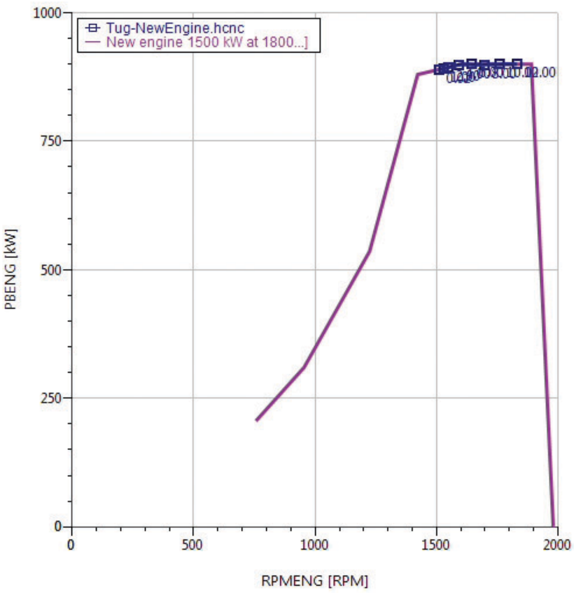
To sum up, even though it is not a complete measure of a tug's comprehensive towing abilities, the measurement and calculation of bollard pull still has commercial value. Right or wrong, it is often the one metric that determines which tug gets the job.

Therefore, a clear understanding of the nature of 'bollard pull' and how it relates to the broader towpull of a tug is critical to successfully meeting expectations.

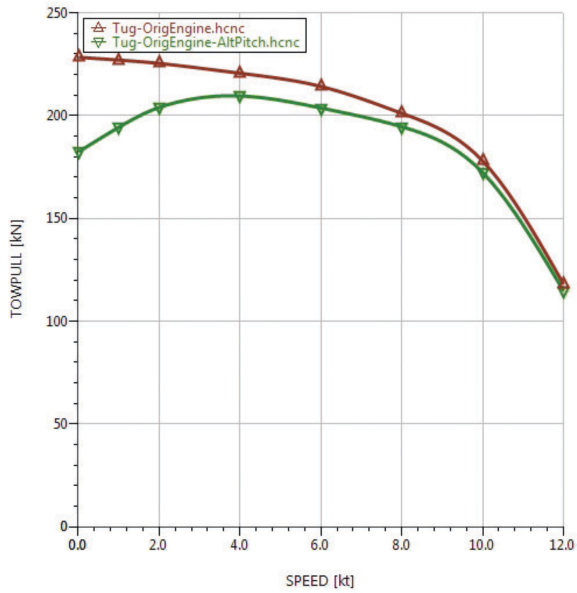
One step that any design office can take is the use of accurate bollard pull and towpull prediction methods. These must properly characterise the integrated physics of the propulsion system – hull, propeller, gearbox and engine.



► *Figure 3 – Increase in towpull with a change in engine power curve*



▲ *Figure 2b – Engine power curve*



▲ *Figure 4 – Bollard pull reduction with over-pitched propeller*