OPERATING CONTROLLABLE PITCH PROPELLERS (CPP) IN KORT NOZZLES

Preamble
There needs to be a good understanding by tugmasters of the Controllable Pitch Propeller (CPP) and how it performs inside a Kort Nozzle.

Most tugs with CPP when engaged in towage operations will operate in the Combination Mode setting, whereby the propeller pitch is linked to the engine RPM. Move the throttle control lever forward to increase the pitch and the engine RPM also increases, and visa versa.

The alternative is to operate in the set engine RPM Fixed Mode and then control the propeller thrust by adjustments of the CPP pitch, again via the throttle control lever that now only influences the propeller blade pitch. This mode is generally used when:

- Fire fighting if the tug's FiFi pump runs off the main engine/s, or
- Undertaking towage in confined waterways such as locks, or
- If there is a shaft generator fitted.

Training Bulletin
This training bulletin has come about following an incident whereby a tug with CPP lost an engine due to automatic overspeed shutdown. It was identified during the investigation that the shutdown of the engine may have been caused by inadvertently incorrect use of the reverse pitch feature of the Controllable Pitch Propeller (CPP).

Given there is generally only one Combinator (throttle) Lever detent at the neutral (0°) pitch position between forward and reverse pitch this is easily done. Consequently, it is felt focus on this is required along with training to ensure appropriate outcomes. It is also recommended that tugmasters read the relevant section of their Azimuth Operating Manual pertaining to the Main Propulsion Control and CPP operational features.

A Possible Scenario
When using the CPP in reverse pitch the propeller has significantly less 'bite' in the water due to the cone shape of the Kort Nozzle around the propeller. I.e. the water instead of flowing into the wide (front) mouth of the Kort Nozzle to increase thrust the water flows into the narrow end (back) of the cone shape of the Nozzle. The outcome is the propeller produces approximately half to one third of the thrust astern with reverse pitch than it would ahead.

Also identified is the throttle movement from the (0°) pitch position to full astern RPM & Pitch position is generally half that of the movement required to go from the (0°) pitch position to full ahead RPM & Pitch position.

In the case of some modern combinator (throttle) levers which seen to be designed more for ascetics than practical application; the very small movement required of the combinator control throttles to go from 0° pitch to 100° pitch means a mistake or over driving of the tug is easily achieved.

Key Points
A possible scenario being:

- ⚓ A tugmaster in the tension of the moment does not realise where the Azi Pod is facing,
    - The Azimuth Pod may be aft if engaged in (say) Bow Ops.
- ⚓ He/she applies full throttle (RPM) then realises it is actually reverse pitch,
    - In turn creating an unwanted outcome.
- ⚓ Realising this the tugmaster then moves the throttle quickly through to full ahead RPM/Pitch.
- ⚓ The engine RPM responses quickly to this throttle command,
    - In trials I have undertaken the engine stays at full RPM throughout.
- ⚓ But the CPP takes significantly more time to take off the reverse pitch and then apply ahead pitch,
    - In trials I have undertaken this can be up to 17 seconds.
- ⚓ This means the engine RPM is accelerating up to full or staying at full with little load (torque) from the propeller when the propeller blades are at of near 0° pitch.
- ⚓ Also of influence is the possible torque created by water flow pressure, should the tug be making way.
- ⚓ This may cause the engine to over-speed, in turn triggering the automatic shutdown due to the over-speed feature of the engine management system.

Management of the Situation
To effectively best manage this situation I recommend the following:

- ⚓ Tugmasters have thorough working knowledge of how the CPP system operates when the propeller is encased in a Kort Nozzle.
    - To this end see Appendix 1.
- ⚓ The dent in the throttle control is adjusted to be as noticeable (firm) to the feel as reasonably possible.
- ⚓ Tugmasters of tugs with Azimuth Pods, Kort Nozzles and CPP should be trained and remain conscious that they should not move the throttle quickly from full astern RPM/pitch to full ahead RPM/pitch (or visa versa) without a pause period of at the 0° dent neutral position, while waiting for the propeller blades to get to 0° pitch and the engine RPM to decrease, before actioning the next step in moving the combinatory throttle control to the next setting.
    - The tugmaster should observe via his/her instrumentation that the CPP pitch is at zone before increasing the engine RPM.
- ⚓ All throttle movements should be slow and controlled.
    - From trials if the throttle is moved from full astern pitch to full ahead pitch in one quick movement the engine RPM remains at full power throughout the entire period of pitch change.
- ⚓ The above in turn means there is a significant period of time when the engine has no propeller load on it,
    - This may expose the engine to over-speed and an associated automatic shutdown.

Different CPP Operating Modes

- ⚓ **Free sailing mode:** is used when the tug is transiting or escorting only, and
- ⚓ **Harbour mode:** is used when the tug is engaged in towage or assisting in berthing.

The difference is in **free sailing mode** you get a bit longer pitch stroke due to reduced engine loads in this type of operation, hence higher vessel speed through the water.

For a more comprehensive understanding of the system tugmasters should read and familiarise themselves with the relevant information to be found in the Azimuth and CPP Operations Manual.

Appendix 1

UNDERSTANDING CPP OPERATING WITHIN A KORT NOZZLE

Controllable Pitch Propellers (CPP)
A Fixed Pitch Propeller (FPP) consists of fixed blades. This means that the position of blades cannot be changed. On the contrary, CPP can move its blade in the desired position by changing the pitch of the blades. So what difference does that make?

With FPP the power generated by the engine and the propulsive forces produced by the propeller cannot be controlled. This leads to high amount of power wastage and increased stresses on the propeller. But in a CPP all these negative effects can be prevented, by just changing the pitch of the CPP propeller.

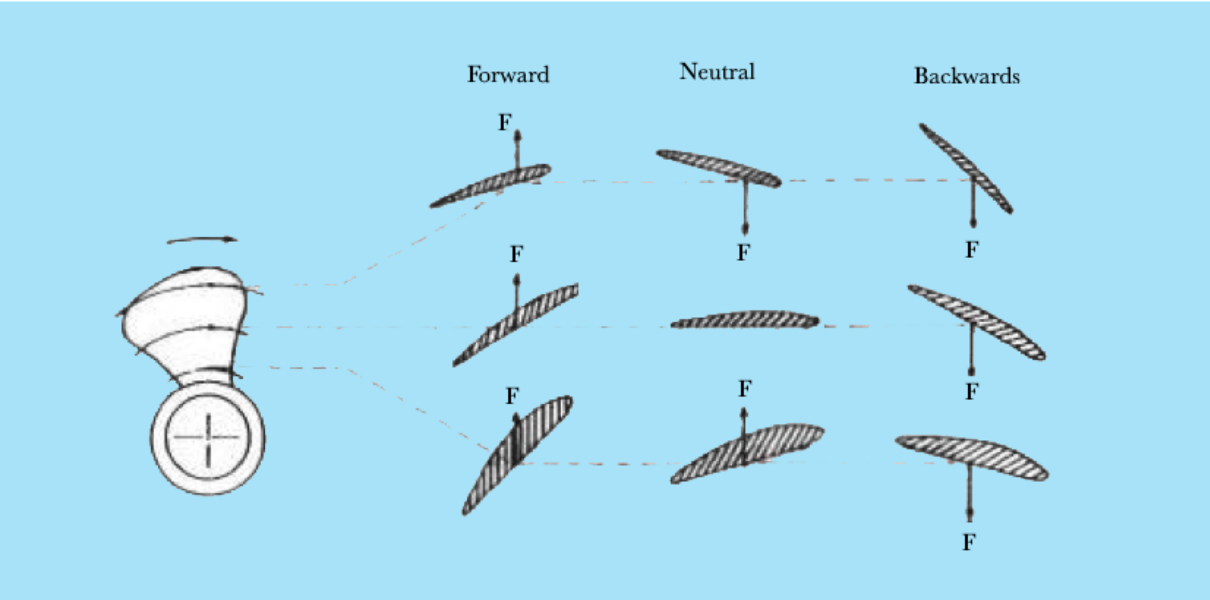
An unique aspect of a CPP is that the propeller rotates in only one direction, unlike FPP. Thus there is no need of a reverse clutch for going astern.

How Variable Pitch Propellers Work?
The mechanism that controls the blades movement is located in the boss of the propeller. This mechanism can be operated from either the engineroom or bridge, with the help of hydraulic cylinders. In case the hydraulic system fails, the blades can be locked in the ahead position with the help of a locking device.

Now let's have a look as to how a ship can be propelled forward and backwards just by movement of the blades.

The diagram shows the cross section of blades. We will assume that the ship is moving in the ahead direction and the arrows shows the direction of the forces generated that pushes the ship forward. When the blade is at zero position, the propulsive forces acting on both the sides are equal in magnitude, but opposite in direction. Even though the net propulsive force is zero, the propeller absorbs a large amount of energy to convert it to wake turbulence. If the ship/tug is to reverse, the blades are moved even further, this will result in a propulsive thrust in the forward direction, facilitating the ship to reverse.

The position of the blades are adjusted according to the load of the ship.



Reference:
https://www.marineinsight.com/naval-architecture/controllable-pitch-propeller-cpp-vs-fixed-pitch-propeller-fpp/

Advantages of CPP

A CPP can operate with minimum or negligible loss in power. This helps to improve maneuverability of the vessel. The direction from ahead to astern can be changed in a relatively short period of time depending on the condition of the load of the ship/tug.

- ⚓ This not only helps to absorb all the power generated by the engine but also helps to prevent wastage of fuel.
- ⚓ In the case of a some vessel/tug CPP the direction of the thrust can be changed within 14 to 17 seconds from.
- ⚓ A CPP can also be connect to a shaft generator or FiFi pump driven via a PTO off the main engine.
- ⚓ It can be used for a wide range of rotational speed.
- ⚓ There is finite control over the propeller wash in confined waterways, such as marina havens or locks.
- ⚓ Slightly higher free running speed can be achieved when compared to a Fixed Pitch Propeller (FPP).

Disadvantages of CPP

The main disadvantage of CPP is that it is a highly complex system.

- ⚓ It is vulnerable due to numerous hydraulic components and sealing rings.
- ⚓ As the sealing rings are outside the ship, damage of a single sealing ring can result in oil pollution.
- ⚓ As the system is complex, repairs and maintenance is difficult.
- ⚓ If encased in a Kort Nozzle the thrust astern when engaging reverse pitch is significantly less than that experienced when thrusting ahead. Usually about half to one third;
    - I.e. If a tug can produce (say) 80 tonne bollard pull with ahead (forward) thrust it will produce ≈40tbp with astern (reverse pitch) thrust.
    - This is due to the water flow coming in the narrow back end of the cone shaped Kort Nozzle.

CPP operating within a Kort Nozzle

To obtain the most thrust, a propeller must move as much water as possible in a given time. A nozzle will assist the propeller in doing this, especially when a high thrust is needed at a low ship/tug speed. If the CPP is within a duct, such as a Kort Nozzle, bollard pull can increase up to 30% over what would be achieved with an open blade propeller.

As we already know, as the propeller blades rotate in the water, they generate high-pressure areas behind the each blade and low-pressure areas in front, and it is this pressure differential that provides the force to drive the vessel. However, losses occur at the tip of each blade as water escapes from the high-pressure side of the blade to the low-pressure side, resulting in little benefit in terms of pushing the vessel forward. The presence of a close fitting duct (nozzle) around the propeller reduces these loses by restricting water flow to the propeller tips.

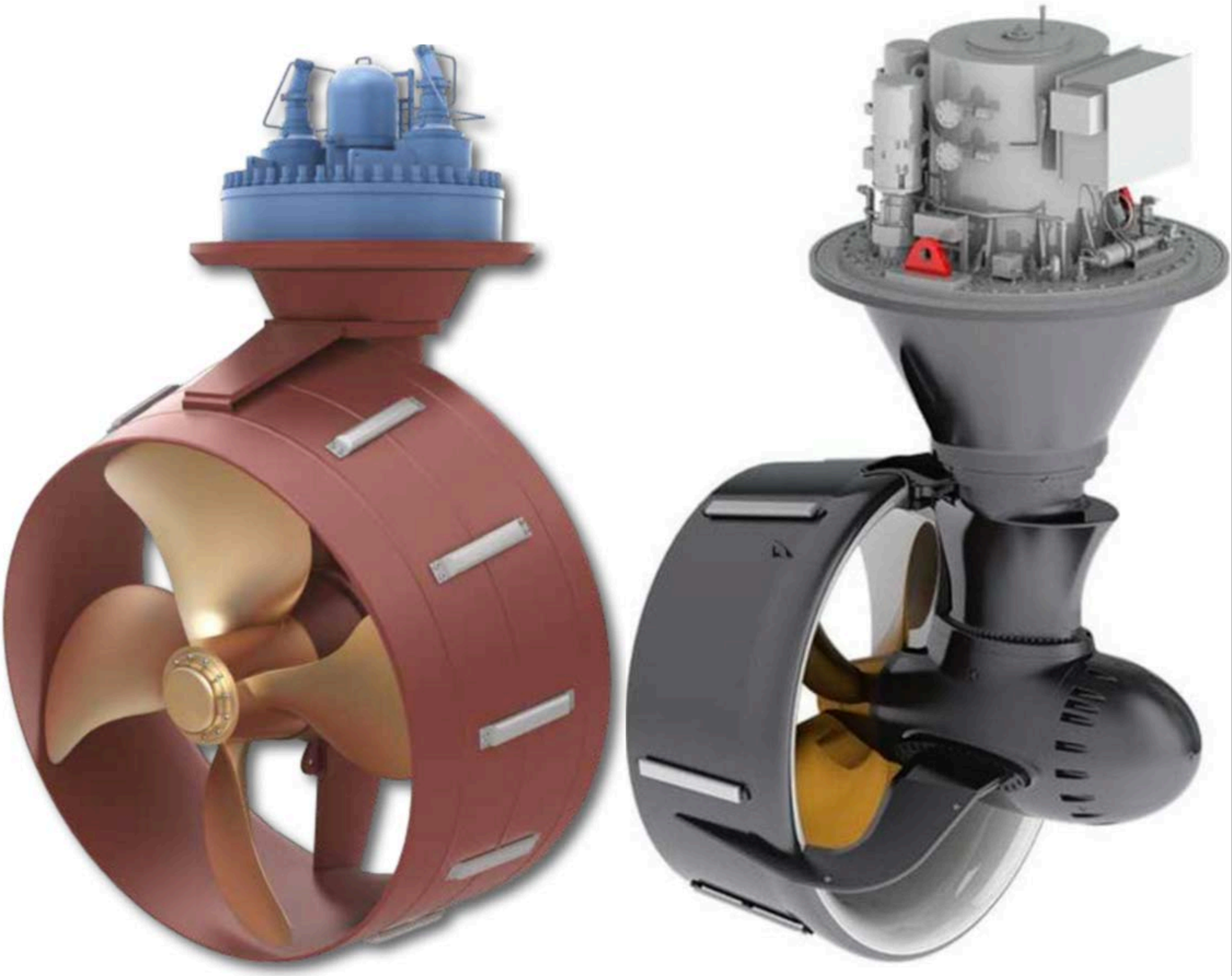
The cross sectional area at the entrance of the nozzle is greater than at the trailing throat. Since the water density is constant, the water must accelerate from one to the other. Hence the water is already moving faster as it reaches the propeller than it would on a conventional open propeller. Therefore, more water is moved and more thrust created for the same input power and torque.

However, there are efficiency gains to be made even when it comes to the nozzle design. Some designs will drag as the speed of the advance increases. With the Kort nozzle design, this drag becomes more significant at higher speeds and can eventually reduce the overall thrust gain to zero.

Types

There are two types of ducts; accelerating and decelerating. With accelerating ducts, the inflow velocity and efficiency of the propeller is increased. This is the type that is used on heavily loaded propellers or propellers with limited diameter. As Ludwig Kort performed extensive research on this type, it is often called a "Kort Nozzle".

In a Kort Nozzle, the inflow velocity is increased, reducing pressure. This lowers thrust and torque of the propeller. At the same time, a circulation occurs, resulting in an inward aimed force, which has a forward component. The duct therefore has a positive thrust. This is normally larger than the thrust reduction of the propeller. The small clearance between the propeller and duct reduces tip vortex, increasing efficiency. As drag increases with increasing speed, eventually this will become larger than the added thrust. Vessels that normally operate above this speed are therefore normally not fitted with ducts. When towing, tugboats sail with low speed and heavily loaded propellers, and consequently are often fitted with ducts.



Above are examples of two leading brands of Azimuth thrusters in Kort Nozzles:

- Rolls Royce (left), with a Fixed Pitch Propeller (FPP) setup
- Schottel (right)