PROPELLER TERMS

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A marine propeller is a fan like mechanism that transmits power by converting the engine's torque into thrust. Usually consisting of two, three, four or more blades, the propeller spins around a central shaft to create dynamics similar to a rotating screw or hydrofoil. When the blades spin, a pressure difference between the forward and after surfaces is produced, accelerating the water behind the blade to create force.

Azimuth Propulsor A propulsion unit consisted of a shroud attached to the vessel's rudder stock with a pod inside fitted with an ordinary propeller and capable of delivering its thrust through 360^{o}.

Blade The blade is an ellipse shaped leaf that extends outward from the propeller boss or hub. The majority of pleasure craft propellers are available in two, three and four blade configurations. Multi-blade propellers offer advantages for high horsepower outboard engines mounted high on the transom with the propeller providing additional bite and stability at higher speed. They can also improve acceleration while maintaining plane with fewer engine revolutions. Because there is more drag, multi-blade propellers do, however, tend to reduce the vessel's top end speed. A high end three bladded propeller usually runs a few miles per hour faster that the same pitched multiple blade design.

The marine surveyor should be familiar with the following terms that attach to the blades of a marine propeller.

- *Blade Back*: This is the suction side or forward side of the blade.
- *Blade Centre Axis*: Linear reference line that indicates propeller rake.
- *Blade Centre Line*: Reference line that intersects each cylindrical section at the midpoint of the blade section width. Is used to indicate propeller skew.
- *Blade Face*: This is the pressure side, pitch side or after side of the blade.
- *Blade Number*: The number of blades attached to the propeller boss, number one blade being that over the key way. The blades are then numbered in accordance with the direction of rotation of the propeller.

- *Blade Root*: This is also called the fillet area and is the area the where each blade attaches to the boss, the region of transition from blade surfaces and edges to the boss periphery.
- *Blade Sections*: These are the shape of a cylindrical section through the blade and are often referred to as Cylindrical Sections. The boss and fillet area account for about the first 20-30% of the propeller's diameter.

- *Blade Sections* are of five different basic types: -

    1. *Circular back sections*: Flat faced with symmetrically rounded back.

    2. *Hydrofoil sections*: Resembling traditional aeroplane wing sections *i.e*., a rounded leading edge with the section's maximum thickness at about one third of the section's length abaft the leading edge.

    3. *Troost B sections*: Sections that are hydrofoil from 0.20 to 0.40 r/R and circular black from 0.65 r/R to the tip and transitional between. The most common modern commercial sections.

    4. *Ogival sections*: Elliptical in shape.

    5. *Supercavitating sections*: A high speed application with a sharp leading edge with the maximum thickness near the trailing edge. Found on surface piercing propellers.

- *Blade Section Length* and *Station*. The section length is the same as blade cylindrical width and each station is expressed as a percentage of the propeller's radius increment.

- *Blade Thickness*: For structural integrity, the blade is thickest at the root. Within each radial section, the point of maximum thickness may not necessarily coincide with the midpoint of the chord length.

- *Blade Thickness Fraction or Ratio*: The maximum blade design thickness as extended to the propeller centre line and divided by the propeller diameter. Blades must have enough thickness to achieve both the desired sectional shape and to provide sufficient strength under loading. Blades that are too thick produce a lower propeller efficiency.

- *Blade Tip*: This is the point of maximum radius of the blade from the centre of the boss and is also the point of separation between the leading and trailing edges.

- *Leading Edge*: This is the edge of the propeller blade adjacent to the forward end of the boss and leads into the flow of water when the propeller is providing forward thrust.

- *Trailing Edge*: This is the edge of the propeller adjacent to the after end of the boss and is the closest when viewing the propeller from aft. The trailing edge retreats from the flow of water when providing forward thrust.

Blade Area Ratio The British Admiralty name for the developed or disc area ratio

Bore The maximum diameter of the hole bored into the boss to take the propeller shaft.

Boss This is the solid cylinder located at the centre of the propeller to which each propeller blade is attached. Boss shapes include cylindrical, conical, radius and barrelled. The centre of the boss is bored to accommodate the engine propeller shaft. In America the boss is called the hub.

Boss Diameter The diameter should be measured and recorded at each end of the boss.

Boss Diameter Ratio The mean diameter of the boss divided by the propeller diameter. Usually about 0.18 to 0.25.

Boss Length The distance between the forward and after faces of the boss.

Camber Often used but usually misunderstood. It is defined as the curvature of the mean thickness line of a given blade section.

Cavitation This term is primarily used in conjunction with propellers and rudders. Often confused with ventilation, cavitation is the phenomenon of water vaporizing or *boiling* due to the extreme decrease in pressure on the forward, or, suction side of the propeller blade. Partial cavitation is normal on most propellers but excessive cavitation can result damage to the propeller's blade surface. Cavitation can be caused by nicks in the leading edge of the blade, bent blades, too much cup, sharp corners at the leading edge, incorrect matching of propeller to the vessel and engine or propeller imbalance. It is usually measured in terms of a non dimensional cavitation number and can be reduced by an adjustment of blade area and/or pitch distribution. When cavitating, the propeller will speed up but power is lost and/or the rudder may lose steering action. Cavitation often occurs when turning and results from a loss of a constant solid water flow. Power catamarans usually require deflectors when a single motor is used, to direct a flow of water to the propeller.

Contra Rotating Propellers A pair of propellers fitted in tandem on the same shaft and rotating in opposite directions. The after propeller is usually somewhat smaller in diameter than the forward propeller.

Cup A propeller is said to have a cup if the trailing edge of the blades formed or cast with the edge curled. Cupped blades are stated to improve the grip of the propeller onto the water thereby reducing ventilation, providing better out of the hole acceleration and allowing the boat to reach higher top speed. Cupping benefits are so desirable that almost all modern recreational, high performance propellers have some degree of cup. Compared with an uncupped propeller with the same pitch, the cupped one will reduce the full throttle engine speed, a single cup by 100-200 rpm and a double cup by 300-400 rpm. Cupping also helps to reduce slip by increasing the hydrodynamic pitch as opposed to the face pitch and thus increases the thrust developed by the propeller.

Cycloidal Propeller A device fitted to vessels requiring a high degree of manoeuvrability and consisting of a number of fairly narrow vertical blades rotating round their own centres which, in turn, rotate around the vertical centre of the device. Hence they perform a cycloidal motion. Sometimes fitted with a horizontal hydrofoil form shield below the blade tips. Often found under the propriety trade name of Voith Schneider.

Cylindrical Section A cross-section of a propeller blade cut by a circular cylinder whose centreline is the axis of rotation. See *Sections*.

Diameter Diameter is twice the distance from the centre of the boss (hub) to the tip of the blade and is the diameter of the circle scribed by the blade tips as the propeller rotates.

Disc Area This is the area of the circle described by the propeller blade tips *i.e.*: -

$$A_D = \pi D_P^2/4 \quad m^2 \qquad (12)$$

where

A_D	=	disc area	m^2
D_P	=	propeller diameter	m

The marine surveyor should be aware that there are three area ratios in common use by naval architects and these are: -

Projected Area Ratio The projected area of propeller blades divided by the disc area and is the smallest area ratio in common use.

Developed Area Ratio The area of the blades rotated to zero pitch divided by the disc area and the most widely used of the ratios.

Expanded Area Ratio Similar to the disc area ratio with the sections unwrapped from the boss. It is the largest of the area ratios.

Ducted Propeller See *Shrouded Propeller*.

Exhaust Propellers In many small installations, particularly outboard units the engine exhaust is routed through the propeller boss or hub. There are three main arrangements usually described using American terminology.

1. *Thru Hub*: where the propellers are designed with an open barrel hub that serves as an outlet for engine exhaust to escape without making blade contact thereby improving acceleration.
2. *Non Thru Hub:* which is the normal arrangements used for vessels fitted with inboard engines with shaft driven propellers

and through hull exhaust, and on some outboards that don't route the exhaust through the lower unit torpedo.

3. *Over Thru Hub*: propellers that allow a controlled combination of thru hub and over hub exhaust flow at lower revolutions, boosting propeller performance during initial acceleration and allowing for a better bite on some engine/boat combinations.

Geometric Pitch Angle — The angle between the pitch reference line and a line perpendicular to the propeller's axis of rotation.

Gill Jet Thruster — An electrically driven axial pump fitted to the bottom of a vessel with a rotating delivery head and capable of delivering the thrust through 360^o.

Handing — See *Rotation*.

Hub — The American name for the boss.

Inboard/Outboard — Also, in America, called a *Stern Drive*. A propulsion system that uses an inboard motor, mounted at the transom, with a propeller assembly, similar to the bottom of an outboard motor, mounted on the outside of the transom, bolted to the motor with the transom sandwiched between. In most designs it can be used optionally with a V or *Jet Drive*.

Keyway — A slender rectangular slot broached into both the interior of the boss and the cone on the propeller shaft. It is fitted with a key which helps to secure the propeller to the shaft and to prevent torsional slipping on the shaft.

Kort Nozzle — See *Shrouded Propeller*.

Leading Edge — The edge of the blade that is forward when the propeller is rotating according to its handing. The opposite of the *Trailing Edge* (*q.v.*).

Mead Width Ratio — This is largely of American use and is the mean width of the propeller blade divided by the propeller diameter. It is related to the developed (or disc) are ratio dar by the formula: -

$$mwr = \pi D_P(dar - 0.04)4Z$$

where

D_P is propeller diameter and Z the number of blades.

The formula assumes that the mean boss diameter is 0.20 x the propeller diameter.

Outdrive — Where an inboard motor drives a propeller unit mounted outboard on a vessel's transom through a system of shafts and bevel gears. Also called a *Z-Drive, Stern Drive* or an *Inboard-Outboard Drive*.

P-effect Also called Propeller Bias, Paddlewheel Effect, Transverse Thrust or Propeller Walk. See *Transverse Thrust*.

Paddlewheel Effect See *Transverse Thrust*.

Pitch Pitch is the theoretical forward movement that a boat propeller travels during one revolution through a solid medium and is measured as the angle at which a propeller cuts through the water and which is calculated from the dimensions and geometry of its blades.

Pitch Angle Angle of the pressure face along the pitch line with respect to the plane of rotation measured in degrees. Not to be confused with pitch. Pitch angle decreases from the blade root to the tip in order to maintain constant pitch. The marine surveyor should understand the relationship between the pitch and the pitch angle which is given by: -

$$\text{Tan } \theta = \text{Pitch}/2\pi r \quad \text{degrees} \qquad (13)$$

where

θ	=	pitch angle	degrees
r	=	propeller radius	inches or mm

Pitch Distribution The variation of the pitch over the length of the blade. The different types of pitch distribution are: -

1. *Constant (fixed) pitch* – the pitch is equal for each radius.
2. *Progressive pitch* – the pitch increases along the cylindrical line from the leading to the trailing edge.
3. *Regressive pit*ch – the pitch decreases along the cylindrical line from the leading to the trailing edge.
4. *Variable pitch* – the pitch is different at each radius.
5. *Controllable pitch* – the blade angle can be mechanically varied. C.P. propellers are nearly always left handed.

Pitch Line This is a line that passes through the leading and trailing edges of the blade and used as a reference for pitch angle.

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- A simple rule of thumb to follow when experimenting with propeller pitch. At wide open RPM, increasing the pitch reduces the revolutions by roughly 200 per inch of pitch. So that switching from a 21 inch to a 23 inch pitch propeller, for example, will lower the maximum revolutions by approximately 400. Going down the same amount in pitch size will have the opposite effect and increase maximum achievable revolutions.

Pitch Ratio This is the most fundamental of the various propeller ratios and is the mean pitch divided by the propeller's diameter.

Propeller — A propeller is a type of fan of radial, spiral shaped blades attached to a central boss usually situated at the after end of a vessel that transmits power by reason of their rotation in water and the blade section angle of attack, converts the torque provided by the engine and gearbox into thrust. A pressure difference is produced between the forward and after surfaces of the hydrofoil sectioned blade and the water is accelerated behind the blade. A right handed propeller is designed to rotate clockwise (when viewed from astern) which, and vice versa for a left handed unit. Larger diameter propellers with greater pitch and producing more thrust are usually needed by narrowboats powered by slow revving traditional engines but at the cost of greater *Transverse Thrust* (*q.v*.). A propeller is sometimes colloquially known as a *Screw*.

Propeller Centre Line — Linear reference line passing through hub centre on the axis of propeller rotation.

Propeller Centre Axis — Linear reference line that locates the blade on the boss and is perpendicular to the Propeller Centre Line.

Propeller Effect — See *Transverse Thrust*.

Propeller Shaft — See *Line Shaft*.

Propeller Singing — A phenomenon occurring in boat propellers at certain rates of revolutions. A strong, almost pure tone is radiated from the propeller into the water but rarely heard on deck because of engine noise. Where this becomes a nuisance the volume or pitch of the tone can be reduced or altered by slightly altering the sectional shape of the trailing edge of the blades.

Propeller Stripper — A pair of blades, one on the propeller shaft and one on the stern tube, with sharp leading edges, to chop up any rope, plastic, tough weeds etc before it becomes tightly wrapped around the propeller or shaft causing vibration, loss of thrust and poor steering or even stalling in severe cases. Sometimes called a weed cutter.

Propeller Walk — See *Transverse Thrust*.

Radius — The distance from the axis of rotation to the blade tip. The radius multiplied by two is equal to the diameter.

Rake — Rake is the angle of attachment of the blade to the boss of the propeller and affects the flow of water through the propeller. Rake has implications with respect to boat performance. Higher rake can improve performance in higher engine elevation and/or ventilating or cavitating situations.

A propeller blade may rake either aft or forward from the blade centre axis.

Aft or Positive Rake the blade tip rakes towards the after end of the boss and such rake is common for planing and combination hulls as it provides increased top end speed while assisting in trimming the bow upward for less wetted surface and frictional drag.

Forward or Negative Rake the blade tip rakes towards the forward end of the boss and such rake is rare but may be found in commercial craft with displacement hulls as it trades speed for steady power that can aid in holding the bow of the boat down and level.

The rake may be specified either in mm or inches at the blade tip or in degrees.

Rotation The direction in which the propeller rotates when viewed from astern.

A *right handed* propeller rotates clockwise.

A *left handed* propeller rotates anti clockwise.

Twin screw applications utilize both left handed (port side) and right handed (starboard side) rotating propellers and are said to be outboard handed. Left handed propellers are primarily used on twin engine boats to cancel the steering bias that would be caused if both propellers spun in the same direction.

Screw A colloquial name for the propeller.

Size The size of a propeller is usually described by two numbers which indicate the sizes of diameter and the pitch respectively.

Shrouded Propeller A hydrofoil sectioned steel ring fitted round a specially designed propeller and found in two forms: -

- The fixed nozzle which is permanently welded to the vessel's hull.
- The nozzle rudder which is attached to the vessel's rudder stock and replaces the rudder.

Skew A blade centre line transverse curvilinear sweeping back from the direction of rotation. The contour of the blade is not radially symmetrical about blade centre axis. Skew forms an asymmetrical shape that can be viewed by looking at the prop blades directly from the fore or aft: -

- *Aft or Positive Skew*: The blade sweeps in the direction opposite to the propeller rotation when moving the craft forward.

- *Forward or Negative skew*: The blade sweep in the same direction to the propeller rotation when moving the craft forward.

Slip — *Because under actual operating conditions the propeller's absolute forward movement (actual pitch) is less than theoretical pitch and the difference is called the slip.* It varies from boat to boat, depending on the weight of the boat and blade surface of the propeller.

Stern Drive — See *Outdrive.*

Stern Gland — An arrangement usually by means of greased packing in a *Stuffing Box* (*q.v.*) or *Stern Tube* (*q.v.*) whereby water is prevented from entering a vessel at the point where the *Propeller Shaft* (*q.v.*) passes through the hull. Also usually contains the *Propeller Shaft*'s aftermost bearing. Some modern pleasure narrowboats have stern glands that are lubricated by water drawn by the propeller's action through the gland by a pipe from the weed hatch.

Taper — The slope of the bore inside the boss. Usually 1 in 12 in Imperial units and 1 in 10 in metric.

Track — This is the measurement of the axial position of all blades with respect to each other and represents the spread distance between individual blade rake distributions. Always a positive value, track is the absolute difference of one blades actual individual blade rake distributions to the corresponding blade rake distributions on a neighbouring blade.

Trailing Edge — The opposite of the blade to the leading edge (*q.v.*).

Transverse Thrust — A propeller not only thrusts a boat forward, it also causes the stern to turn to one side, which side depends on whether the propeller is right or left handed. This transverse thrust (also called the p-effect, paddle wheel effect or propeller bias or walk) results in the tendency of the propeller to create a transverse force causing the stern of the vessel to creep either to port or starboard side depending on the handing of the propeller. The effect is especially noticeable when the vessel is on a stern board where there is greater vessel resistance to move sternwards thus making it easier for the propeller to push the vessel's stern sideways. If the propeller is right handed (*i.e*. it revolves clockwise in forward gear when viewed from astern), the vessel will normally veer to port going ahead and clockwise going astern and *vice versa* for a left handed propeller. Thus it is impossible for a single propeller boat to go dead straight without constant minor adjustments to the rudder. When fully understood, good use of this effect can benefit close manoeuvres. Not to be confused with *Interaction* (*q.v.*).

Under Propped Said of a propeller having too small or too fine a pitch to produce enough thrust to efficiently drive the boat.

Ventilation Sometimes the term *cavitation* is used when in reality *ventilation or air drawing* is actually occurring. Ventilation is air being drawn down from the water surface or the introduction of exhaust gases into the propeller blades both of which cause the propeller to race and lose thrust. Ventilation can be useful in the bottom end acceleration by allowing the propeller to slip a regulated amount, allowing the engine to revolve higher during initial acceleration. It is usually achieved by ventilation holes at the root of each blade or the use of an over hub design. Ventilation is for through hub exhaust propellers only. Causes of ventilation include excessively tight cornering, over trimming of the engine and mounting an outboard motor too high on the transom.

Voith Schneider See *Cycloidal Propeller*.

Z-drive See *Outdrive*.