Advanced Propulsion System GEM 423E

Week14: Surface Piercing Propeller

Dr. Ali Can Takinacı
Assosciate Professor
in
The Faculty of Naval Architecture and Ocean Engineering
34469
Maslak – Istanbul – Turkey

Contents

What is surface propulsion system?

- Surface Propulsion systems all are configured to position the propeller shaft approximately on the surface of the water.

- This results in a propeller that operates only partially submerged.

- Surface propulsion system offer numerous advantages over other types of propulsion systems.
- The primary advantage is efficiency.
- Other advantages include optimization of reduction ratios, shallow water capabilities and the elimination of cavitation.

Surface Piercing Propeller History

- Shortly after the development of the marine screw propeller as we know it today, the partially submerged or surface piercing propeller was proposed as an alternative to the paddle wheel.
- The first patent was issued to Mr. C. Sharp of Philadelphia in 1869 for a unit that incorporated many of the features found important in current surface piercing propellers, notably cupped blades for improved performance and multiple blades to reduce the unsteady forces of propellers operating on the surface.

- The first surface piercing propellers were designed primarily for shallow water applications.
- A variety of other inventors have been involved in the development of surface piercing propellers since the first patent was issued although the emphasis gradually shifted from the original shallow water applications to high speed applications.

- Admiral D.W. Taylor ran the first known model tests on partially submerged propellers, showing that these propellers had low thrust and torque coefficients and high efficiency.
- Albert Hickman, the inventor of the sea sled, used surface piercing propeller technology almost exclusively prior to 1920.

- Starting in the 1950's, with the unlimited hydroplane Slow Motion IV, the surface propeller started becoming more accepted in the racing circuit.
- This has progressed to a point where virtually all high speed racing applications use surface piercing propellers in one form or another

Why Use a Surface Propeller?

- Propeller Efficiency
- Cavitation
- Appendage Drag
- Variable Geometry
- Shallow Draft

Propeller Efficiency

- Traditional propeller design and selection is almost always an exercise in trading off diameter against several other performance-limiting parameters.
- Basic momentum theory tells us that for a given speed and thrust, the larger the propeller, the higher the efficiency.

- These include blade tip clearance from the hull, maximum vessel draft, shaft angle, and engine location. While this may at times make life easy for the designer - the propeller diameter specified is simply the maximum that fits - it can also result in a considerable sacrifice of propulsive efficiency.
- And if these geometric limits on propeller diameter are exceeded, the result can be excessive vibration and damage due to low tip clearances, or a steep shaft angle with severe loss of efficiency and additional parasitic drag, or deep navigational draft that restricts operation or requires a protective keel and its associated drag. In many cases, the best design solution is to live with a mix of all of the above problems to some degree.

- The surface-piercing propeller frees the designer from these limitations.
- There is virtually no limit to the size of propeller that will work.
- The designer is able to use a much deeper reduction ratio, and a larger, lightly-loaded, and more efficient propeller

Cavitation

- When a submerged propeller blade cavitates, the pressure on part of the blade becomes so low that a near vacuum is formed.
- This happens more easily than one might think - atmospheric pressure is only 14.7 psi, not a very big number considering the size of a typical propeller and the thrust it is required to produce.

- If the suction on the low-pressure side of the propeller blade dips below ambient pressure - atmospheric plus hydrostatic head - then a vacuum cavity forms. (To be strictly correct, there is water vapor in the cavity, and the pressure is not a true vacuum, but equal to the vapor pressure of the water.)

- When these vacuum cavities collapse, water impacts on the blade surface with a local pressure singularity - that is, a point with theoretically infinite velocity and pressure.
- The effect can approximate that of hitting the blade with a hammer on each revolution.
- Cavitation is a major source of propeller damage, vibration, noise, and loss of performance.
- And although high- speed propellers are often designed to operate in a fully- cavitating (supercavitating) mode, problems associated with cavitation are frequently a limiting factor in propeller design and selection.

- The surface propeller effectively eliminates cavitation by replacing it with ventilation.
- With each stroke, the propeller blade brings a bubble of air into what would otherwise be the vacuum cavity region.
- The water ram effect that occurs when a vacuum cavity collapses is suppressed, because the air entrained in the cavity compresses as the cavity shrinks in size.
- Although the flow over a superventilating propeller blade bears a superficial resemblance to that over a supercavitating blade, most of the vibration, surface erosion, and underwater noise are absent.

- In theory there is a slight performance penalty for allowing surface air into the low-pressure cavities.
- Instead of near-zero pressure on the forward side of the blades, now there is 14.7 psi pushing backwards.
- But in practice, this effect is not significant considering the total thrust pressures involved in high-speed propellers.

- Note that cavitation can also be associated with sudden loss of thrust and high propeller slip, often caused by a sharp maneuver or resistance increase.
- This can still occur with surface propellers, although the propeller is ventilating rather than cavitating and the result is not as damaging.

Appendage Drag

- Exposed shafts, struts, and propeller hubs all contribute to parasitic drag.
- Inclined the exposed shafts not only produces form and frictional drag, but there is also induced drag associated with the magnus-effect lift caused by their rotation.

- There is a surprising amount of power loss resulting from the friction of the shaft rotating in the water flow.
- In fact, for conventional installations a net performance increase can often be realized by enclosing submerged shafts in non- rotating shrouds, despite the increase in diameter.
- Surface propellers virtually eliminate drag from all of these sources, as the only surfaces to contact the water are the propeller blades and a skeg or rudder.

Variable Geometry

- When a surface propeller is used in conjunction with an articulated drive system, the vessel operator then has the ability to adjust propeller submergence underway.

- This has roughly the same effect as varying the diameter of a fully submerged propeller, and allows for considerable tolerance in selecting propellers - or it allows one propeller to match a range of vessel operating conditions.
- This capability is somewhat analogous to adjusting pitch on a controllable pitch propeller.

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- When the articulated drive is used for steering, the result can be exceptionally good high-speed maneuvering characteristics.
- On single-shaft applications, drive steering can also be used to compensate for propeller-induced side force, without resorting to an excessively large rudder or skeg.

Shallow Draft

- This is the characteristic that motivates many designers to investigate surface propeller propulsion in the first place.
- The vessel's navigational draft can be as low as half a propeller diameter.

- Compared with other options for shallow water propulsion - most notably waterjets - surface propellers enjoy a very significant efficiency advantage.
- This advantage is most dramatic for low-speed applications, but is still present throughout the performance spectrum.
- In the case of articulated drives, the propellers can be trimmed up until just the tips are submerged for intermittent operation in very shallow water, including beaching.
- Sometimes the design allows the propellers to trim sufficiently above the baseline so that the vessel can "dry out" with the props well clear of the bottom.

- These are the intrinsic performance advantages of surface propellers.
- Other desirable characteristics include flexibility in machinery arrangement, ease of maintenance and repair, and simplified installation.
- In some applications involving hybrid propulsion systems, such as the combination of diesel cruise engines with a gas turbine sprint engine, the ability to retract one set of propellers completely clear of the water when not in use is an overriding consideration

STYLES

- Today there are a variety of propeller styles for surface piercing applications to choose from.
- In addition, there are numerous manufacturers that claim to have the best propellers available.

- Be cautious when selecting propellers – It is easy to get swept up in the enthusiasm of a new project and allow a vendor to sell you a product that isn’t the best fit for your application.
- Months later reality catches up in the form of a vessel that will not perform, or can’t even get on plane.
- We are frequently involved in the problem solving of these situations after the fact.
- Many times a propeller supplier will make recommendations based on what they have on the shelf or have patterns for.

- Sometimes gear ratios are compromised for the same reasons or to stay under a torque rating to use a smaller ASD unit.
- These issues almost always lead to a disastrous application.
- If you are considering using the ASD system, please contact us at H/RI before finalizing your equipment.
- We will perform an analysis on your application and make our recommendations at no charge. We offer this service to enhance the successful use of the ASD system..

SURFACE PIERCING PROPELLER STYLES - 1

Cleaver

- The propeller that readily comes to mind for most people when discussing Surface Drives is the cleaver propeller.
- This is understandable as the ASD system was born in a racing environment.
- The cleaver propeller is typically manufactured out of stainless steel, with some larger configurations made out of NiBrAl Bronze.
- Heavy cambered wedge sections, similar to super cavitating propellers, are standard with a blunt, squared-off trailing edge.

- Up to 8-blade cleaver propellers have been used to allow smoother operation and an increase in efficiency with reduced propeller submergence.
- These propellers typically are used for vessel speeds in excess of 50 knots.
- Depending on the size of the craft, the performance gains fall off using cleavers for the slower speed applications.
- As a general rule, there are better styles for the slower speed applications.

SURFACE PIERCING PROPELLER STYLES - 2

Low Rake, Round Ear Propellers

- Low rake propellers have a very similar appearance to conventional propellers.
- Typically blade areas range from 0.75 for a 4-blade to 1.25 for a 6-blade.
- These propellers have a cambered blade section with a trailing edge cup.
- Sometimes, for slow speed applications, the cup is extended forward of the maximum radius on the propeller.

- The design and application for this style of propeller has come a long way recently.
- This is the propeller of choice for most applications under 50 knots.
- Propeller geometry can be altered on these propellers to enhance the slow and mid speed performance.
- Many propeller shops can undertake the repair of this style of propeller.

SURFACE PIERCING PROPELLER STYLES - 3

High Rake Propellers

- The high rake propeller was developed primarily as a "poor man's cleaver."
- This is a propeller that is easily manufactured and has evolved from the standard wedge-shaped cleaver propeller.
- These propellers generally are for use on the light, high-speed, small vessel applications.

SURFACE PIERCING PROPELLERS’ EXAMPLES

- These are some examples of surface Piercing Propellers propellers that H/RI has been involved in**.**

- 32" (813mm) diameter, manufactured in India, used on a 47' (14.3m) class of patrol boats. The propeller was made of Nibral to ISI 484 class

- Standard round ear propeller of the style used on the majority of surface piercing applications. These propellere are typically manufactured out of NiBral or Superston 70 (shown) and are available in four, five or six blade configurations.

- This five blade 26" (660 mm) surface piercing propeller was developed for increased slow speed and mid range performance.
- This propeller exhibited exceptional smoothness over all of the power ranges.

- 6 bladed NiBral cleaver style propeller.
- This style pf propeller is generally used for higher speed applications.

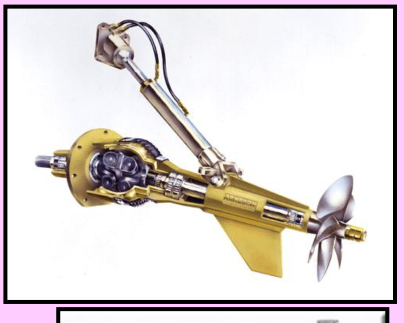
Advantages and Disadvantages

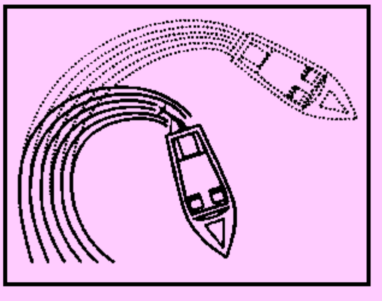
Advantages of surface propulsion system

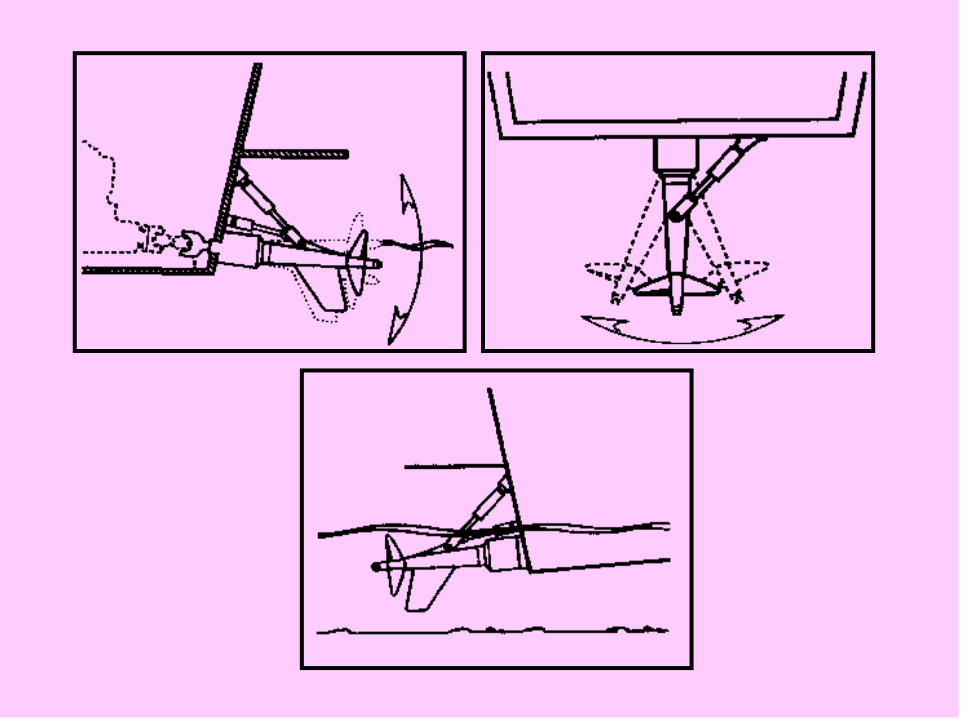
- Efficiency
- Shallow water capabilities
- Payload
- No cavitation
- Maneuverability
- Greater speed opposed to same boat with submerged drive.

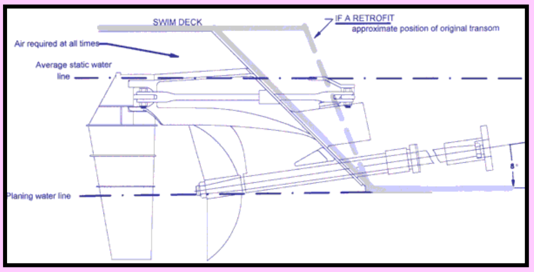
Disadvantages of Surface Piercing Propeller

- Vibration
- Backing Performance
- Difficult on turns.
- Harder to set-up.
- Not efficient at low revs.





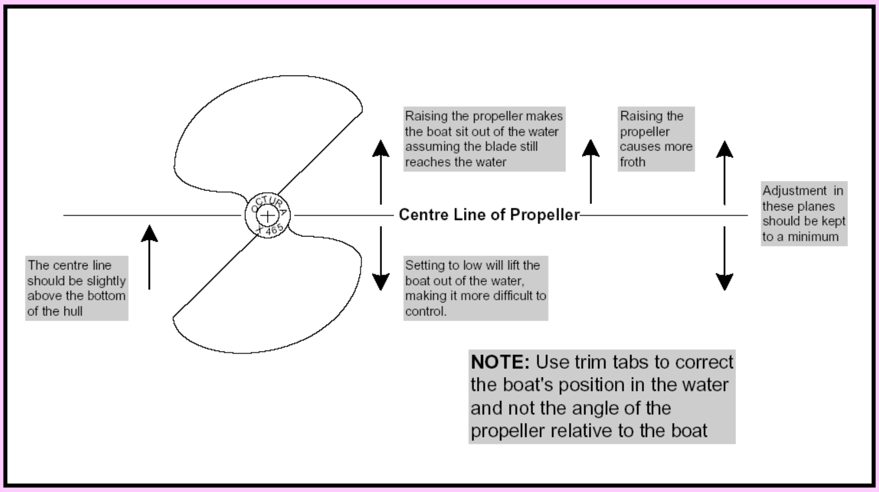


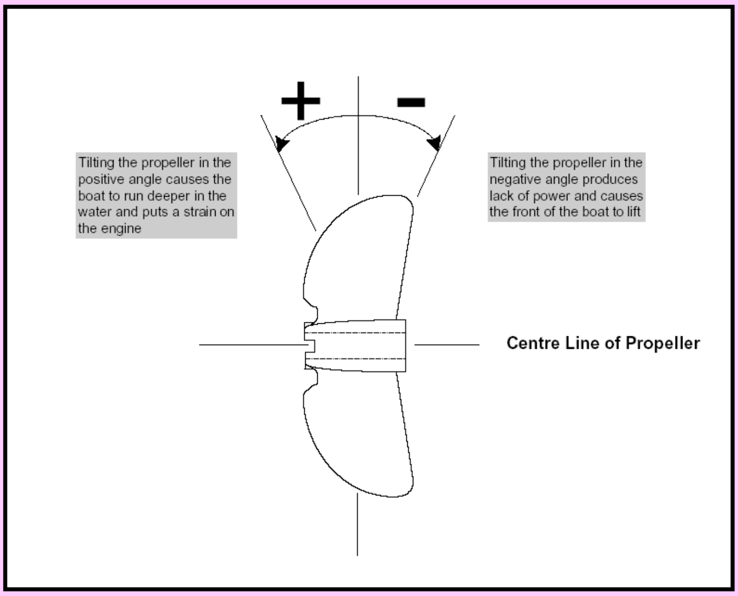


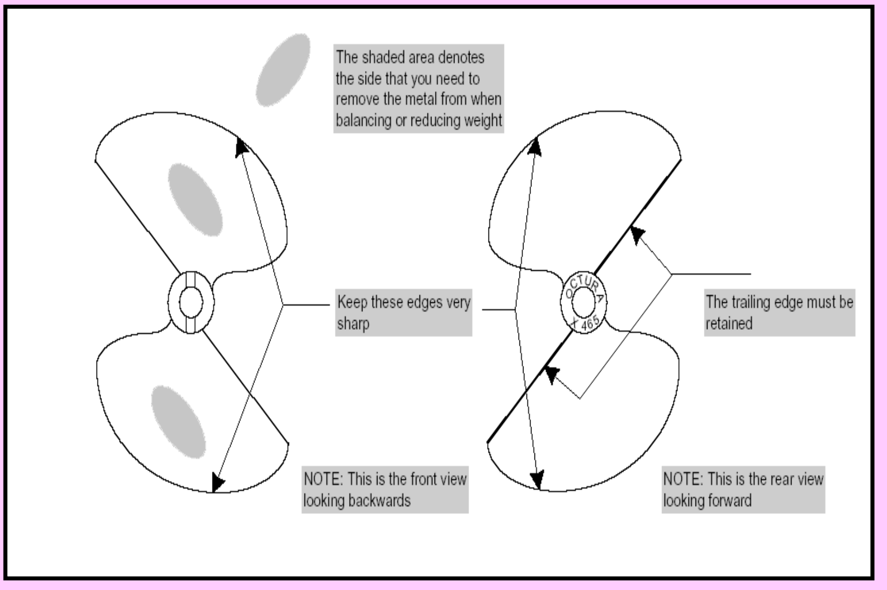
SWIM DECK
IF A RETROFIT
approximate position of original transom
Air required at all times
Average static water line
8°
Planing water line

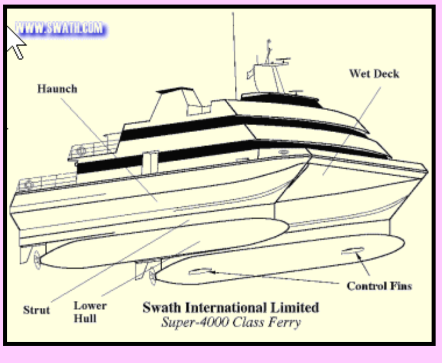
SEALBOAT

Surface Piercing Propeller Set-up









Swath concept

Typical application

Propeller Selection

- Surface propellers are usually associated with the stainless steel "cleaver" style common to race boat applications.
- These propellers have straight trailing edges, razor-sharp leading edges, and sometimes as many as eight blades.

- Probably because the roots of surface propulsion technology are so firmly imbedded in the race boat world, it's no surprise that the popular perception is that all surface propellers are cleavers.
- Yet the vast majority of surface propellers being sold today have round-tipped blades, are made of bronze (or NiBrAl), and have only three or four blades.
- In fact, at first glance there is very little to distinguish them from conventional, fully submerged props.

- What distinguishes a surface propeller from an underwater design?
- The pressure face of the blade is always concave, the leading edge is relatively sharp with a narrow entry angle, and the hub and blade root are built to withstand heavy eccentric and alternating loads.
- There is major incentive to keep the blade section thin (it's the strength of the steel blades that really gives cleavers the edge at high speeds and loadings).
- Nearly all successful designs have moderate to heavy trailing edge cupping.

- Propeller selection begins with an estimate of required thrust at the design speed.
- This is usually based on one of several computational methods, but can also be generated from empirical formulas or, if available, trial data from nearly similar vessels.
- Then a preliminary gear ratio and diameter is chosen, adjusting both until slip and pitch/diameter ratio are optimal and the required thrust is generated.
- This will generally result in a non-standard reduction ratio, so the remainder of the process involves adjusting diameter and pitch to fit the available drive train hardware.

- This is, of course, a somewhat simplified description of a "design spiral."
- Usually the initial design conditions will be modified in the course of the analysis, and there are numerous other considerations such as number of blades, propeller submergence, drive train structural limitations, and vessel trim.
- Note that unlike propeller selection for a large proportion of conventional applications, diameter remains a variable parameter troughout the entire process.

- The drive or propeller vendor is usually eager to perform these calculations for you, and in some cases can supply you with a computer program that will enable you to play with various options on your own.

- For the video would you please point the mouse and open the speakers.