Advanced Propulsion System
GEM 423E

Week 10: VSP/Cycloidal Propellers

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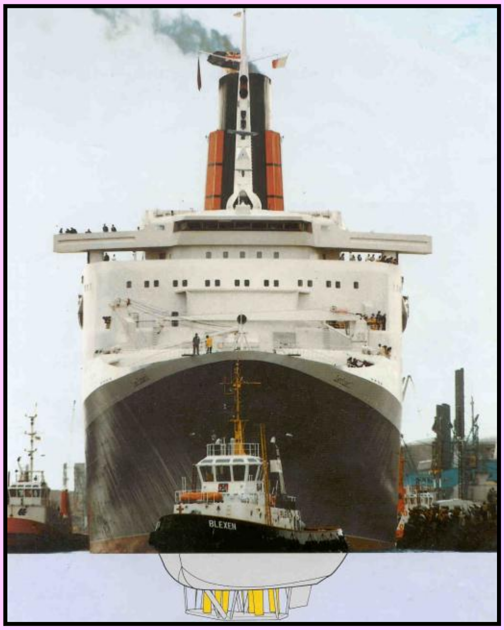

Cycloidal Propeller History

- Frederick Kurt Kirsten (1920) first investigated VSP at the University of Washington, developed a pitch cycloidal blade motion cycloidal propeller and investigated the possibilities of putting the device on several different air vehicles.

- In the 1930's Kirsten proposed modifying the U.S. Navy's Shenandoah lighter than airship to use cycloidal propellers, but the Shenandoah crashed before the modification could be made.

- Also in the 1930’s, John B. Wheatley began work on cycloidal propulsion.
- He developed accurate blade motion and developed a supporting modeling theory.

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- Wind tunnel tests at the Langley 20-foot wind tunnel were completed using an 8-foot diameter model.

Background

- On a Cycloidal propeller the blades project below the ships hull and rotate about a vertical axis, having an oscillatory motion about its own axis superimposed on this uniform motion.
- The blade’s oscillating movement- a non-stationary process in hydrodynamic theory- determines the magnitude of thrust through variation of the amplitude,the phase correlation determining the thrust direction between 0 and 360 degree.

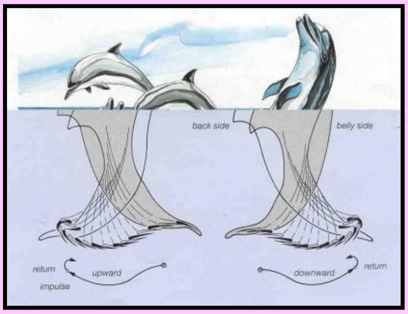
- Therefore there is no prefered direction. Both variables-magnitude and direction- are controlled by the propeller, with a minimum of power consumption.
- The control mechanism developed for the cycloidal propeller is based on a fourbar linkage system controlling the individual blades.
- This system has the advantage of rugged simplicity while still closely matching the assumed ideal blade profile.

- By moving a single point common to each of the blades four-bar linkages, the magnitude and direction of the blades profile can be controlled.

The "Voith Schneider Propulsion"

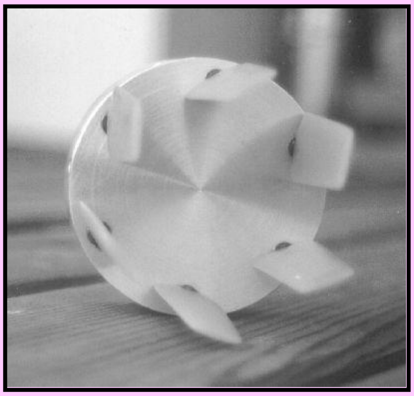
- **The Voith Schneider Propeller is a ship propulsion system that allows optimum maneouverability!**
- **The extraordinary agility may be compared to the fascinating dexterity of a dolphin which performs in its watery element with playful ease- simply by movement of a tail.**

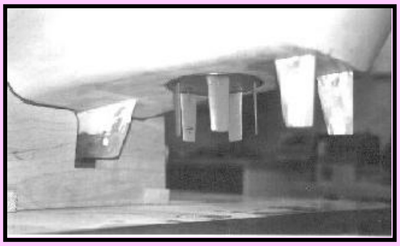
It was modelled on nature: Animals with such movement have the optimal adoption to their living environment(movement path of dolphin's tail).



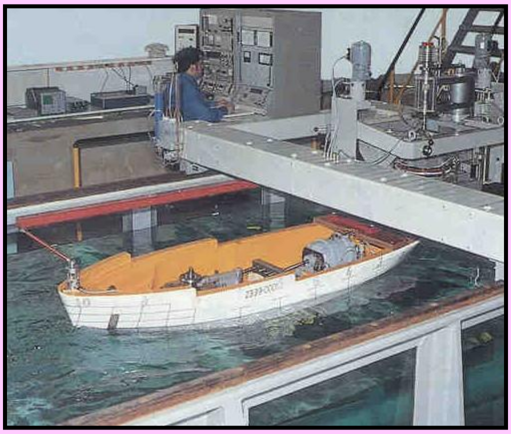
A fish’s fin action or bird’s wing action not only produces a force in the direction of motion but simultaneously forces normal to that direction as with dynamic lift during a bird’s flight or a fish’s steering force.

Model of Voith Schneider Propellers



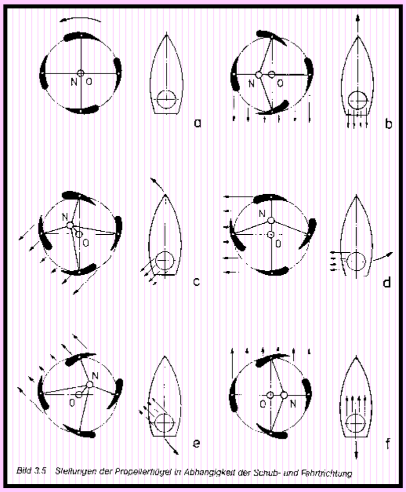


Laboratory of Voith Schneider Group for Propulsion Tests

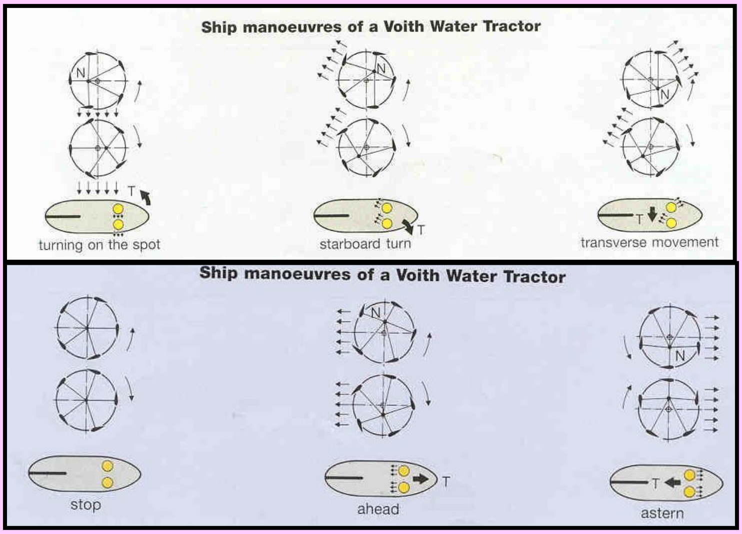


How does it work?

- **See the picture, it tells more than thousands of words**



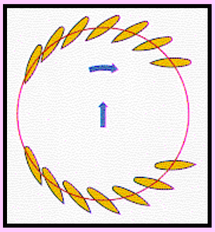
Manoeuvres of VSP propelled ships

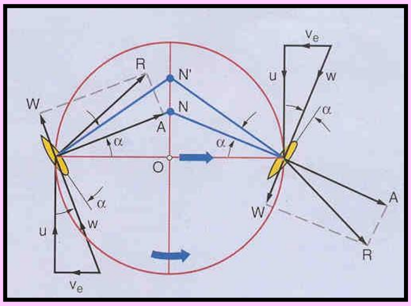


- **Some words are needed although:**
- **The blades of the propeller rotate constantly in one direction with a constant revolution speed.**
- **The Blades are connected to the point "N" which is not rotating with the rest of the rotor.**
- **If "N" moves out of the center of the prop the angle of every blade is changing during one revolution.**
  Steering the ship is as easy as putting "N" into any position!
- **The more "N" is away from "0" the more power is provided by the prop**

VELOCITIES ON A VSP BLADE:

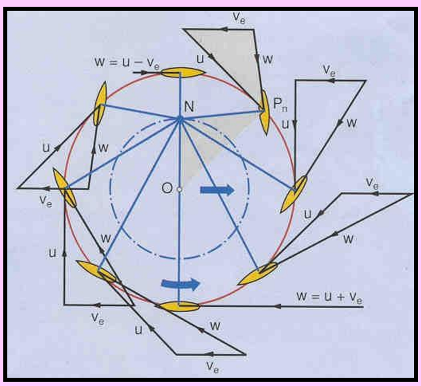
- For the ‘non-slip’ condition of the propeller (the hydrodynamic lift is zero) the blades are set in such a manner that at each point the veocity w, resulting fron the circumferential velocity u and the forward velocity ve, is directed towards the profile axis (zero lift).





VELOCITIES ON A VSP BLADE-1

- The geometric triangle NOPn is similar to the velocity triangle uvew for all blade positions
- The perpendicular to the profile axes for all blade positions during one revolution must meet at one point, ‘the steering centre N’. During thrust generation the steering centre N is always displaced at the right angles to the resultant thrust direction by the dimension ON from the centre of rotation(eccentricity).



Velocity triangles on the blade.

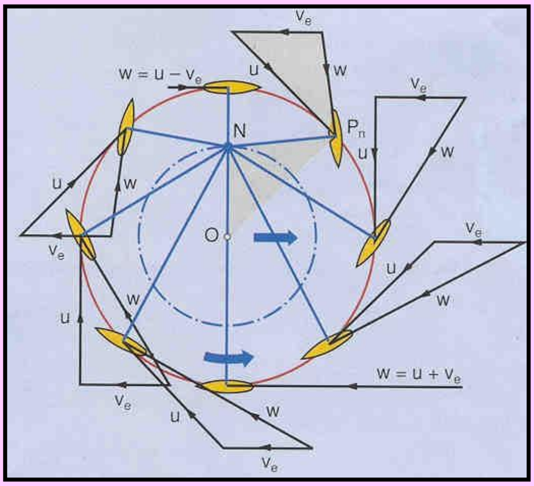
O propeller centre — u circumferential velocity

N steering centre — ve ship’s speed reduces by wake

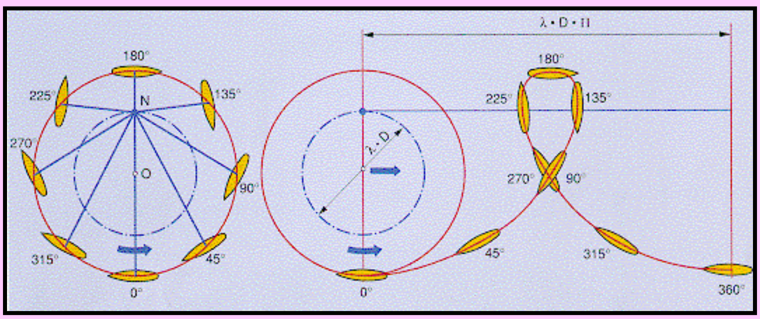
Pn oscillating centre of the blade — w resultant velocity

VELOCITIES ON A VSP BLADE-2

- The ratio of the distance N/(D/2) corresponds to the ratio of velocities e/u,‘the advance coefficientl’.
- As long as propeller generates no thrust the advance coefficient is identical to the pitch ratio.



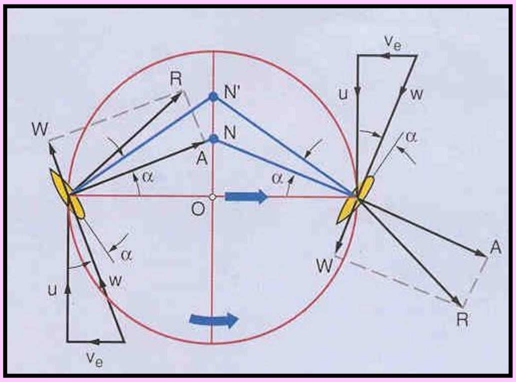
ACTUAL PATH OF ONE VSP BLADE (CYCLOID)



- By superimposing the rotary movement of the propeller on a straight line perpendicular to the rotational axis (to represent the movement of the vessel), the blade of the VSP follows a cycloid. The rolling radius of cycloid is equal to λ *D/2 and the forward motion of the propeller during one revolution is therefore λ*D*π.

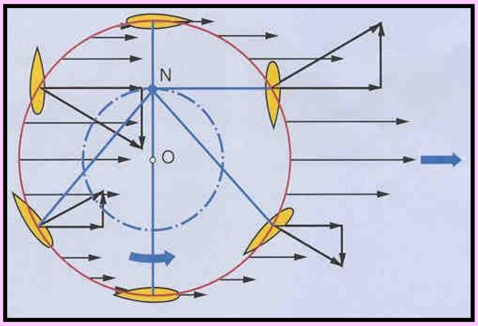
Thrust generation by the VSP - 1

- To generate thrust the blade profile mustbe turned against the blade path by the angleα by moving the steering centre from N to N'. The ratio ON'/(D/2)=λo is the pitch ratio of a VSP. Through this angle of attack hydrodynamic lift will be generated at right angles to the resultant velocity w, perpendicular to the cycloidal path.The magnitude of hydrodynamic lift depends on angle of attack α and the inflow velocity w.



Thrust generation by the VSP - 2

- Since the propeller thrust is always perpendicular to line ON' (bollard condition) or NN'(free-running condition) thrust can be produced in any direction merely through displacement of the steering centreN'.
- Due to the rotational symmetry of the VSP there is no preferred thrust direction.
- For the bollard conditions a circular thrust diagram is achieved through the possible movement of ON' through 360 degrees.
- However, as thrust is perpendicular to NN' for free-running conditions, a steering angle higher than the bollard conditions is produced.



The ‘heart’ of VSP: The Kinematics-1

- *The hydrodynamic principle of the blade action are produced mechanically by the kinematics.*
- *For the reasons of compact construction the kinematics must produce the correct angular movement of the blade through an eccentricity smaller than the steering centre eccentricity l_o* D/2.*

The ‘heart’ of VSP: The Kinematics-2

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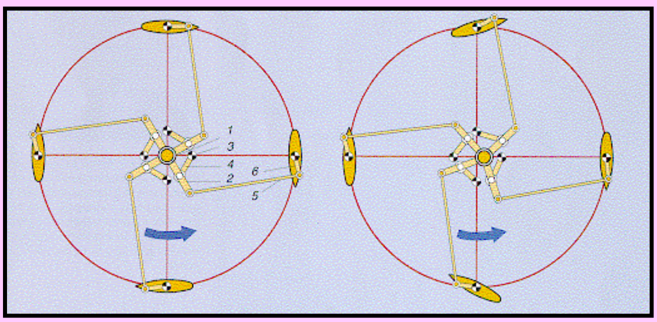
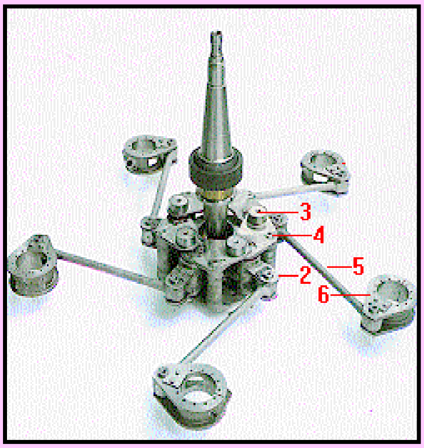


- Crank type kinematics.
- 1 lower spherical bush — 4 crank
- 2 link — 5 connecting rod
- 3 bearing pin — 6 actuating lever

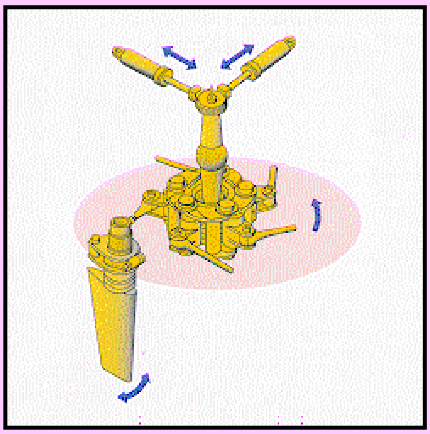
The ‘heart’ of VSP: The Kinematics-3

1. **Lower spherical bush**
2. **Link**
3. **Bearing pin**
4. **Crank**
5. **Connecting rod**
6. **Actuating lever**



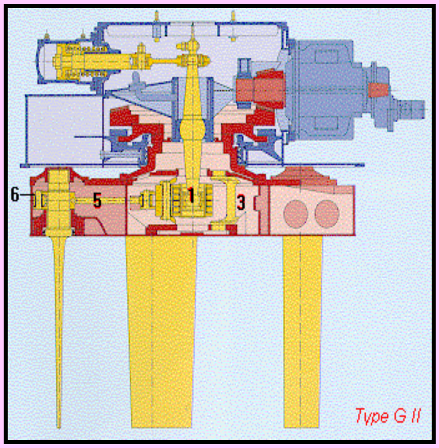
The ‘heart’ of VSP: The Kinematics-4

- On a modern VSP this is achieved using crank type kinematics. The links of each blade actuating system are directly supported by the lower spherical bush of the control rod which can be displaced eccentrically and connected to the crank which pivots around the bearing pin fitted to the rotor casing.
- A connecting rod transfers this movement to the blade through the blade actuating lever



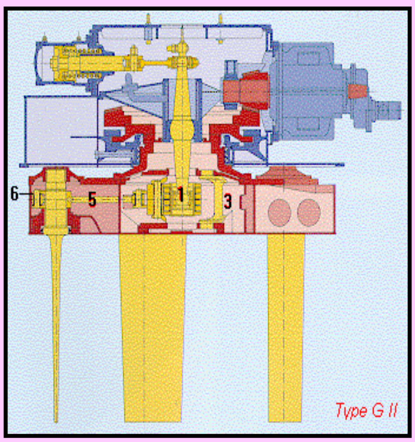
CONSTRUCTION - 1

1. Voith-Schneider Propeller type G11 rotor casing
2. Blade
3. Thrust plate
4. Roller bearing
5. Propeller gear
6. Reduction gear
7. Level gear
8. Driving sleeve
9. Control rod
10. Servomotor
11. Gear pump



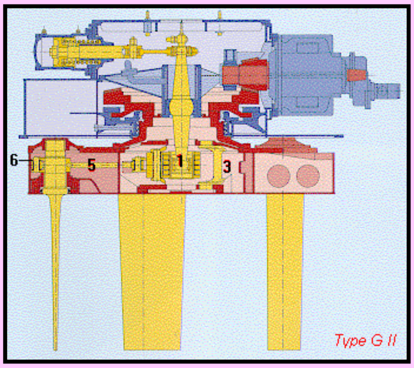
CONSTRUCTION - 2

- The rotor casing carries 4 and 5 blades around its circumference, their axes lying parallel to the propeller's main axis.
- The blade shafts are supported by gland bearing or special roller bearings with seals protecting against leakage of oil and water entry.
- The rotor casing is axially supported by the thrust plate and radially by a roller bearing.
- Whilst the roller bearing centers the rotor casing and transmits the thrust through the propeller housing to the ship's hull, the thrust bearing supports the weight of the rotating parts and the tilting forces generated by propeller thrust and gear tooth pressure.



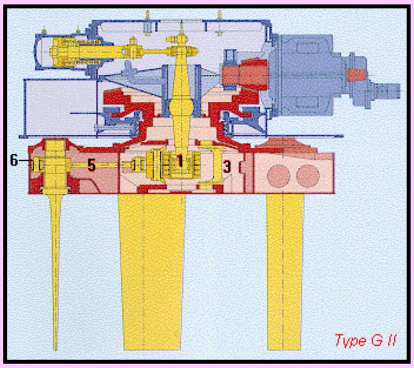
FUNCTION OF VSP

- The rotor casing is driven by reduction gear flanged on to the propeller housing and a bevel gear with cyclopalloid teeth.
- The Crown wheel is connected to the rotor casing through the thrust plate and the driving sleeve.



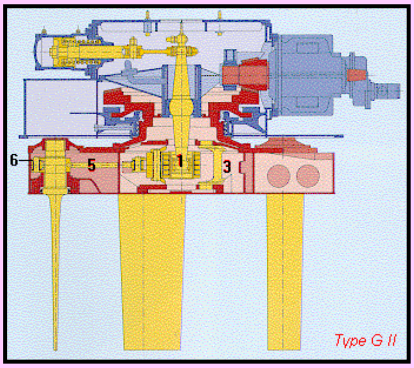
CONTROL OF KINEMATICS

- The control of the kinematics is achieved by the control rod, which is actuated by two oil-pressure servomotors arranged at 90 degree to each other.
- The speed servomotors controls the pitch component for longitudinal thrust (ahead and astern), the steering servmotor controls the pitch component for the transverse thrust (port and starboard).

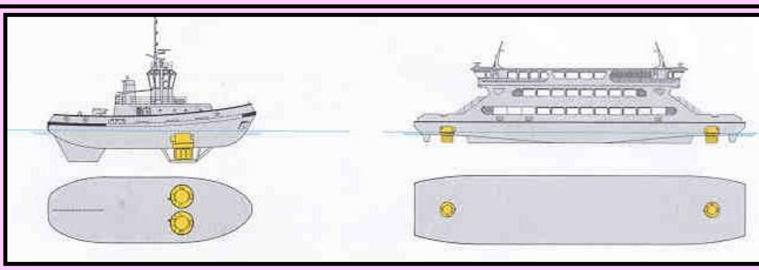


FUNCTION OF GEAR PUMP

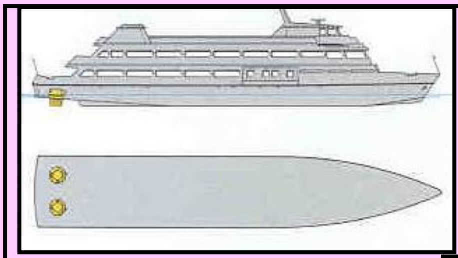
- The pressure oil for the servomotors and the required lubricating oil is supplied by a gear pump flanged on the reduction gear.
- This pump circulates oil from the propeller housing through a high pressure circuit to the servomotors and through a lowpressure circuit to the lubricating points.



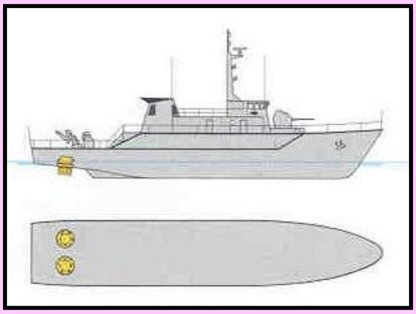
The Correct Ways of VSP Applications - 1



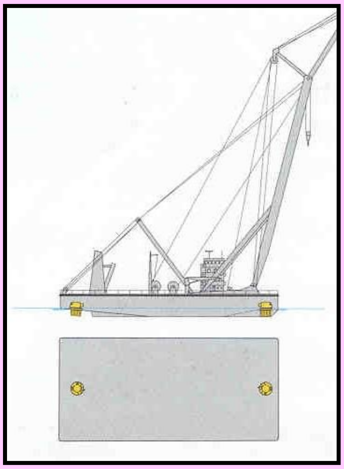
The Correct Ways of VSP Applications - 2



The Correct Ways of VSP Applications - 3



The Correct Ways of VSP Applications - 4



Different Sizes of Cycloidal Propellers With Nowadays Technology