

7. RESTRICTED WATER EFFECT

7.1 Effect of restricted depth of water on ship resistance and powering

Shallow water is when $h < \approx (4 \div 5)T$ where: h - depth of water, T - draft of ship

Shallow water has considerable effect on ship behaviour:

- Resistance of the ship is increasing causing reduction of speed
- Draft of the ship is increasing (squat), trim is changing
- Manoeuvring characteristics change

Critical speed in shallow water:

$$v_{crit} = \sqrt{gh} \approx 3.13\sqrt{h} \text{ [m/s]} = 6.1\sqrt{h} \text{ [knots]}$$

Normally ships cannot sail faster than about 75% of the critical speed (except high speed craft)

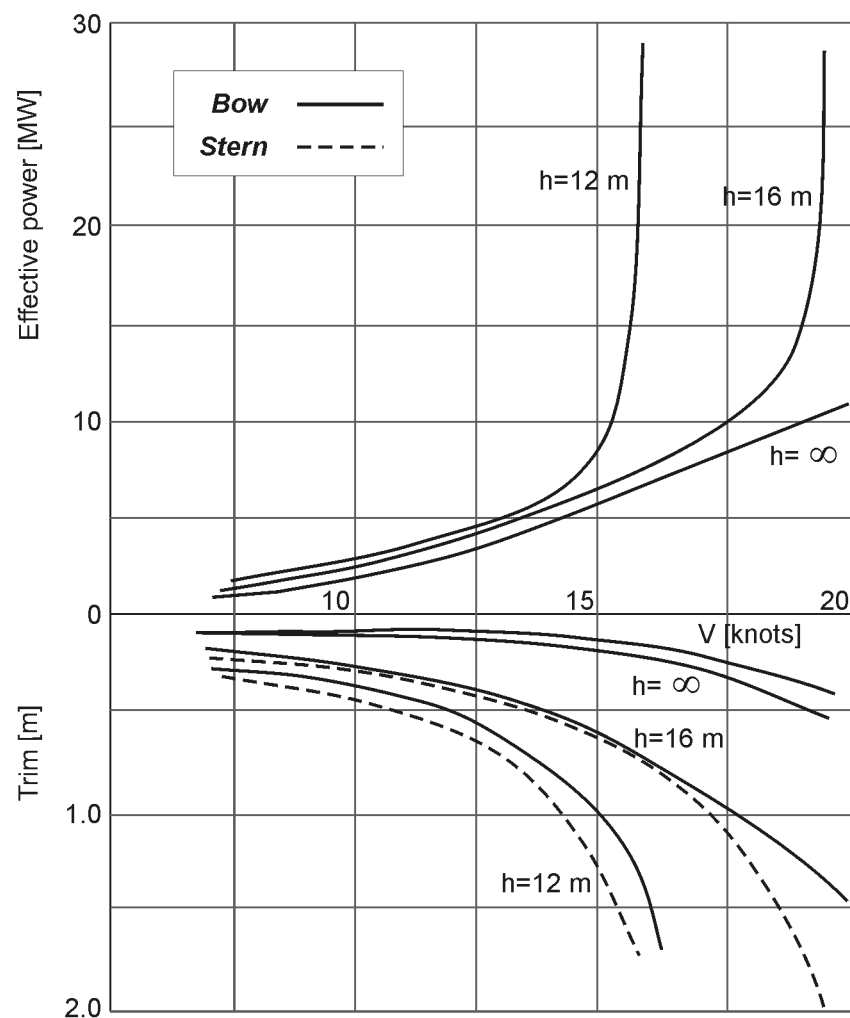


Fig. 7-1 Diagram showing influence of water depth on effective power and trim

[Example ship: RO-RO, $L=210\text{m}$, $T=9.05$]

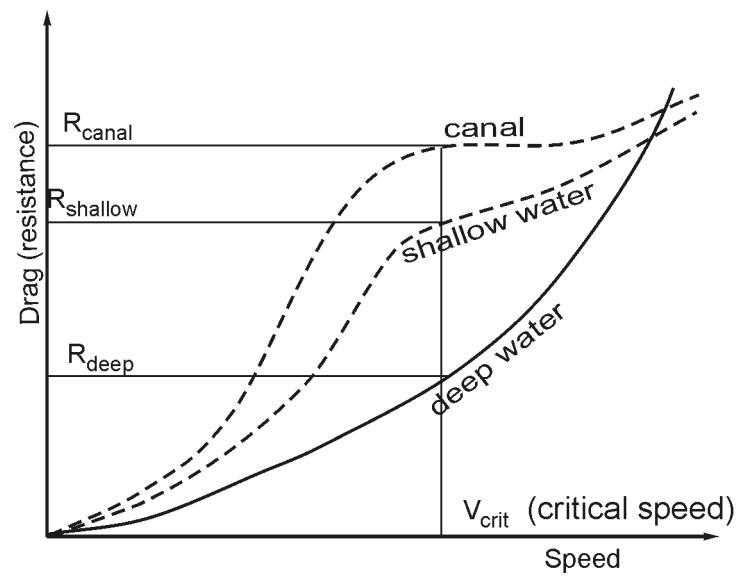


Fig. 7-2 Effect of restricted water on drag (resistance) force

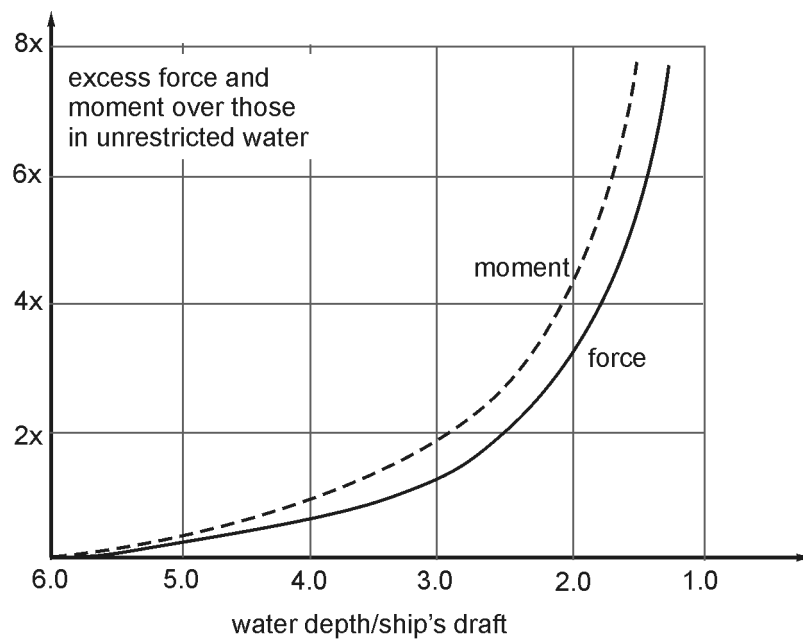


Fig. 7-3 Effect of shallow water on lateral force and moment

7.2 Effect of shallow water on manoeuvring

Shallow water affects considerably manoeuvring characteristics of ships

- Turning circles become larger in shallow water
- Course keeping ability is in shallow water better
- Stopping ability is slightly worsening in shallow water

The effect of shallow water on manoeuvring characteristics is illustrated on the example of full-scale tests of a tanker 278 000 tdw in deep and shallow water.

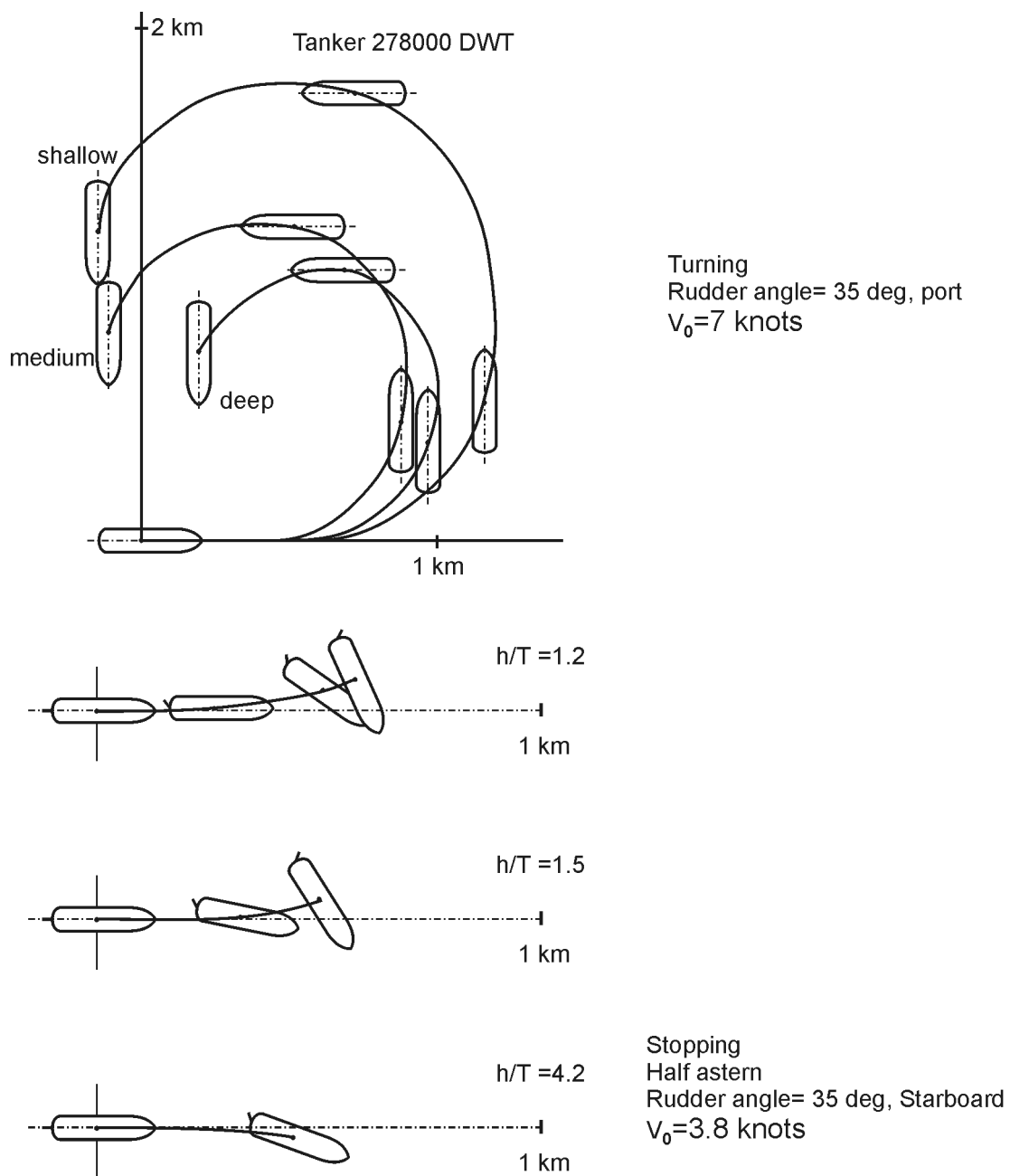


Fig. 7-4

7.3 Wall or bank effect

7.3.1 Bernoulli's law and continuity law

In order to understand the effect of a solid bank or wall on the behaviour of moving ship along it, it is necessary to study pressure distribution around ship's hull and relevant basic laws governing flow phenomena.

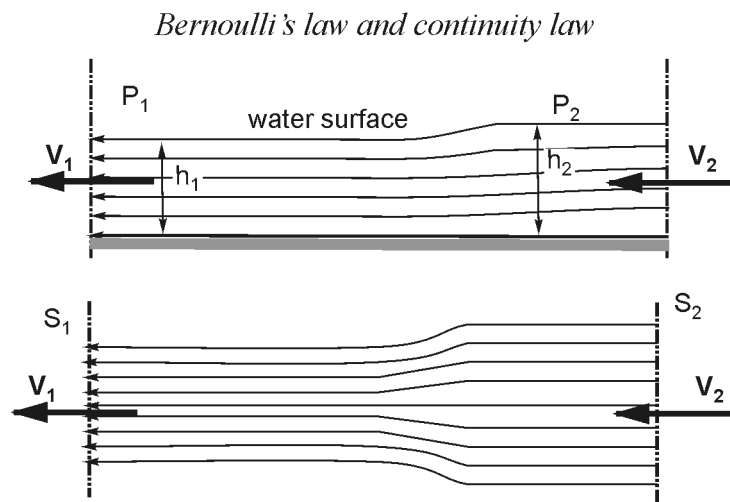
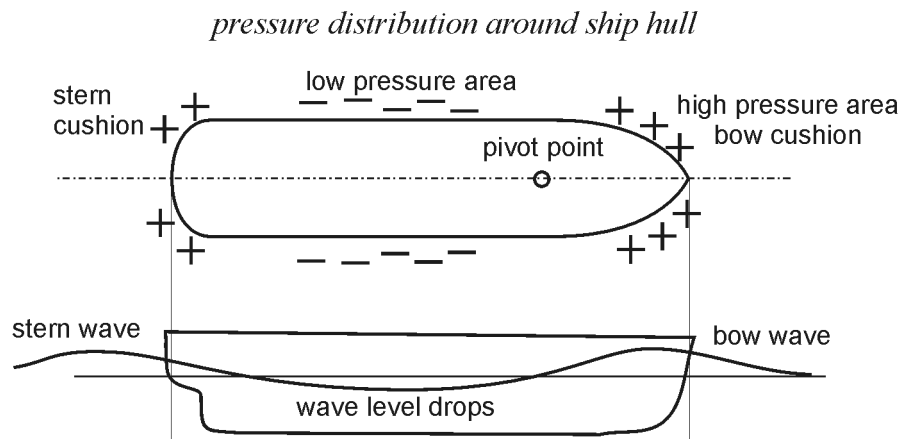


Fig. 7-5

Continuity law: Velocity x cross section = const
 $V_1 \times S_1 = V_2 \times S_2 = \text{const.}$

Consequence: if cross section decreases, velocity increases and vice versa

Bernoulli's law: static pressure + dynamic pressure = const.
 Static pressure = atmospheric pressure + head of water
 Dynamic pressure = $C \times \text{velocity squared}$

Consequence: if velocity increases, dynamic pressure increases and static pressure and head of water decreases and vice versa.

7.3.2 Suction force

When the ship is moving close to a solid wall or bank suction force is created drawing the ship closer to the bank. This is because of reduced cross section, accelerated flow and reduced pressure in the space between the ship and bank.

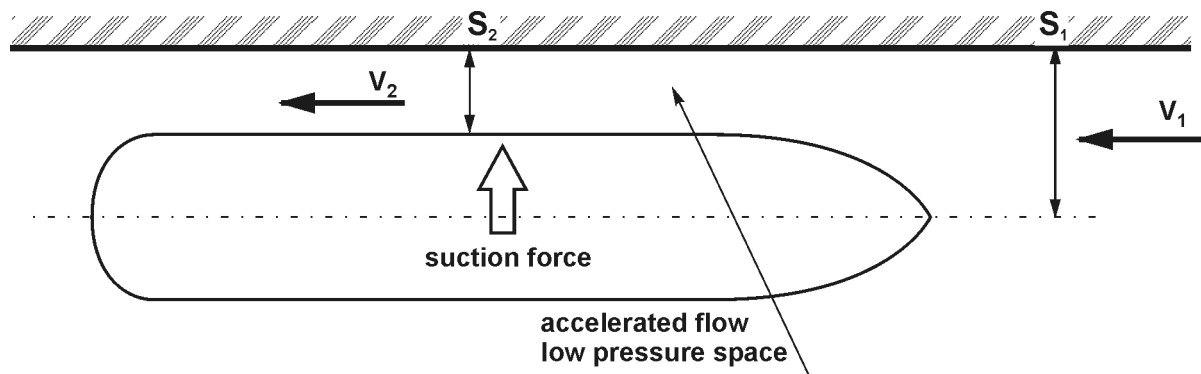


Fig. 7-6

Suction force is proportional to the speed of the ship squared and inversely proportional to the distance from the bank. Suction forces calculated for example ship are shown below:

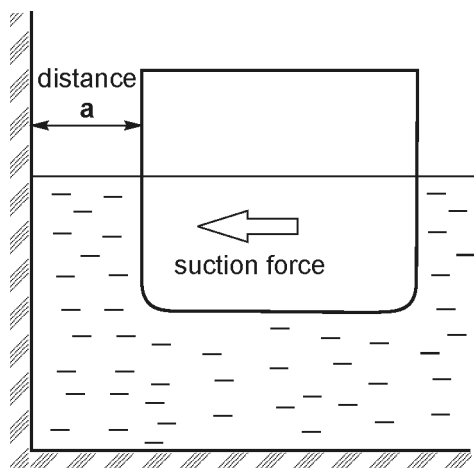


Fig. 7-7

Suction force (Tanker 148000 tdw)		
Distance a [m]	Speed [kn]	Force [Ton]
50	5	21
	10	83
30	5	31.6
	10	124.5
5	5	63
	10	250

Reduced cross section in proximity of the bank:

- velocity increases
- static pressure drops
- water level drops

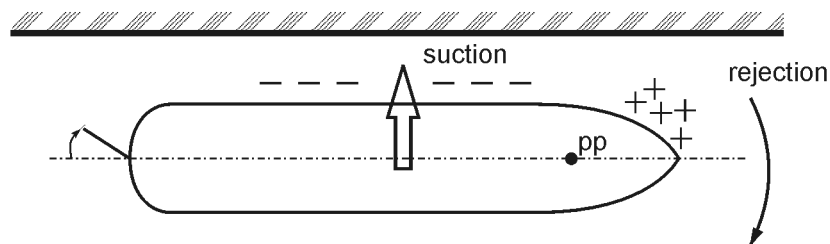
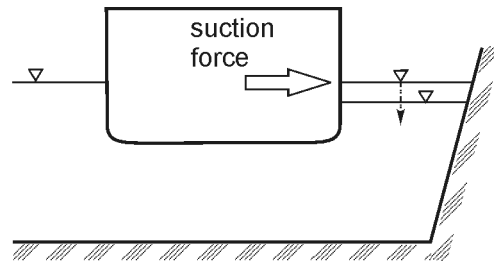


Fig. 7-8

Suction force together with bow cushion effect make stern to move closer to the bank. Rudder is to be used to counter this effect.

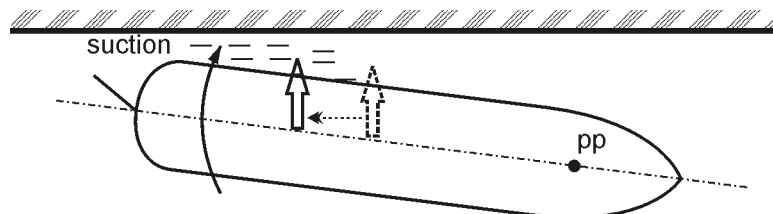


Fig. 7-9

Because of the proximity of the bank ship takes a sheer and suction force moves close to the stern.

7.3.3 Using suction force to the advantage

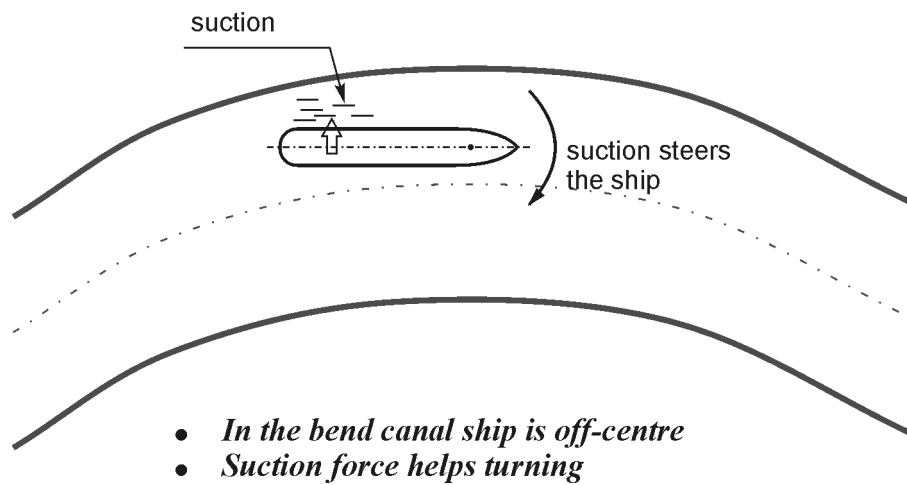


Fig. 7-10

7.3.4 Passing through narrow passage

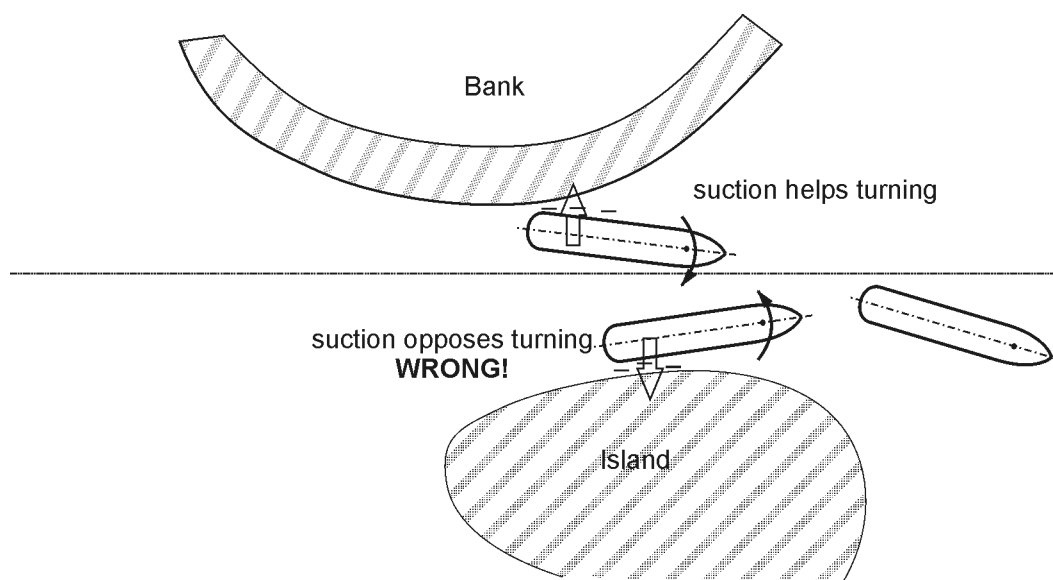


Fig. 7-11

Entering the passage closer to the bank helps turning to starboard as needed. If the ship is entering closer to the island, suction is in the wrong quarters and opposes turning to starboard.

7.4 Squat

7.4.1 Definition

Squat is increased sinkage of the ship in shallow water. It causes reduced clearance below the keel. Squat is caused because of accelerated flow and reduced pressure under the bottom of the ship.

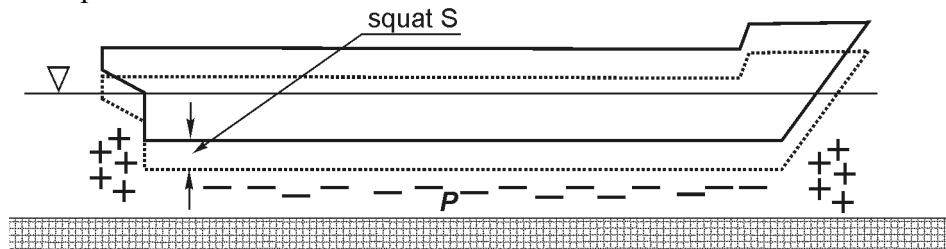


Fig. 7-12

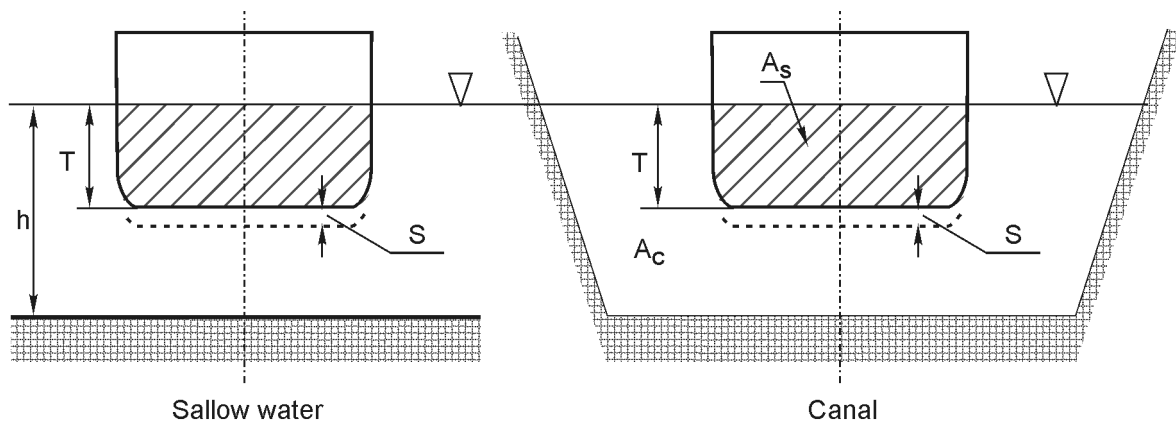


Fig. 7-13

Squat $-S-$ could be calculated using simple formulae developed by Barras.

7.4.2 Barras formulae:

Shallow water: $S = C_B \cdot \frac{V^2}{100}$ valid for $\frac{h}{T} = 1.1 \div 1.2$

Ship in the canal: $S = C_B \cdot \frac{V^2}{50}$ valid for $\frac{A_s}{A_c} = 0.06 \div 0.30$

Where : S - squat in meters
 V - ship speed in knots
 A_s - cross - section of the ship
 A_c - cross - section of the canal
 h - dpth of water
 T - draft of ship

Note: these formulae provide approximate values of squat for the ship in even keel

7.4.3 Effect of heeling, trim and turning on squat

7.4.3.1 Effect of heeling:

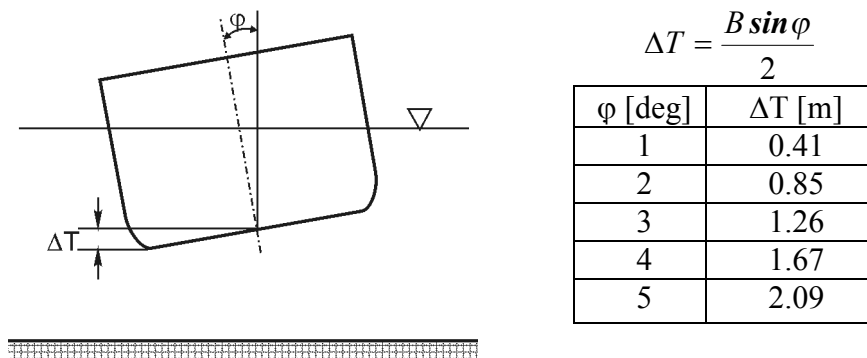


Fig. 7-14

➤ The calculated example is for Tanker with $B=48$ m

7.4.3.2 Sinkage when turning

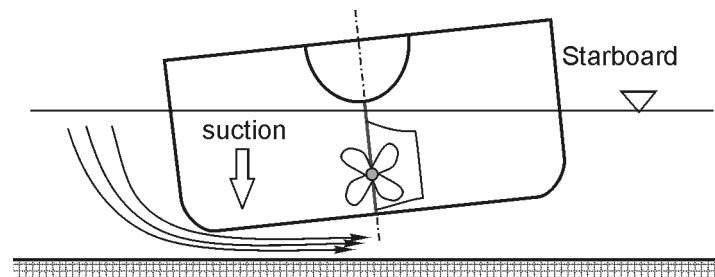


Fig. 7-15

7.4.3.3 Effect of trim

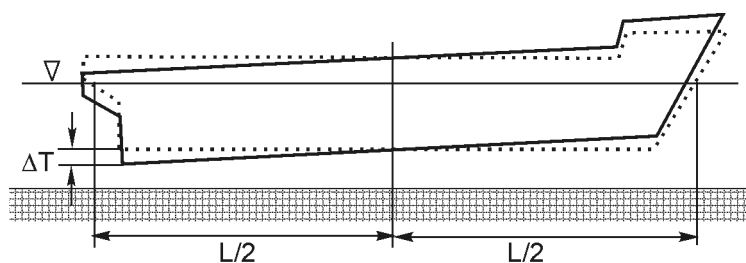


Fig. 7-16

$$Trim = T_S - T_B$$

$$\text{or } t = \frac{T_S - T_B}{L}$$

$$\Delta T = t \cdot \frac{L}{2}$$

7.5 Entering or leaving shallow bank

When the ship is entering a shallow bank then due to restricted cross-section and reduced pressure under bow portion of the ship trim to bow may occur and the ship may hit the bottom with the bow.

When the ship is leaving shallow bank and entering deep-water area, the opposite may occur and the ship may hit the bottom with the stem.

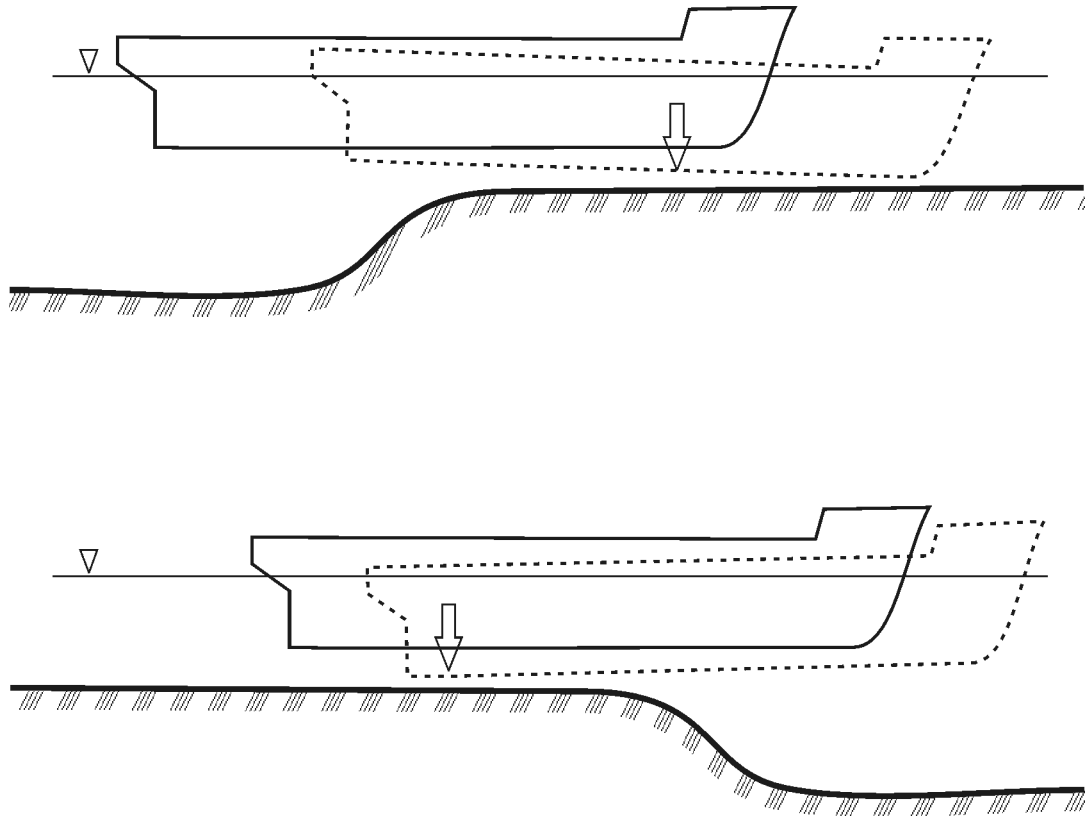


Fig. 7-17