

3 MEASURES AND CRITERIA OF MANOEUVRABILITY

MANOEUVRING TESTS

3.1 Measures of manoeuvrability

The following measures of manoeuvrability are recognized:

3.1.1 Course keeping ability – dynamic stability

Course keeping ability is the ability to sail on chosen course without excessive deviations from this course and without using rudder corrections to often.

Course keeping ability is related to dynamic stability on straight course. Ship is dynamically stable if after small disturbance will remain on the new straight course slightly deviated from the previous one without using rudder. There is, however, no force that can bring the ship to the original course without using rudder. Dynamically unstable ship will make a turning circle with rudder amidships

Ships can be dynamically stable or dynamically unstable. Dynamically unstable ships are more difficult to handle, and if the amount of dynamical instability is large, they might be dangerous.

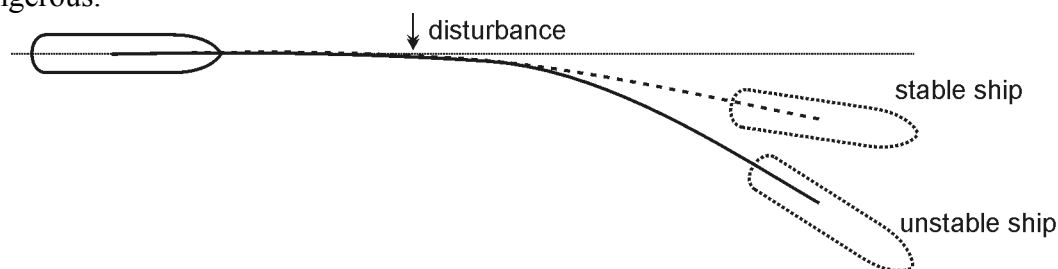


Fig. 3-1

3.1.2 Turning ability – initial turning ability

Turning ability is assessed by the dimensions of the turning circle executed after the rudder is deflected to the maximum angle to starboard or to port (usually 35 deg) and kept in this position. The smaller is diameter of the turning circle the better is turning ability.

Initial turning ability is assessed by the deviation from the original course caused by small deflection of the rudder (e.g. 10 degrees). The larger is deviation the better is initial turning ability.

3.1.3 Yaw checking ability

The measure of the yaw checking ability is the response of the ship to counter rudder during the initial phase of turn. This is measured by the amount of the “overshoot” angle. Yaw checking ability is related to dynamical stability – the dynamically unstable ships have worse yaw checking ability.

3.1.4 Stopping ability

Stopping ability is the ability to stop the ship on the shortest possible distance. It is assessed by the head reach from the point where the command “full astern” is given to the point where the ship stops.

3.2 Recommendations of IMO related to manoeuvrability

The International Maritime Organisation (United Nations Agency responsible for safety at sea, having its headquarters in London) adopted the following recommendations related to manoeuvrability of ships:

1. Interim Guidelines for Estimating Manoeuvring Performance in Ship Design, adopted by MSC/Circ. 389, 10 January 1985
2. Provision and Display of Manoeuvring Information on Board Ships, adopted by Resolution A.601 (15) on 19 November 1987
3. Interim Standards for Ship Manoeuvrability, adopted by Resolution A.751 (18) on 4 November 1993
4. Explanatory Notes to the Interim Standards for Ship Manoeuvrability, adopted by MSC/Circ.644 on 6 June 1994

MSC/Circ.389 defines specific manoeuvring characteristics, which quantify manoeuvrability and recommends estimation of these characteristics during design both for the fully loaded ship and test condition in deep water. They also outline full-scale tests to be performed in view of estimating manoeuvring performance of a ship. The specific manoeuvres include:

1. Turning circle test
2. Yaw checking ability- zigzag test
3. Initial turning test
4. Course keeping information tests
 - 1.1. The pull-out test
 - 1.2. The direct spiral test
 - 1.3. The reverse spiral rest
5. Stopping tests

Resolution A.601 (15) recommends to require that the following manoeuvring information is on board available to navigators:

- 1) Pilot card
- 2) Wheelhouse poster
- 3) Manoeuvring booklet

Resolution A.751 (18) recommends application of the interim standards for ship manoeuvrability specified below for ships longer than 100 metres and for all gas carriers and chemical tankers. The standards comprise

1. Turning ability
2. Initial turning ability
3. Yaw checking and course keeping abilities
4. Stopping ability

MSC/Circ. 644 is intended to provide Administrations with specific guidance on unified interpretation, application and consistent evaluation of the standards for ship manoeuvrability adopted by Resolution A.751 (18).

3.3 Manoeuvring tests

3.3.1 Turning ability – turning circle test

Turning circle test to be performed to both starboard and port with 35° rudder angle or the maximum design rudder angle permissible at test speed.

Test speed is estimated according to the formula: $V_T = C_B \cdot V_D$

Where: V_T - test speed; V_D - design speed; C_B - block coefficient

The ship is making a turning circle. A turning circle of at least 540° should be completed to determine the main parameters of the manoeuvre and allow correction for any drift caused by a steady wind or current. Characteristics of the turning circle are:

Advance, at 90° change of heading;

Tactical diameter at 180° change of heading;

Transfer at 90° change of heading as additional measure of some interest.

Advance, tactical diameter, and transfer are given as multiplicity of ship's length.

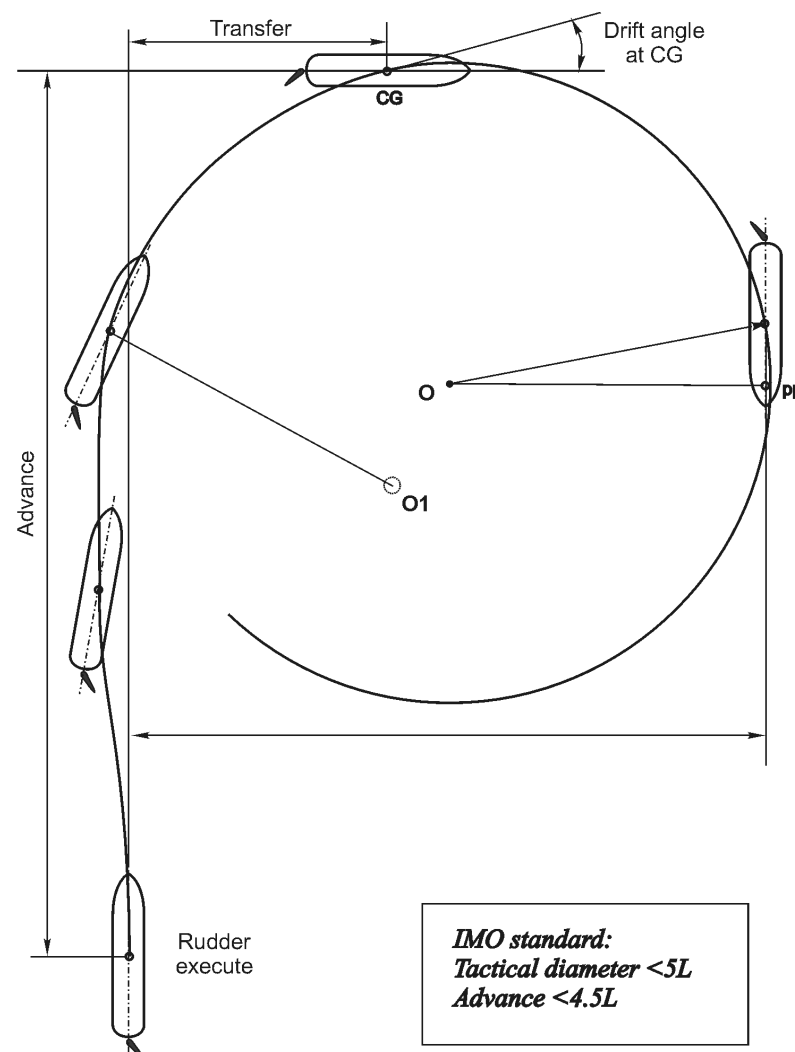


Fig. 3-2

3.3.2 Yaw checking ability, zig-zag test

Yaw checking ability is a measure of the response to the counter rudder applied in certain state of turning. Standard zigzag test is used in order to assess yaw-checking ability.

Standard zigzag tests:

- 10/10 deg (shown below)
- 20/20 deg

Non-standard: 5/5 deg or 5/10 deg

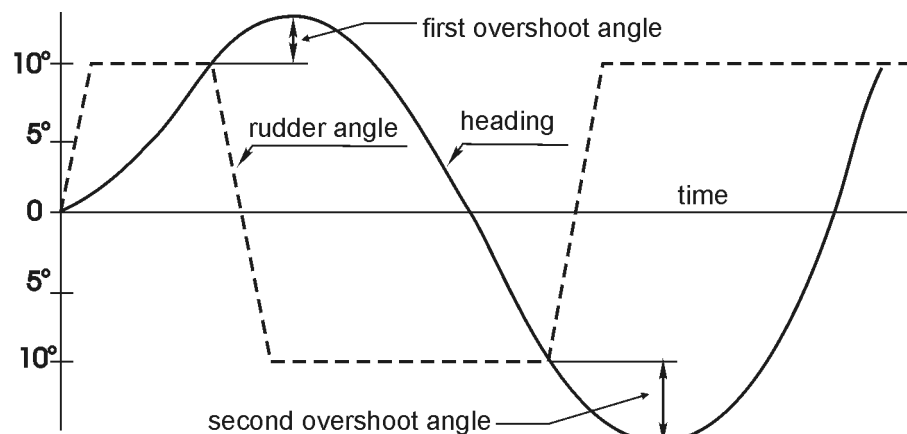


Fig. 3-3

IMO standard – Res. A 751(18) 1993

Applicable to all ships over 100m in length and all chemical tankers and gas carriers

In 10/10 deg zigzag test

- **First overshoot angle should not exceed 10 deg, if L/V is $< 10s$; 20 deg if L/V is $> 30s$ (linear interpolation for L/V between those values)**
- **Second, overshoot angle not more than 15 deg above those values**

In 20/20 deg zigzag test

- **The first overshoot angle should not exceed 25 deg**

Large tankers are dynamically unstable. If the amount of instability is large then zigzag test 5/5 deg, 5/10 deg (or sometimes even 10/10 deg) cannot be performed, because first (or second) or second overshoot angles are infinite. (Counter rudder limited to 5 or 10 deg is not enough to bring back the ship)

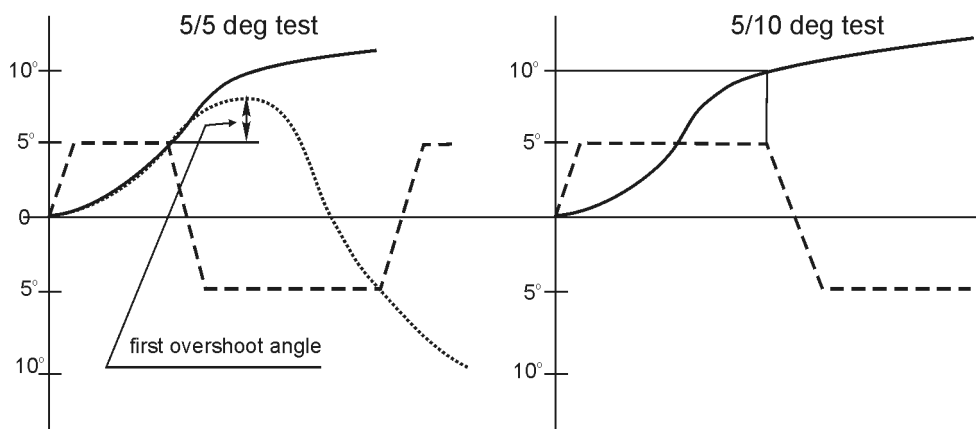


Fig. 3-4

3.3.3 Initial turning test

Initial turning ability is a measure of the reaction of the ship to small angle of rudder. Is defined by the distance travelled before realizing certain heading deviation when rudder is applied. Usually in initial turning test 10° rudder and 10° degrees rudder deviation is used.

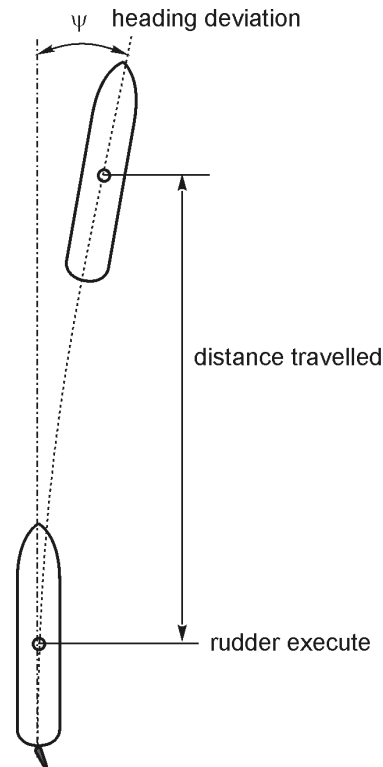


Fig. 3-5

IMO standard:

**With 10° rudder angle and 10° heading deviation,
distance travelled $< 2.5L$**

3.3.4 Stopping test

Stopping test should be performed from the test speed with maximum astern power. As indicated in figure, the ship's track and heading after astern order are plotted versus time. Head reach and lateral deviation are presented in terms of the number of ship lengths.

The time lag between issuing the astern order and the moment when the propeller stops and reverses should be measured.

Test speed:

$$V_T = C_B \times V_D$$

V_T : test speed

V_D : design speed

C_B : block coefficient

IMO standard:

Track reach $< 15L$

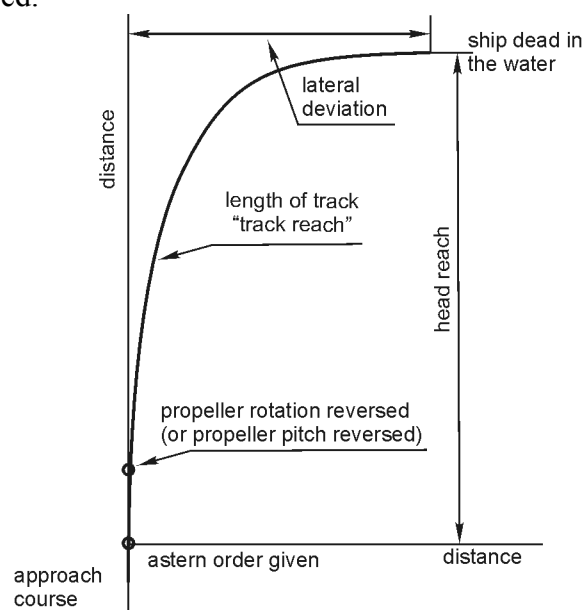


Fig. 3-6

3.3.5 Course keeping information tests

A. Pull-out test

The pullout test gives a simple indication of ship's dynamic stability on a straight course. The ship is first made to turn with a constant rate of turn in either direction, upon which the rudder is returned to midship. If the ship is stable, the rate of turn will decay to zero for turns to both starboard and port. If the ship is unstable, then the rate of turn will reduce to some residual rate of turn.

The pullout tests should be performed to both port and starboard side to show possible asymmetry (see figure). Normally, pullout tests are performed in connection with the turning circle tests, zigzag tests or initial turning tests.

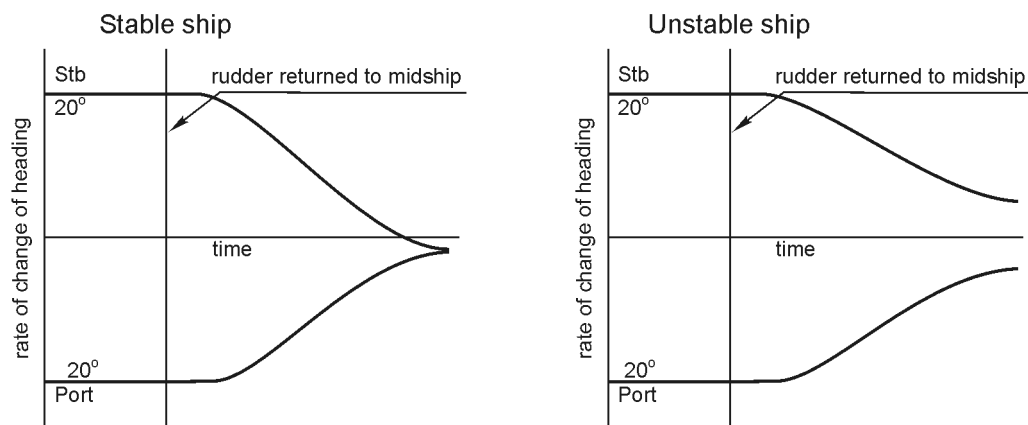


Fig. 3-7

Tankers and other full-bodied ships are, as a rule, dynamically unstable

B. Spiral tests direct and reverse

The amount of dynamic instability could be established by spiral test. The spiral test is an orderly sequence of turning circle tests to obtain a steady turning rate versus rudder angle relation.

With the ship on initial straight course, the rudder is put to about 20° starboard and held until the rate of change of heading is constant. The rudder angle is then decreased by 5° and again held until steady conditions of turning have been obtained. This procedure is repeated until the rudder has covered the range from 20° on one side to 20° on the other side and back again. Over a range of rudder angles of 5° to 10° on either side of zero or neutral rudder angle, these intervals should be reduced to 1° .

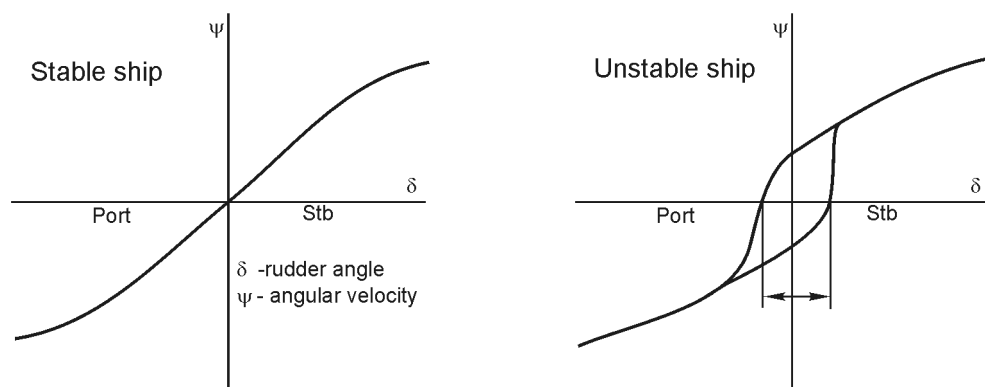


Fig. 3-8

➤ *Width of instability loop is a measure of the amount of instability*

3.4 Effect of ship size on turning performance

Turning characteristics depend on the ship size. The tactical diameter is not proportional to the displacement of the ship but relative tactical diameter D/L is equal for ships geometrically similar of different size as well as for full-scale ship and its model.

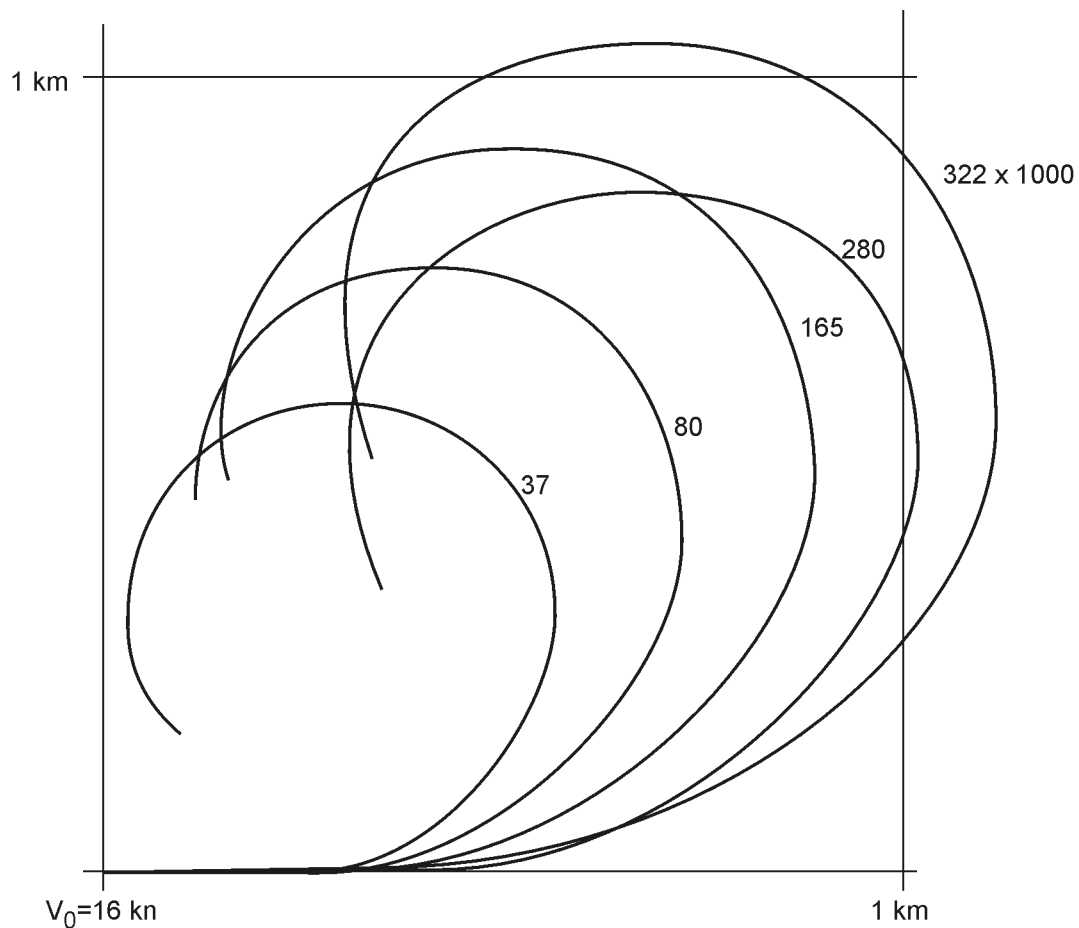


Fig. 3-9 – Turning ability for tank vessels (deep water)

3.5 Effect of ship parameters on turning performance

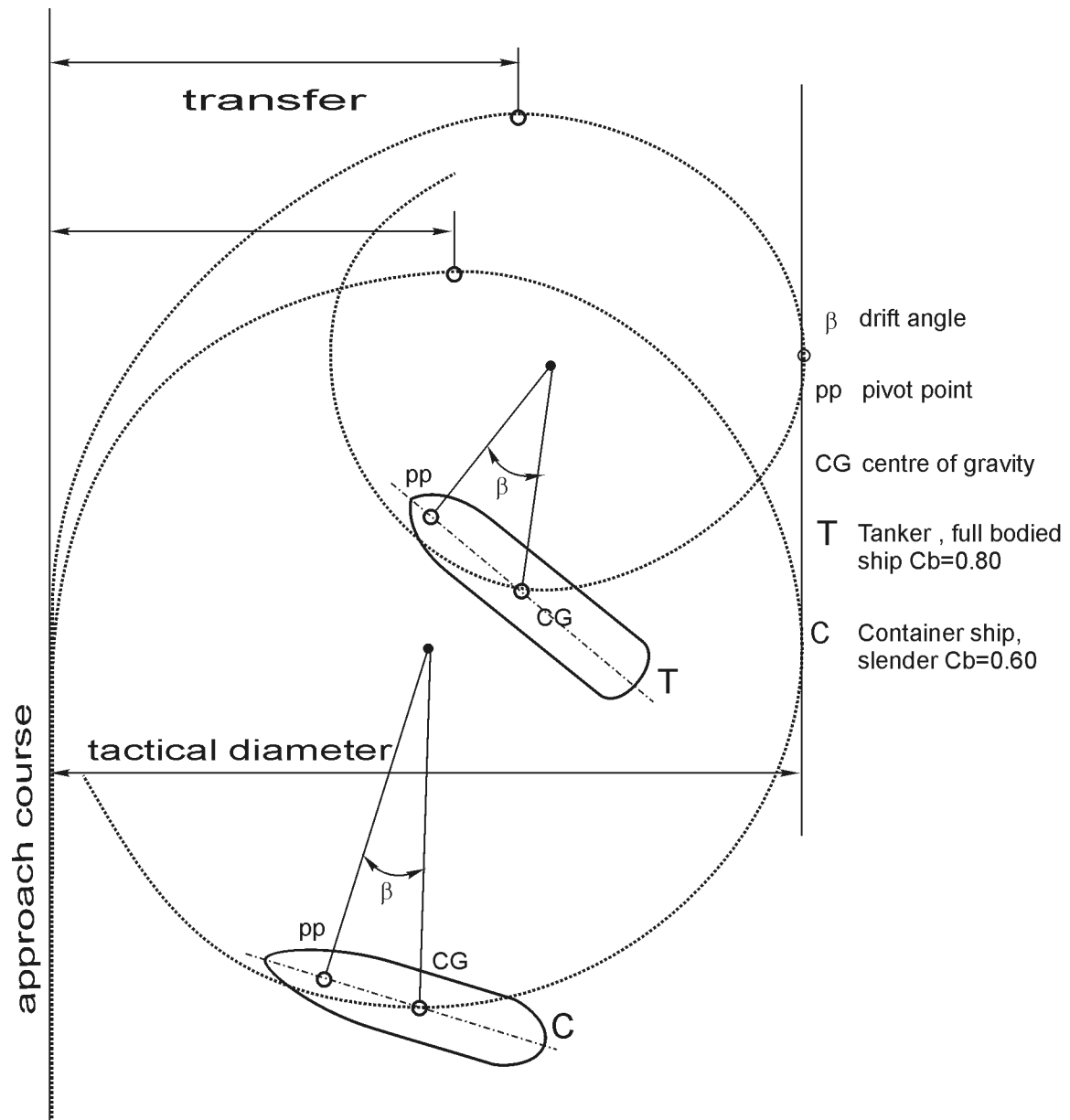


Fig. 3-10 Comparison of turning characteristics of full and slender ship

- *Two ships of the same length have nearly the same transfer*
- *Tactical diameter for both ships is almost the same*
- *Radius of the steady turning circle is much smaller for tanker*
- *Drift angle is much larger for tanker*
- *Pivot point is closer to the bow in tanker*

3.6 Effect of ship parameters on turning and course keeping

Manoeuvring performance depends on ship form and proportions. Table below shows the effect of ship performance on manoeuvring characteristics.

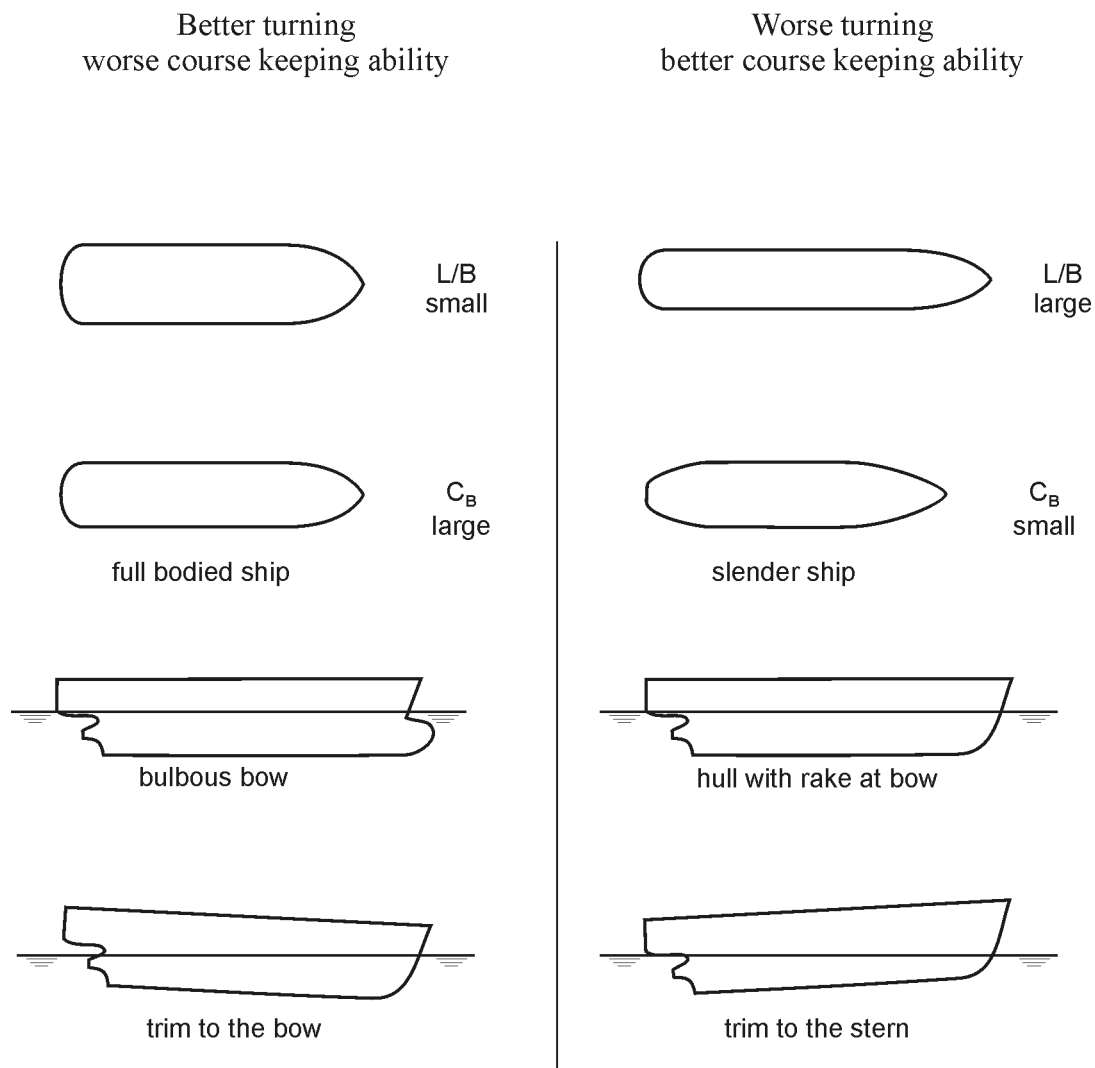


Fig. 3-11

Normally in calm water fully loaded ship at speed about 5 knots with rudder hard over (35 deg) will turn round 180 degrees in less than 4 ship's lengths. With smaller rudder angle the ship will make longer turning circle and gain more speed.