1. DETERMINING ABSORBED ENERGY OF A BERTHING SHIP (Continued)

Therefore, Energy to be absorbed by the fender system is:

\[ E_{\text{fender}} = E_{\text{Ship}} \times f \]

Where

\[ f = C_e \times C_m \times C_s \times C_c \]

- \( C_e \): Eccentricity Factor
- \( C_m \): Virtual Mass Factor
- \( C_s \): Softness Factor
- \( C_c \): Berth Configuration Coefficient

These variables are covered in detail on the following pages. Also, convenient charts are provided in Section 2.3 which indicate the amount of berthing energy generated by various ship sizes under standard conditions.

2. CALCULATING BERTHING ENERGY

2.1 KINETIC ENERGY EQUATION

The equation detailing the variables:

\[ E_{\text{fender}} = \frac{1}{2} M V^2 \times C_e \times C_m \times C_s \times C_c \]

2.2 VARIABLES

a) Mass - \( M \)

One or more of the following weights should be readily available from the facility user:

- Displacement Tonnage - \( D_T \)
  - This is the weight of the water displaced by the immersed part of the ship.
- Dead Weight Tonnage - \( DWT \)
  - This is the weight that the ship can carry when loaded to a specified load draft. (Includes cargo fuel, stores, crew, passengers.) It is the most common measurement.
- Gross Tonnage - \( GT \)
  - This is based on the cubic capacity of the ship below the tonnage deck with allowance for cargo compartments above.

When calculating the mass - \( M \), use the loaded displacement tonnage \( D_T \). Typically \( D_T \) is 30% - 40% greater than \( DWT \).

Where:

\[ M = \frac{D_T}{g} \]

\( D_T \) = Displacement Tonnage (tonnes)
\( g \) = Acceleration Due to Gravity = 9.81 M/Sec²

b) Velocity - \( V \)

As can be seen from the Kinetic Energy Equation, the energy to be absorbed is a function of the square of the approach velocity. For this reason, DETERMINING THE VELOCITY IS ONE OF THE MOST IMPORTANT DECISIONS IN THE DESIGN. The choice of design velocity (velocity component normal to the dock) is a judgement based on ship size, site exposure and berthing procedure. Environmental aspects such as wind and current forces may be an influence. Section 2.4 b) describes how these forces can be calculated. Consultation with Port Management, ship operators and any other available information should be used when making the judgement.

The following chart is offered as a guide to assist in selecting a design velocity:

![Chart showing Velocity vs. Navigation Conditions]

- **NAVIGATION CONDITIONS**
  1. Easy Docking; Sheltered
  2. Difficult Docking; Sheltered
  3. Easy Docking; Exposed
  4. Good Docking; Exposed
  5. Difficult Docking; Exposed

The graph illustrates the relationship between the eccentricity coefficient and the distance "\( a \)" (as shown above).

![Graph showing Eccentricity vs. Distance]

\[ C_e = \frac{K^2}{a^2 + K^2} \]

Where:

- \( K \) = radius of longitudinal gyration of the ship
- \( a \) = distance between the ship’s center of gravity and the point of contact on the ship’s side projected onto the longitudinal axis (in terms of \( L \) - the ship’s length)

The value of \( K \) is related to the block coefficient of the ship and its length. It can be approximated by the following expression:

\[ K = (0.19 C_b + 0.11) \times L \]

and the block coefficient \( C_b \)

\[ C_b = \frac{D_T}{D \times B \times L \times W_o} \]

Where:

- \( D_T \) = Displacement of the ship (tonnes)
- \( D \) = Draft (m)
- \( B \) = Width (m)
- \( L \) = Length (m)
- \( W_o \) = Water Density (tonnes/M³)

Typical Seawater \( W_o \) = 1.025 tonnes/M³ (64 lb/ft³)

Typical Freshwater \( W_o \) = 1.00 tonnes/M³ (62.3 lb/ft³)