Aalto University
School of Engineering

MEC-E1004 Principles of Naval Architecture

Tutorial 3 – Main dimensions

Exercise 1 (Understanding coefficients)

- **Question 1A :** Find the area of the waterplane of a ship 200 meters long, 30 meters beam, which has a coefficient of fineness of 0.8?

✓ Area of waterplane = L x B x Cw = 200 x 30 x 0.8 = 4800 sq m

- **Question 1B :** A ship 64 meters long, 10 meters maximum beam, has a light draft of 1.5 meters and a load draft of 4 meters. The block coefficient of fineness is 0.600 at the light draft and 0.75 at the load draft. Find the deadweight.

✓ Light displacement = L x B x draft x Cb = 64 x 10 x 1.5 x 0.600 = 576 cubic meters
✓ Load displacement = L x B x draft x Cb = 64 x 10 x 4 x 0.750 = 1920 cubic meters
✓ Deadweight = Load displacement – Light displacement = 1920 – 576 cubic meters
✓ Deadweight = 1344 cubic meters = 1344 x 1.025 tonnes = 1378 tonnes.

- **Question 1C :** Explain in detail the principles of the prismatic coefficient (see next page)

Exercise 1 (Understanding coefficients)

- **Question 1C :** Explain in detail the principles of the prismatic coefficient

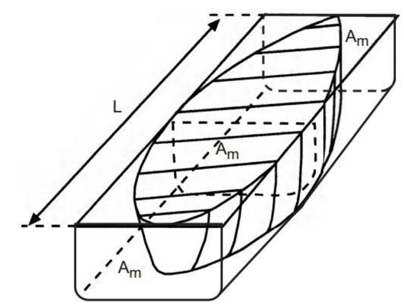
The prismatic coefficient of a ship at any draft is the ratio of the volume of displacement at that draft to the volume of a prism having the same length as the ship and the same cross-sectional area as the ship's midships area. The prismatic coefficient is used mostly by ship-model researchers. In the figure below the shaded portion represents the volume of the ship's displacement at the draft concerned, enclosed in a prism having the same length as the ship and a cross-sectional area equal to the ship's midships area (Am).

Prismatic coefficient (Cp) = Volume of ship ÷ Volume of prism
= Volume of ship ÷ (L x Am)
Volume of Ship = L x Am x Cp

Note that Cp is always slightly higher than Cb at each waterline.

Cm x Cp = [Am ÷ (B x d)] x [Volume of ship ÷ (L x Am)]
= Volume of ship ÷ (L x B x d)
= Cb

Cm x Cp = Cb or Cp = Cb ÷ Cm



The Prismatic Coefficeint

Exercise 2 (Reference ship + Normand's no)

- Assume Reference ship
  - *Main dimensions of ship: L = 150 , B = 21 m, T= 9 m and CB = 0.72*
  - *Lightship weight*
    - Hull WH = 4 000 ton
    - Machinery WM = 1 500 ton
    - Outfitting WO = 1 000 ton
  - *Deadweight includes 1 500 ton fuel*

- Create a new ship using the reference ship approach
  - *Deadweight is increased by 4 000 ton*
  - *Speed and autonomy time is unchanged*
  - *Draught is not possible to increase*
  - *Calculate the new ship's main dimensions and displacement*

Exercise 2 (Reference ship + Normand's no)

- In order to calculate Normand's number, the displacement of reference ship is needed (ρ = 1025 ton/m3, λ factor is 1.006):

$$\boldsymbol{N} = \frac{\boldsymbol{d\Delta}}{\boldsymbol{dW}} = \frac{\Delta}{\Delta - \boldsymbol{W_{H+O}} - \frac{\mathbf{2}}{\mathbf{3}}(\boldsymbol{W_M} + \boldsymbol{W_F})} = \mathbf{1.5}$$

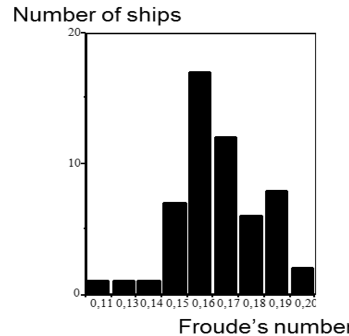
- Thus, the displacement of new ship is $\Delta_u = \Delta + NdW = 27\,050\ ton$

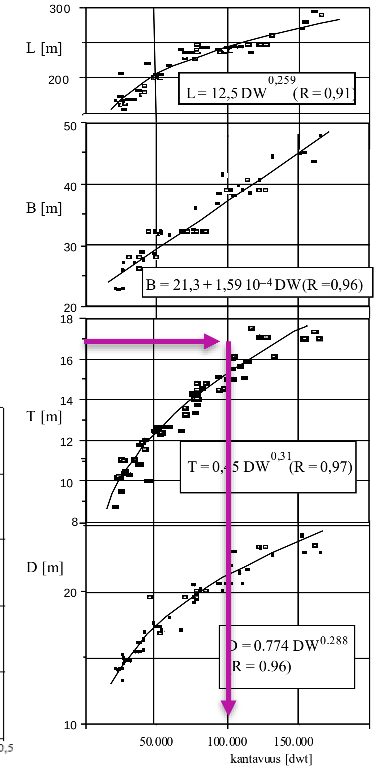
- When the new main dimensions is determined, it is assumed that the L / B ratio (7.14) and the block CB and draught remain unchanged. Based on the weight equation, the main dimension of new ship is:
  - *L = 170 m (previously 150 m)*
  - *B = 23,8 m (previously 21 m)*
  - *T = 9 m (unchanged)*
  - *CB = 0,72 (unchanged)*

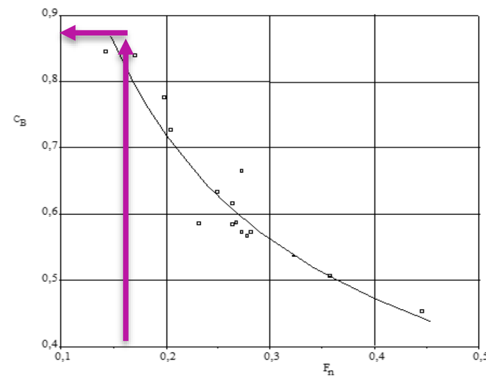
- These main dimension give the displacement of 27 035 ton, which agrees the required value with sufficiently accuracy

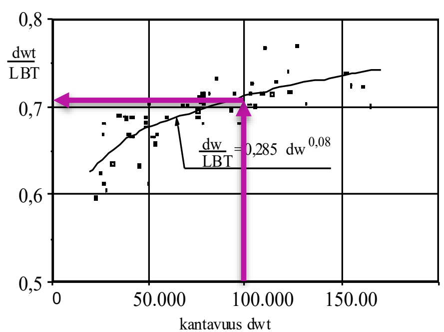
Example 3 – The satistical approach

- Define main dimensions of a bulk carrier
  - *The ship's is to transport coal to Finland. Density (stowage) factor for coal is assumed to be 1.3 m3/ton. The maximum allowed draught for Denmark Strait is 15 m, and the target speed is 15.5 knots.*
    - $T_{max} = 15\ m$ → DWT ≈ 100 000 t
    - $\frac{DWT}{LBT} \approx 0.72$
    - LBT = 100 000/0.72 ≈ 139 000 m3
    - Assumption: Fn=0.16 → $C_B \approx 0.81$
    - Displacement = C_BLBT = 112 500 m3



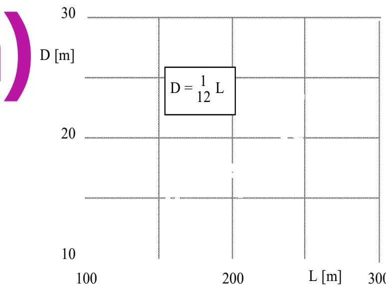


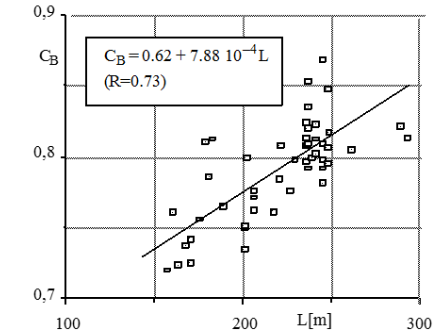


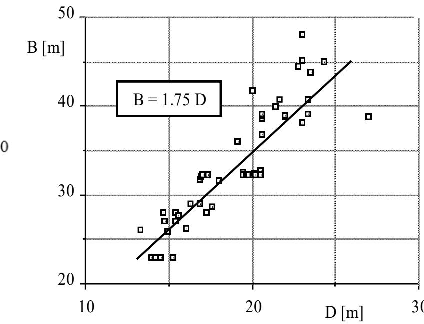


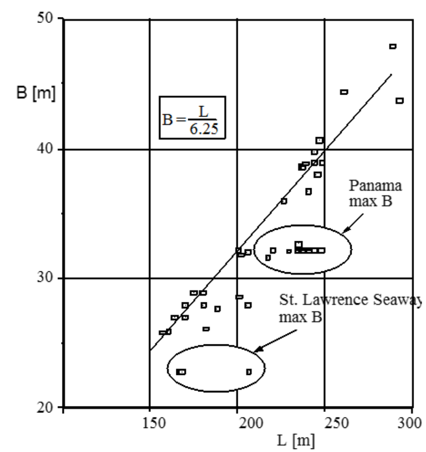
Example 3 (Satistical approach)

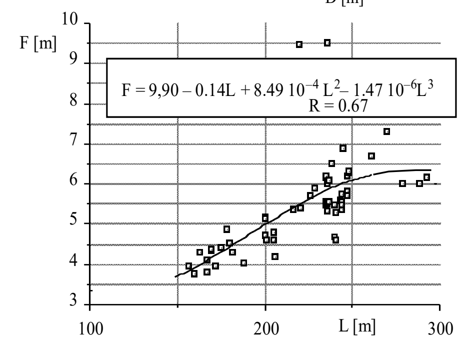
- Displacement = C_BLBT = 112 500 m3
- Ship length according to Schneekluth
- L=(C_B-0.62) / 7.88*10^-4 ≈ 241 m
- B=L/6,25 ≈ 38.6 m
- LBT = 241m * 38.6m * 15m ≈ 140 000 m3
- Δ=ρλC_BLBT = 1,025 ton/m3 * 1.006*0.81*241m*38.6m*15 m ≈ 117 000 t
- DWT/Δ = 100 000 t/ 117 000 t ≈ 0.85
- Lightship weight = W_{LS} = 117 000 t – 100 000 t ≈ 17 000 t
- D = L/12 = 241 m/12 ≈ 20 m (grap 1)
- D =B/1.75 = 38.6 m / 1.75 ≈ 22 m (grap 1)
  - Let's select the higher (22 m) since the density of cargo is low
- Freeboard = D-T = 22 m – 15 m = 7 m





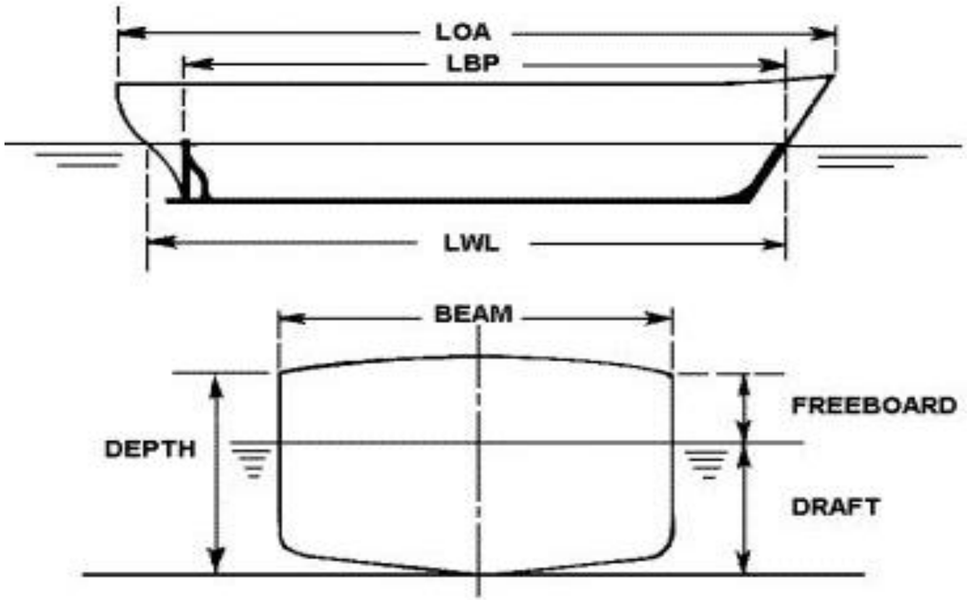






Example 3 (Satistical approach)

- Length (L) = 241 m
- Breadth (B) = 38.6 m
- Draught (T) = 15 m
- Depth (D) = 22 m
- Block coefficient (C_B) = 0.81
- Freeboard (F) = 7 m



Example 4 (Direct Calculations)

- Shipowner requirements
  - *Modern Ropax ship for the route Aberdeen – Kirkwall – Lerwick*
  - *Lloyd's Register of Shipping*
    - + 100A1, Roll on/Roll off Cargo and Passenger Ferry +LMC, NAV1, UMS, LI
  - *600 passenger and 40 crew member*
    - 50 cabins for 2 person, 50 cabins for 4 person
    - 10 officer cabins and 27 crew cabins
  - *About 430 lane meters for trucks or 530 lane meters for cars on the main deck*
    - 25 cars on the other cargo deck (4.25 m / car)
  - *Speed 24 knots, design draught*
  - *Deadweight 1560 t, design draught*

Example 4 (Direct Calculations)

- Breadth is function of lane width and width of double side: $\boldsymbol{B = 2x2m + 5x3m = 19m}$

  In comparison to reference ship, B is reasonable

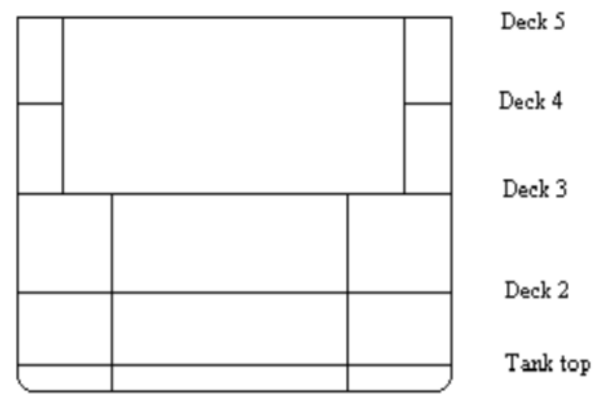
- For car-passenger ferries with the speed of about 24 knots, the Froude number is about 0.35

$$\boldsymbol{L = \frac{v^2}{F_n^2 g} = 126.8\ m} \qquad \boldsymbol{C_B = 1.09 - 1.68F_n = 0.502}$$

- L / B ratio = 6.67
  - *In comparison to the references, this is reasonable*

- Ro-ro deck requires about 4.5 meters free height and the web frame requires about 1 m

$$\boldsymbol{B = (4.5 + 1 + 1 + 2x3.5)m = 13.5m}$$



L	126.8 m	C_B	0.502
B	19 m	F_n	0.35
T	5.25 m	Δ	6510 t
D	13.5 m	W_{LS}	4950 t

Example 4 (Direct Calculations)

- Steel weight W_{ST} (t): $W_{ST} = 0.135W_{DW} + 2\,500\ t = 2\,707\ t$
- Estimation of the machinery weight W_Q(t) is based on the power requirement (BkW), which based on the reference ship is assumed 20 000 kW

$$W_Q = \frac{BkW(895 - 0.0025BkW)}{10\,000} = 1\,690\ \text{t}$$

- Outfitting weight : $W_{OA} = 277 + 0.115LB = 554\ t$
- Lightship weight: $W_{LS} = W_H + W_M + W_O \approx 4\,950\ t$
- Displacement: $\Delta = W_{LS} + W_{DW} = 6\,510\ t$
- Draught with the sea water density of ρ = 1.025 t /m3: $T = \frac{\Delta}{C_B \rho LB} = 5.25m$

Summary

The main dimensions consist of

- Linear dimensions: length, breadth,...
- Area based dimensions
- Volume based dimensions

The selection of appropriate main dimensions is very important as they define to a large extent a ship's technical and economical performance

- Can be selected/determined in various ways
  - *Based on a reference ship*
    - The dimensions can be scaled using the Normand's number
  - *Based on statistical data*
  - *Based on direct calculations*

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Bonus material

Examples of Main Dimensions

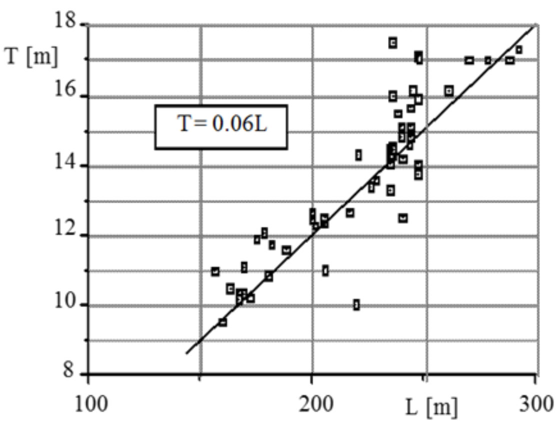
- Slenderness ratio describes the ratio between length and volume
- Ratio of principal dimensions
  - *L/B describes relative breadth, 4-10*
  - *B/T describes relative breadth, 8 – 5*
  - *L/T describes beam characteristics, 10 – 30*
  - *L/D describes beam characteristics, 10 - 20*
- Hydrodynamic speed, Froude number:

$$F_n = \frac{v}{\sqrt{gL}}$$

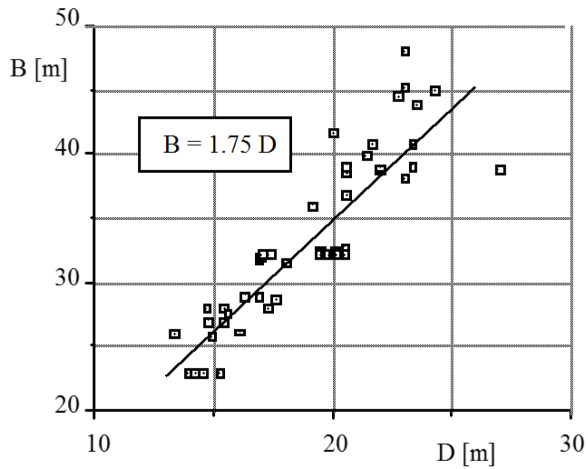
parametri	Passenger ship	Container ship	Crude oil tanker	Oil product tanker	War ship
L_{OA} [m]	301,75	262,13	335,28	201,47	135,64
L_{pp} [m]	275,92	246,89	323,09	192,02	124,36
L[m]	286,99	246,89	323,09	192,02	124,36
D[m]	22,63	20,12	26,21	13,79	9,14
B[m]	30,94	32,23	54,25	27,43	13,74
T[m]	9,65	10,67	20,39	10,40	4,37
D SW [ton]	46.720	50.370	308.700	43,400	3390
C_B	0,532	0,579	0,842	0,772	0,449
C_M	0,953	0,965	0,996	0,986	0,741
C_P	0,558	0,600	0,845	0,784	0,605
C_W	0,687	0,748	0,916	0,854	0,727
C_{VP}	0,774	0,774	0.919	0,904	0,618
LCB, % L	mid-ship	-1,1	+2,7	+1,9	-1,4
$L/\nabla^{1/3}$	8,03	6,62	4,82	5,51	8,36
L/B	9,28	7,94	5,96	7,00	9,05
B/T	3,21	2,91	2,66	2,64	3,14
L/T	29,74	23,14	15,85	18,46	28,46
L/D	12,68	12,27	12,33	13,92	13,61
P_S [MW]	117,9	32,2	26,11	11,19	29,84
V [knots]	33	25	15,2	16,5	30
F_n	0,320	0,261	0,139	0,196	0,442

Statistical relationships between various main dimensions

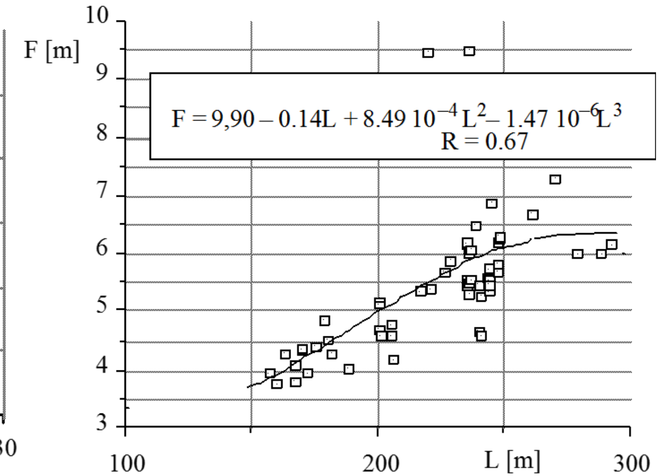
Length (L) vs. Draught (T)



Depth (D) vs. Breadth (B)

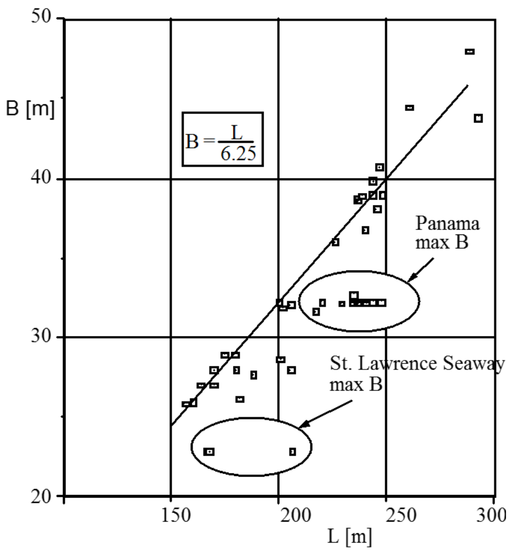


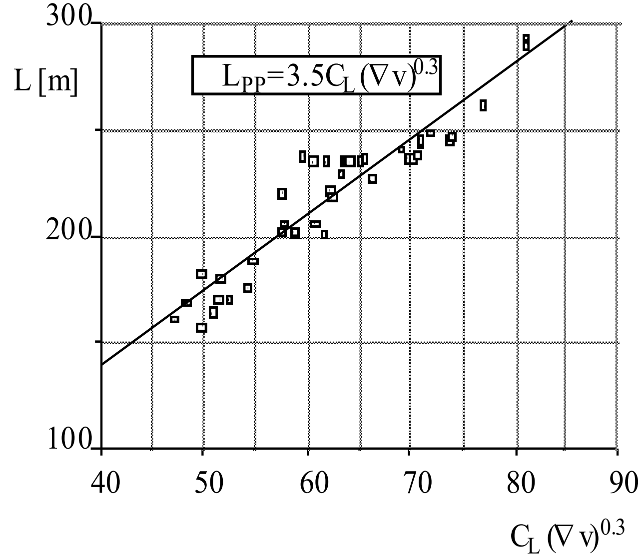
Length (L) vs. Freeboard (F)

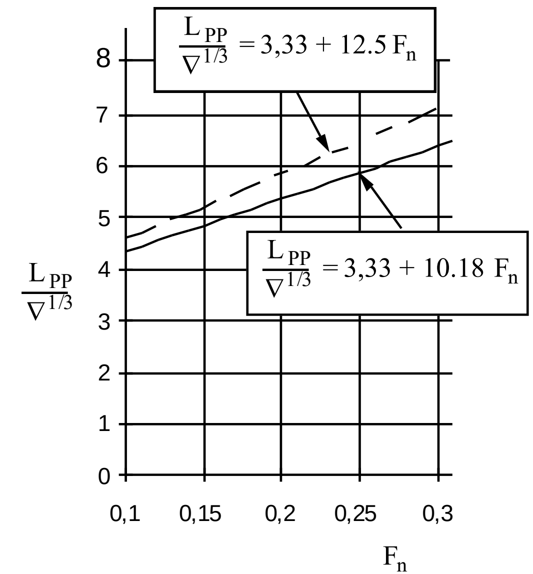


Statistical relationships between various main dimensions

Length (L) vs. Breadth (B)







Statistical relationships between various main dimensions