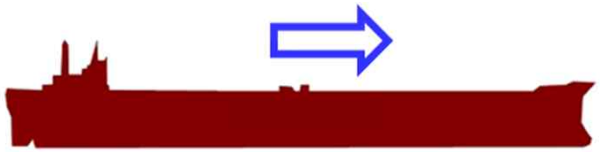
❑ What is resistance?

- Impossible directly to predict the resistance of a ship in sailing.
- Indirect prediction of the ship resistance in sailing.
  - $\eta_D = \frac{EHP}{DHP} = \frac{R \cdot V}{2\pi \cdot n \cdot Q}$
  - $R = (1 - t) \cdot T$

❑ How to predict resistance?

- Experiment or CFD based on the Froude's hypothesis
- Coordinate system


W. Froude (1810~1879)

Moving ship	Fixed ship
	
Towing tank experiment	Circulating experiment, CFD

❑ Prediction of resistance performance in calm water at model scale

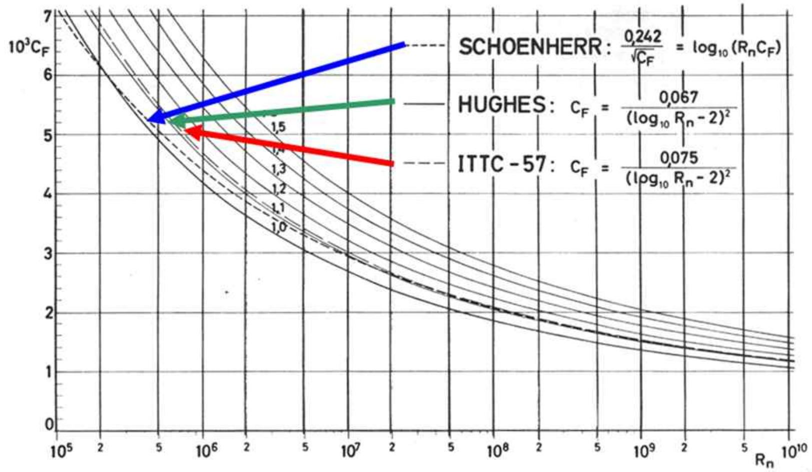
❍ Total resistance (C_{TM}): Exp.

- **3-D analysis method (ITTC-78 method)**

$$C_{TM} = C_{VM}(R_N) + C_R(F_N) = (1+k)\cdot C_{FM\,O} + C_R(F_N)$$

where $C_{FO} = \frac{0.075}{(bg\ _{10}R_N-2)^2} = (1+0.1194)\frac{0.067}{(bg\ _{10}R_N-2)^2}$ **(ITTC 1957 model-ship correlation line)**

Form effect Hughes flat plate

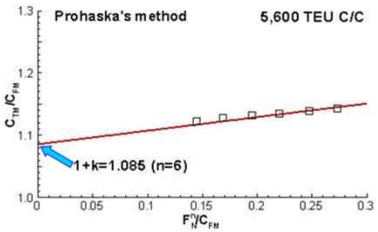


Total (Exp.)

- Residual (C_R)
- Viscous resistance (C_{VM})
  - Form effect ($k \cdot C_{FO}$)
  - Equivalent flat plate (C_{FO})

❑ Prediction of resistance performance in calm water at model scale

- **Total resistance (C_{TM}): Exp.**
  - **Form factor (1+k): Prohaska's method (1966)**



- **Assumption: $C_R(F_N) \sim a \cdot {F_N}^n$ in low speed range**
- $C_{TM} = (1+k) \cdot C_{FM\,O} + a \cdot {F_N}^n$ or $\frac{C_{TM}}{C_{FM\,O}} = (1+k) + a \cdot \frac{{F_N}^n}{C_{FM\,O}}$
- **Note that**

① **Separation on a model may give too high a form factor.**

② **Laminar flow on a model may give too low a form factor.**

③ **Wave braking may disturb the linearity of the resistance coefficient.**

④ **A bulb may also disturb the linearity.**

⑤ **Interaction between propeller and hull may influence the form factor.**

⑥ **It may difficult to take the appendage into account.**

⑦ **Tank blockage may influence the form factor.**

⑧ **The form factor is dependent on the F_N.**

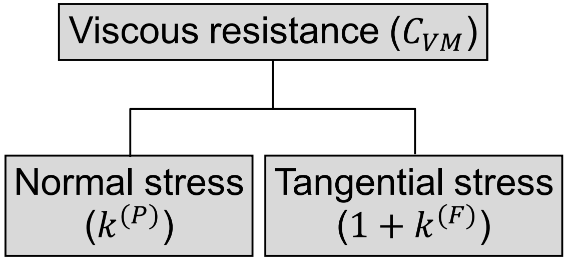
⑨ **The form factor may be dependent on the R_N.**

❑ Prediction of resistance performance in calm water at model scale

❍ Viscous resistance (C_{VM}): CFD

- **Assumption: Total resistance of a double-body model is equal to the viscous resistance (OE, 2010).**

$$C_{VM}(R_N) = (1+k)C_{FMO}$$

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Resistance and propulsion characteristics of various commercial ships based on CFD results

J.E. Choi *, K.-S. Min, J.H. Kim, S.B. Lee, H.W. Seo

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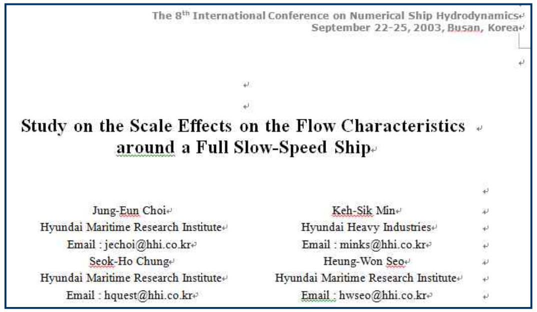
- **Scale effect of form factor (ICNSH, 2003)**

$$1+k = \left(1+k^{(F)}\right) + k^{(P)}$$

Table A Comparison of form-factor components

R_N	1.111×10^6	6.831×10^6	2.151×10^9
$1+k^{(F)}$	0.943	0.991	1.165
$k^{(P)}$	0.196	0.194	0.197
$1+k$	1.140	1.185	1.363


The 8th International Conference on Numerical Ship Hydrodynamics
September 22-25, 2003, Busan, Korea

Study on the Scale Effects on the Flow Characteristics around a Full Slow-Speed Ship

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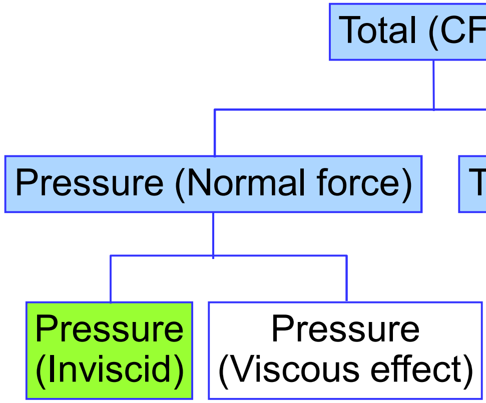
❑ Prediction of resistance performance in calm water at model scale

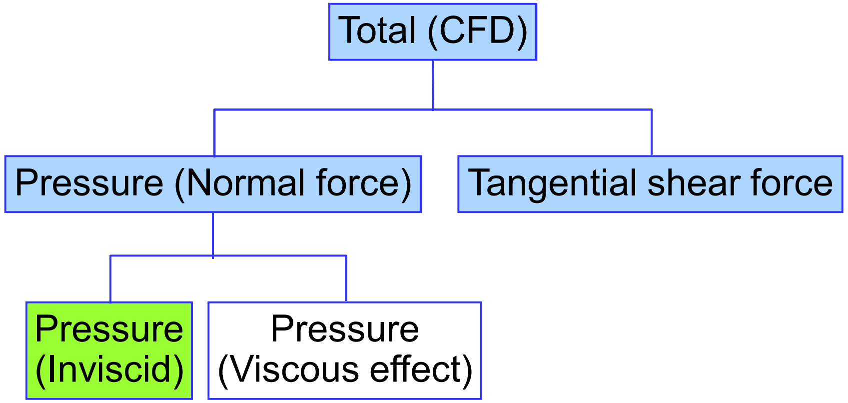
❍ Total resistance (C_{TM}): CFD

- $C_{TM} = \iint_S (c_p \cdot n_x + c_{fx}) \cdot dS = C_{TM}{}^{(P)} + C_{TM}{}^{(F)}$



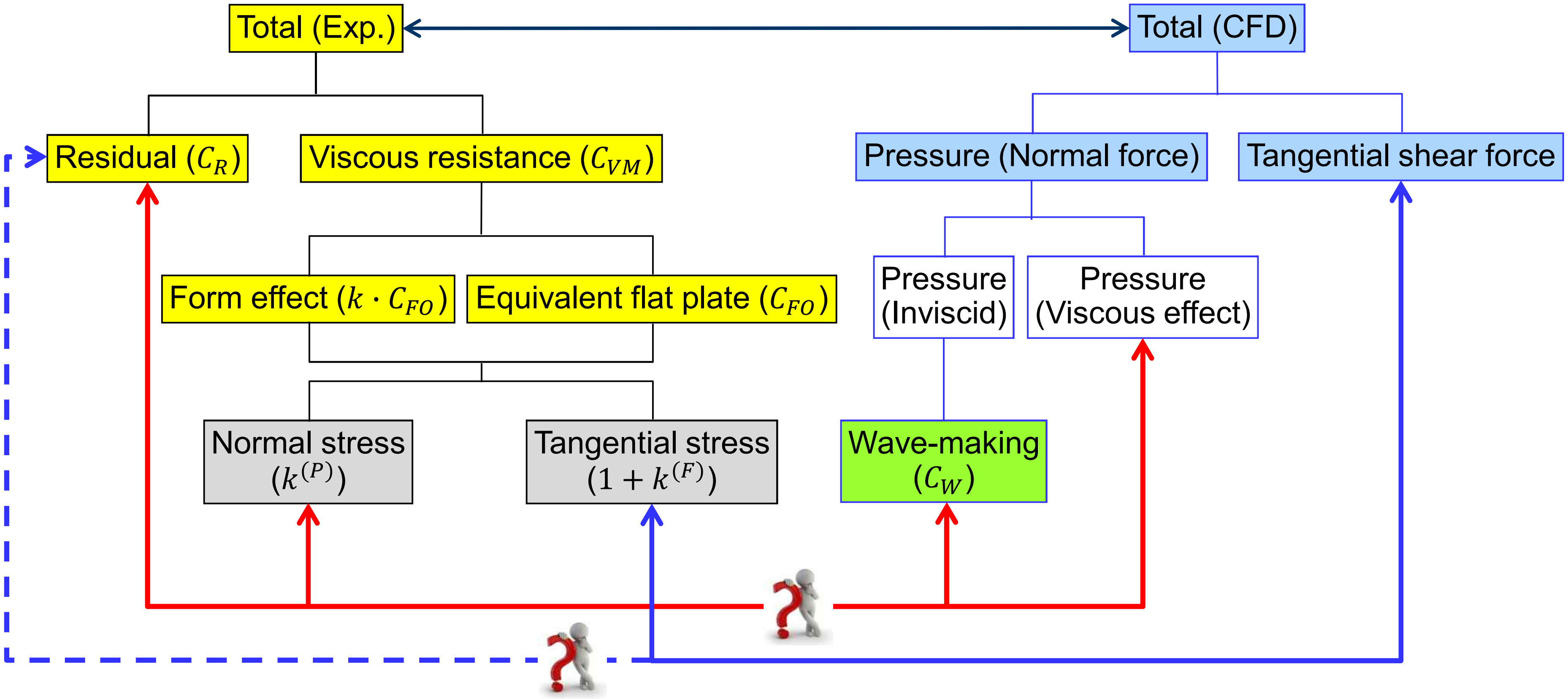
Prediction of resistance performance in calm water at model scale

- **Wave-making resistance (C_W): Potential-flow solver**
  - $C_W = \iint_S c_p \cdot n_x \, dS$



❑ Prediction of resistance performance in calm water at model scale

❍ Relationship between resistance components



❑ Future works

- **Program debugging and making manual of potential solver (PotWave)**
- **Objective ships: KVLCC2 and KCS**
- **Computations:**
  - **Potential flow solver**
  - **Viscous flow solver: Double-body and free-surface models**
- **Experiments (PNU, KRISO, HMRI, …)**
  - **Attached rudder or not?**
- **Relationship between resistance components**
  - $C_W + C_{TM}{}^{(P\_Vis)} = C_R{}^{(P)} + k^P \cdot C_{FM\,O}$ ➔ $C_W > C_R{}^{(P)}$ since $C_{TM}{}^{(P\_Vis)} < k^P \cdot C_{FM\,O}$
  - $C_R{}^{(F)} + (1 + k^F) \cdot C_{FM\,O} = C_{TM}{}^{(F)}$ ➔ Scale effect of C_R since $(1 + k^F) \cdot C_{FM\,O} \neq C_{TM}{}^{(F)}$
  - $1 + k = \left(1 + k^{(F)}\right) + k^{(P)}$ ➔ Scale effect of (1+k) since $k^F \neq 0$
  - **Full scale prediction method:** 

$$C_{TS} = \frac{S_S + S_{BK}}{S_S}\left[(1 + k) \cdot C_{FS} + \Delta C_F\right] + C_R + C_{AA}$$