Report of the Specialist Committee on Powering Performance Prediction

Presenter: Sverre Steen, Norway

Committee Members

- **Sverre Steen**, *Chair*
  Norwegian University of Science and Technology, Norway
- **Maria Bobo**, *Secretary*
  Canal de Experiencias Hidroninámicas de El Pardo, Spain
- **Gabor Karafiath**
  Naval Surface Warfare Center – Carderock Division, USA
- **Mustafa Insel**
  Istanbul Technical University, Turkey
- **Richard Anzböck**
  Vienna Model Basin, Austria
- **Jinho Jang**
  Samsung Heavy Industries, Korea
- **Naoji Toki**
  Mitsubishi Heavy Industries, Japan
- **Dexiang Zhu**
  CSSRC, Shanghai Branch, China
- **Wei Qiu**
  Memorial University of Newfoundland, Canada

Committee Meetings

1. China Ship Scientific Research Centre, Shanghai Branch, November 2005 (7)
2. Istanbul Technical University, Turkey, October 2006 (6)
3. Norwegian University of Science and Technology, Norway, September 2007 (6)
4. Memorial University of Newfoundland, Canada, March 2008 (6)

Tasks of the committee

1. Review and update the Speed/Power Prediction procedure (7.5-02-03-01.4),
   - Make use of the dataset of over 120 ships, which has been collected,
   - Complete the outstanding set of resistance, open water and load varying self propulsion tests initiated by the 24th ITTC
2. Make the Speed/Power Prediction (7.5-02-03-01.4) and the Predicting Powering Margins (7.5-02-03-01.5) procedures consistent with the Analysis of Speed/Power Trial Data (7.5-04-01-01.2).
3. Review and update the procedures for predicting the resistance and propulsion of high speed marine vehicles, including multihull vessels (7.5-02-05-01 / 02) to assess power requirements, taking into account drag reduction, hull appendage interactions, hull/propulsor interaction and hydrodynamic loads in waves.

Philosophy of procedure updates

- A change should reflect a proper balance between current practice and state-of-the-art.
- A change should reflect physical aspects correctly.
- A change should have a *significant* impact on the results.

Outline of presentation

- Update of the 1978 powering performance prediction procedure (Task 1)
  - Questionnaire and state-of-art study
  - The ”database of 120 ships”
  - Form factor scale effect
  - Use of a new friction line?
  - Roughness allowance, correlation and other issues
- Update of the Predicting powering margins procedure (Task 2)
- Update of the Resistance of HSMV-procedure (Task 3)
  - Summary of updates
  - Outstanding issues
- Recommendations to the conference

Questionnaire

- <u>Objective:</u> survey of current practice in powering prediction
- Sent to most ITTC member organisations
- 42 replies
- 14 questions related to conventional ships
- 13 questions related to HSMV

Conventional ships - Results – Form factors

- 31 of 42 use form factor in resistance prediction
  - 25 use Prohaska method (or similar)
  - 14 measure form factor at low *Fn*
  - 6 uses empirical methods to determine *k*
- 20 org. Use form factor to calculate tow rope force F_D
  - 19 do not use fom factor for this purpose

⇒Most organisations use a form factor approach

Conventional ships - Results – Friction line

- 29 org. uses the ITTC’57 line as standard
- 8 uses Schoenherr line
- 2 uses Prandtl-Schlicting
- 1 uses Hughes line
- 1 uses Karman Schoenherr

⇒ITTC’57 is still dominating

⇒None reports using Grigson as standard

Conventional ships – Roughness correction

- 36 org. apply a roughness correction to the full scale frictional resistance
  - 13 use the Bowden Davidson formula from the ITTC'78 method
  - 13 include the roughness correction in C_A
  - 13 use other method

⇒There is no commonly agreed method of roughness correction

⇒Bowden Davidson is still the dominating formula

Conventional ships – Wake scaling

- 32 org. scale the wake of single screw ships
  - 21 uses the method in ITTC'78 procedure
- 20 org. scale the wake of twin screw vessels
  - Of those, 3 apply scaling only for twin-skeg
  - 14 uses the method in ITTC'78 procedure

$\Rightarrow$ There seems to be no commonly used alternative approach to wake scaling

Conventional ships – Results – Open water characteristics

- 11 org. scale the propeller open water characteristics
  - 9 use the method in the ITTC'78 procedure
  - 1 uses Lerbs-Meyne
  - 1 uses an empirical method

⇒ Surprisingly few organisations scale the propeller open water characteristics

Conventional ships – Results – ”Propulsion test only” method

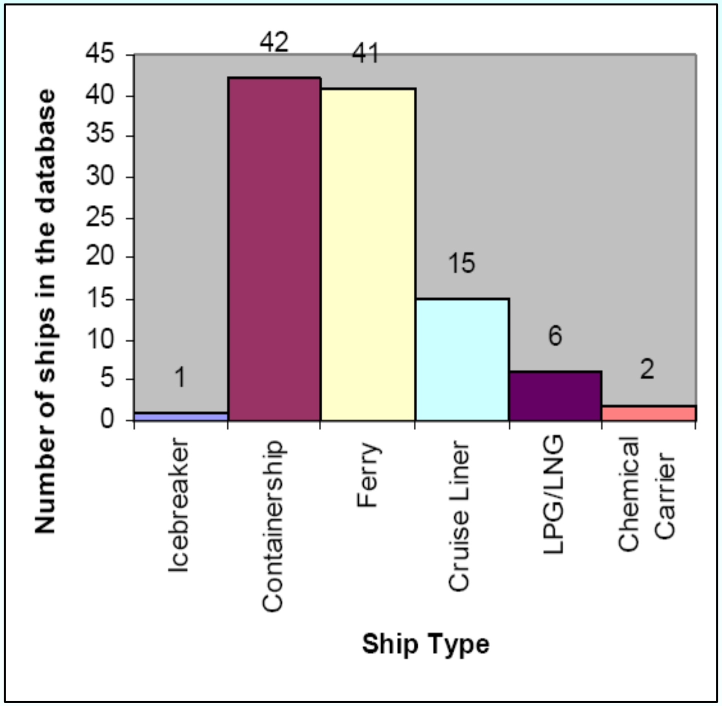
- 12 org. apply ”propulsion test only” methods
  - 3 uses this as their standard method
  - 5 uses this only for research purposes
  - 4 do this occasionally, as a supplement

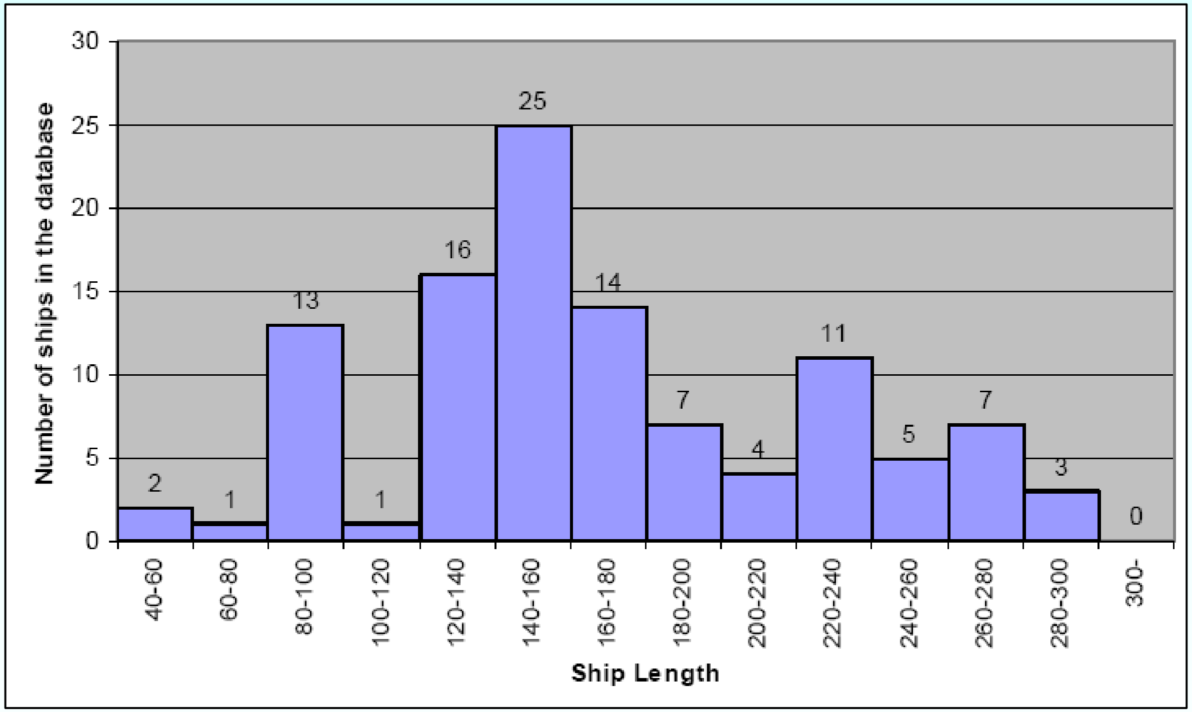
$\Rightarrow$ ”Propulsion test only” methods are still very rarely used

Questionnaire – conclusions regarding conventional ships

- *To follow the current practice of the majority of ITTC members (or replies) we need not change the powering prediction method, except to remove the scaling of the open water characteristics*

"The database of 120 ships"





- Collected by the Powering Prediction Committee of 24th ITTC
- A set of load-varying model propulsion tests of was performed by SVA Vienna for two ships in the database
  => completion of Task 1 b.

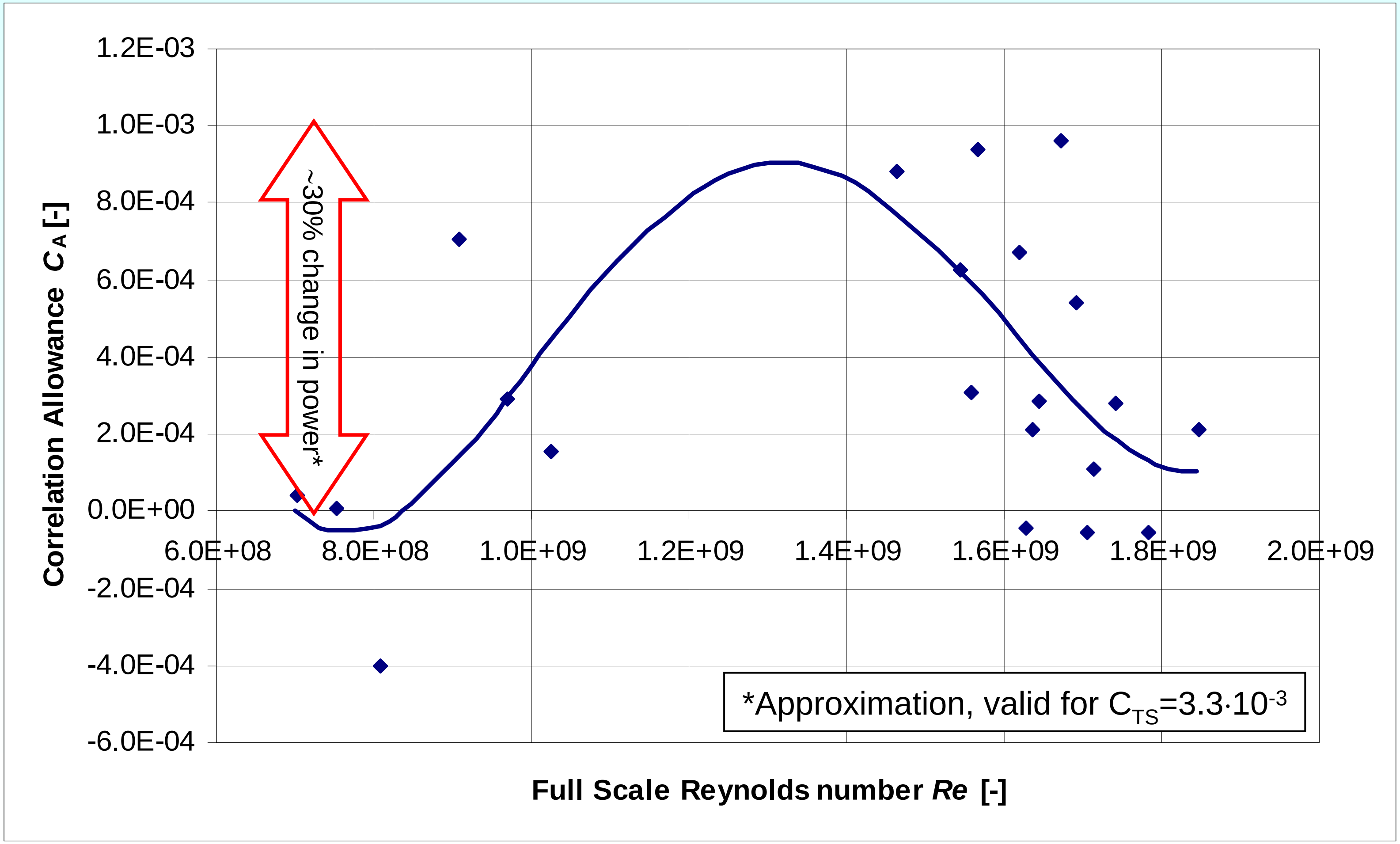
Possible use of ”The database of 120 ships”

- Evaluate different correlation and powering prediction methods by looking at scatter and size of the derived correlation factors
  - The use of form factor, with or without scale effect
  - The use of different friction lines
  - The use of roughness allowances
  - The methods of appendage scale effect corrections

Status of the database

- Only 12 ships in the database have sea trials that can be used without correction
  - Reliable correction of the sea trial results in the database is mostly difficult, due to lack of documentation of wind and waves
- Of these 12 ships, none are tested with design propellers

Derived correlation factors for 12 ships from the ITTC database



Conclusions regarding the database – in present form

- Can't be used to derive reliable correlation factors
- Can't be used to evaluate powering prediction methods
- Needs more datasets with:
  - Model tests with design propellers
  - High quality full scale measurements
    - Fixed pitch propellers
- Questionnaire indicates 5 org. that are willing to share comparable model-full scale data
  - Needs further work by the next ITTC

Form factor scale effect

- The common assumption is that the form factor *k* is equal in model and full scale
- Work by Tanaka and others suggest that this is not entirely true
- A paper by Garcia-Gomez from 2000 gives a formula to calculate the magnitude of this scale effect:

$$k_S - k_M = 1.91 \cdot (\lambda - 1) \cdot 10^{-3}$$

  – Include this formula in the updated powering performance prediction procedure?

Geosim model data analysed by the committee

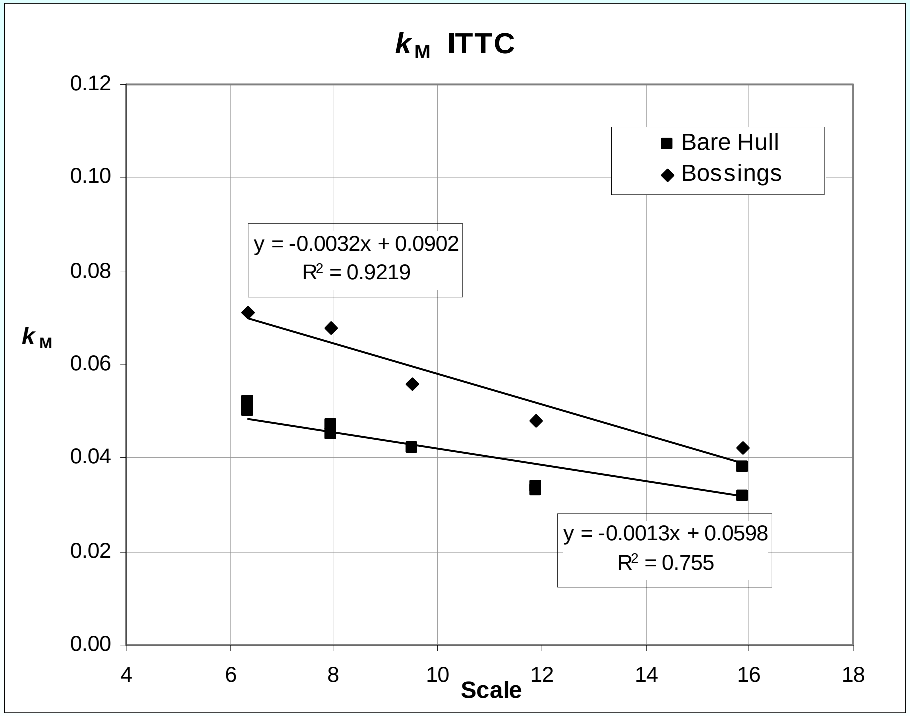
Ship data			BSRA C_B=0.75	Veedol tanker MHI	Victory ships	”Lucy Ashton” Re-analysed	LPG Carrier Marintek	USN 710 DTMB
Length	L	[m]	121.92	217.3	135.562	58.064	164.8	116.74
Breadth	B	[m]	16.77	30.5	18.898	6.43	28.2	12.31
Draught at $L_{PP}/2$	T	[m]	7.92	11.32	8.687	1.417	10.3	4.18
Trim	t_s	[m]	0	0	0	0	0	0.305
Block Coefficient (L_{PP})	C_B	[-]	0.748	0.7984	0.6876	0.712	0.7106	0.5273
Volume displacement	∇	[m^3]	12042	59000	15019	380.5	33023.3	3167.6
Wetted surface	S	[m^2]	3157	9612	3687	404.6	6322.1	1631.1
Model scales			15 17 21 22.5 30 45	21.3 30.429 50.714	6 18 23 30 40 50 60	6.350 7.938 9.525 11.906 15.875 21.167	45.000 28.634 21.311	13.000 18.450 31.915

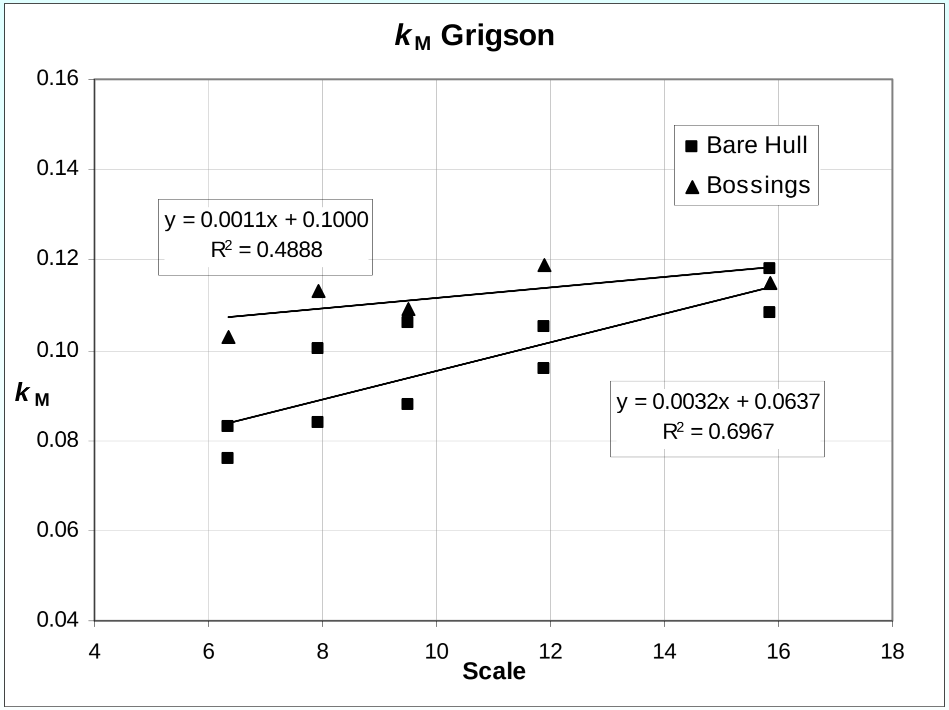
Most suitable friction line study (BSRA, Veedol tanker, Victory ships, "Lucy Ashton")

Form factor scale effect study ("Lucy Ashton", LPG Carrier, USN 710)

Form factor dependency of scale

Re-analysis of Lucy Ashton geosim model tests

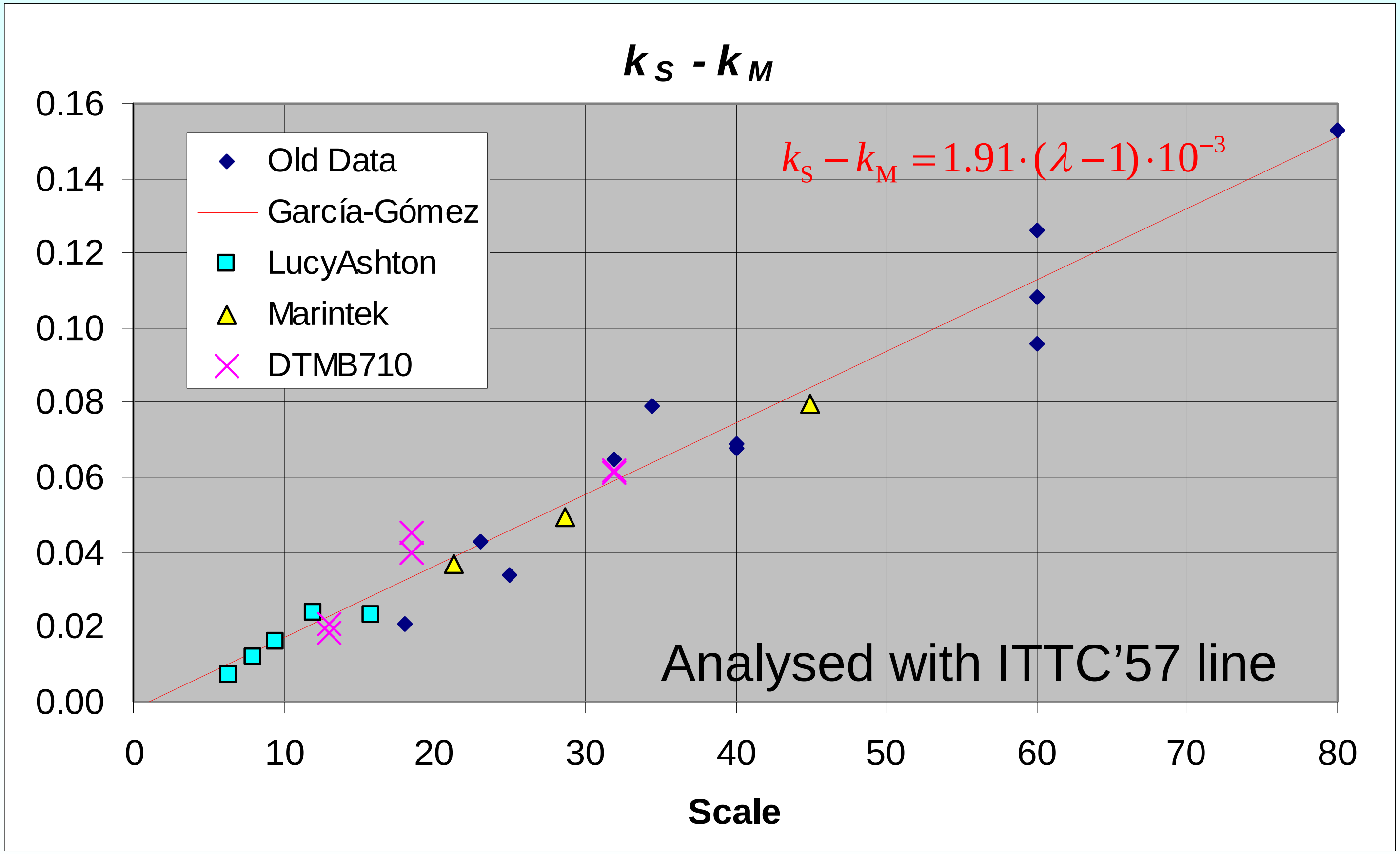




⇒ The form factor derived from a model test depends on the size (or scale) of the model

⇒ The choice of friction line influences both magnitude and scale effect of the form factor derived from model tests

Form factor dependency of scale



⇒ The analyses of the committee agrees well with the previous findings of Garcia-Gómez

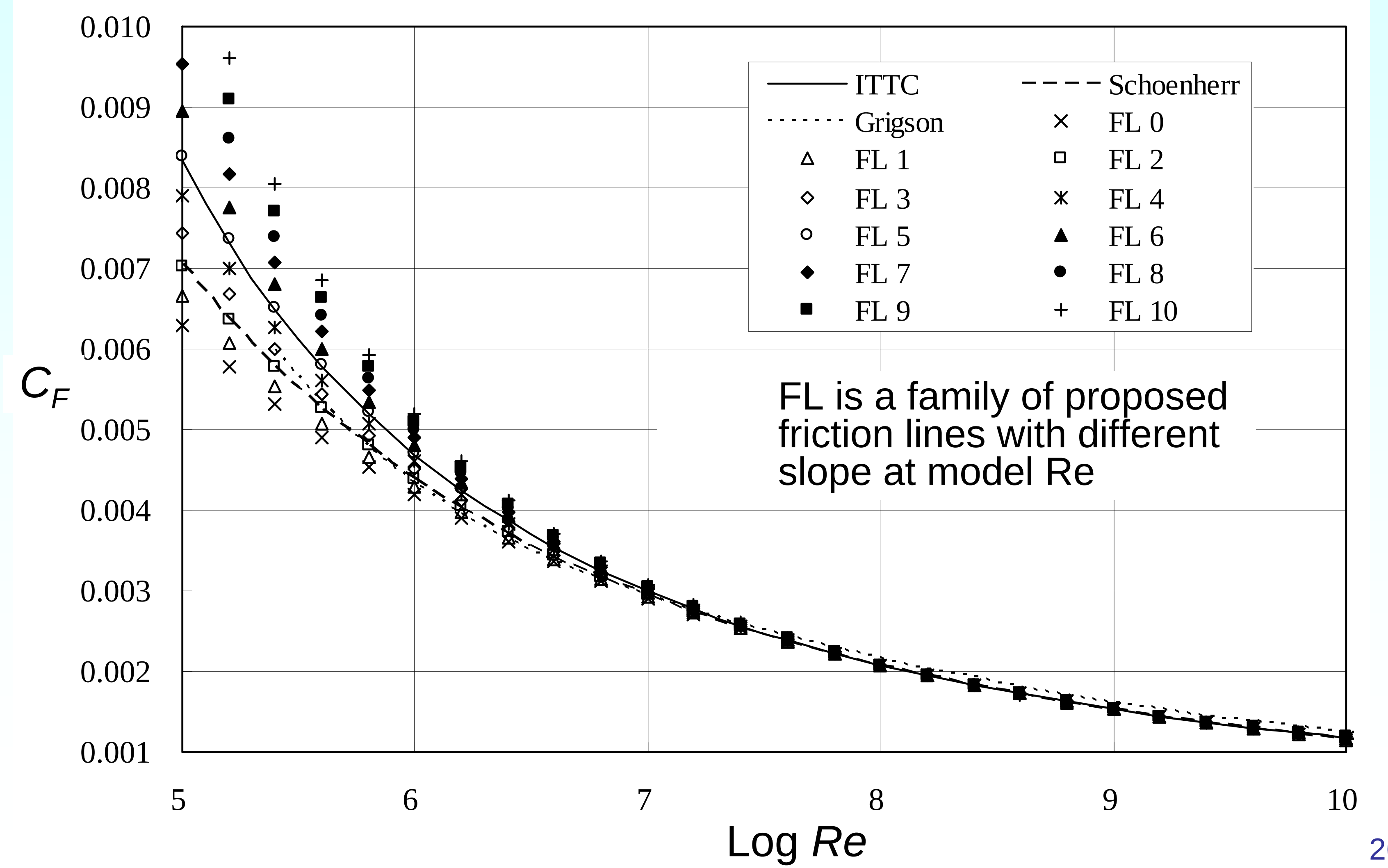
Form factor scale effect - Conclusions

- There is generally a scale effect on the form factor
- The magnitude of the scale effect depends on the friction line in use
  - For ITTC'57 $k_S > k_M$
  - For Grigson line, the scale effect is smaller, and with opposite sign
- The Garcia-Gomez formula predicts the form factor scale effect fairly accurately, when ITTC'57 is used
- Is there a friction line that effectively removes the scale effect?

Series of new Friction Lines - FL

- On the form: $C_F = \dfrac{A}{\left(\log Re - B\right)^C}$
- Set equal to C_F of ITTC'57 at log(*Re*)=8 and log(*Re*)=9
- Value of C_F at log(*Re*)=6 systematically varied to vary slope at model Re
  - Parameters *A*, *B*, and *C* can be found for each value of C_F at log(*Re*)=6

Various friction lines



$$\frac{\sum_{k=1}^{N_j} (C_R \text{deviation})_{i,j,k}^{\ 2}}{N_j}$$

How to find a most suitable Friction Lines

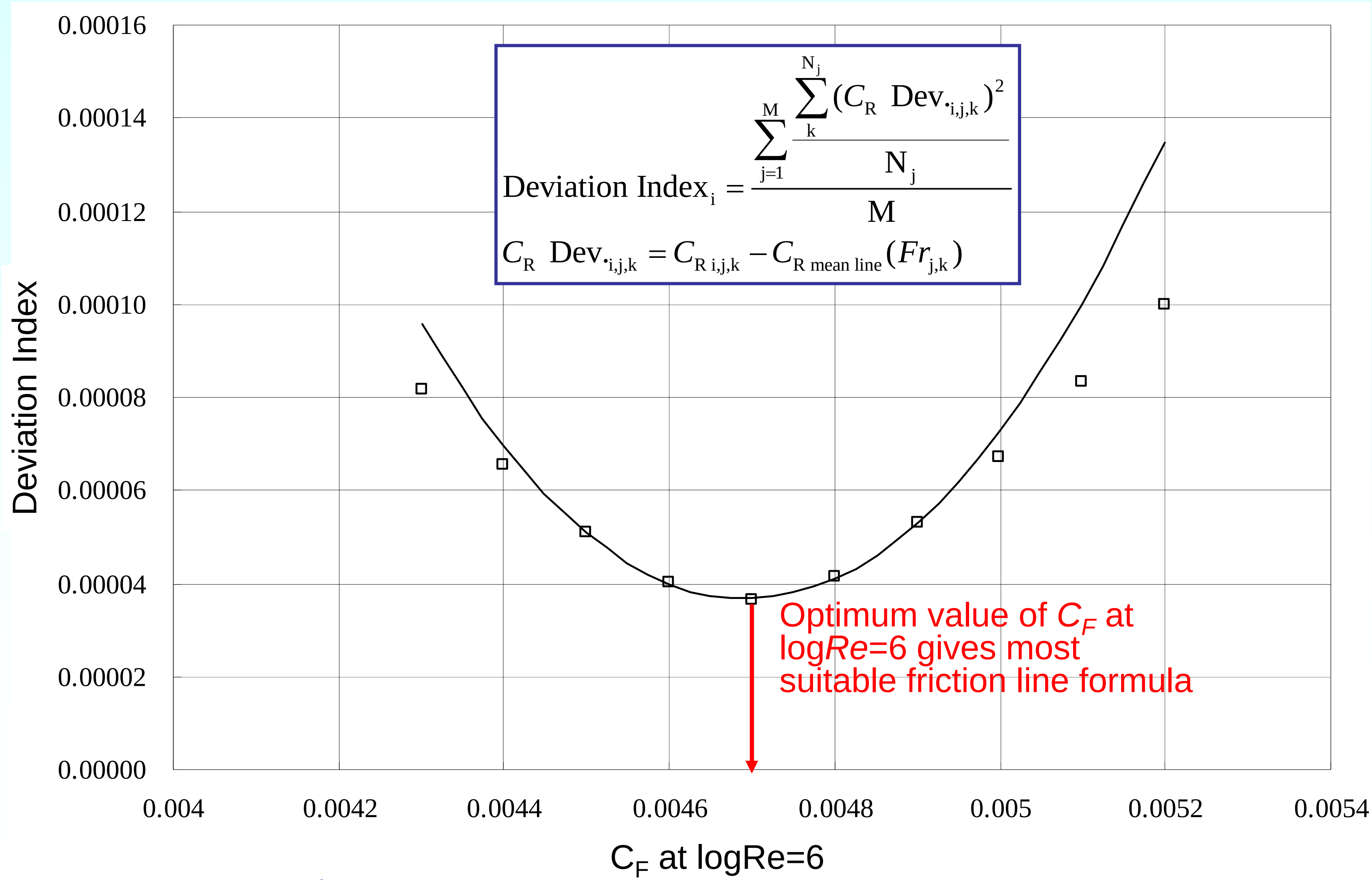
- By using each of Series Friction Lines. Geosim data set is analysed.
- Magnitude of data Scatter is evaluated by

$$(C_R \text{ deviation})_{i,\, j,\, k} = C_{R,\, i,\, j,\, k} - C_{R \text{ mean line } i,\, j,\, k}$$

$$(\text{VR } C_R)_{i,j} = \frac{\sum_{k=1}^{N_j} (C_R \text{deviation})_{i,j,k}^{\ 2}}{N_j}$$

$$(\text{Deviation index})_i = \sqrt{\frac{\sum_{j=1}^{M} (\text{VR } C_R)_{i,j}}{M}}$$

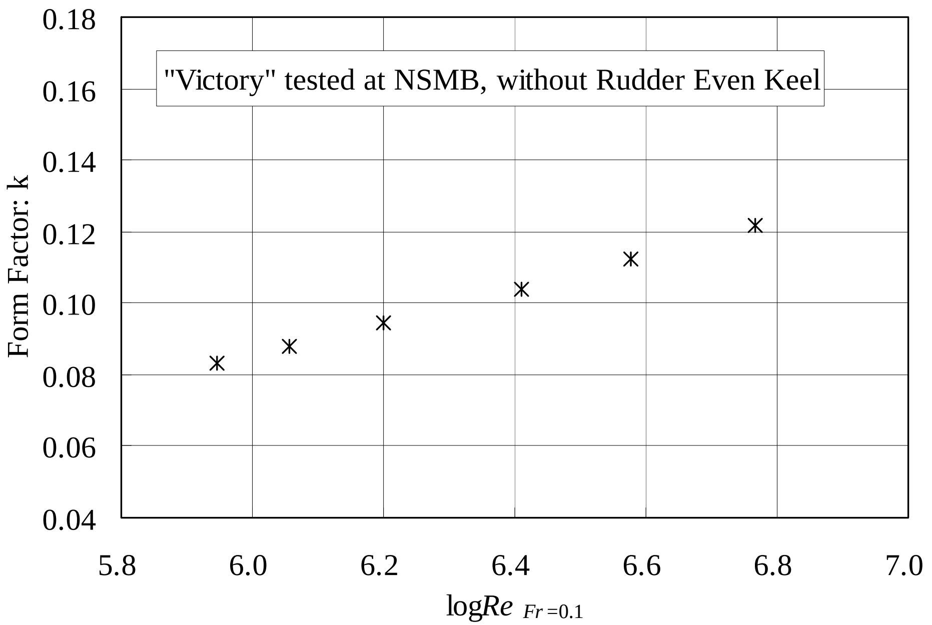
Deviation Index vs. Parameter of Series Lines



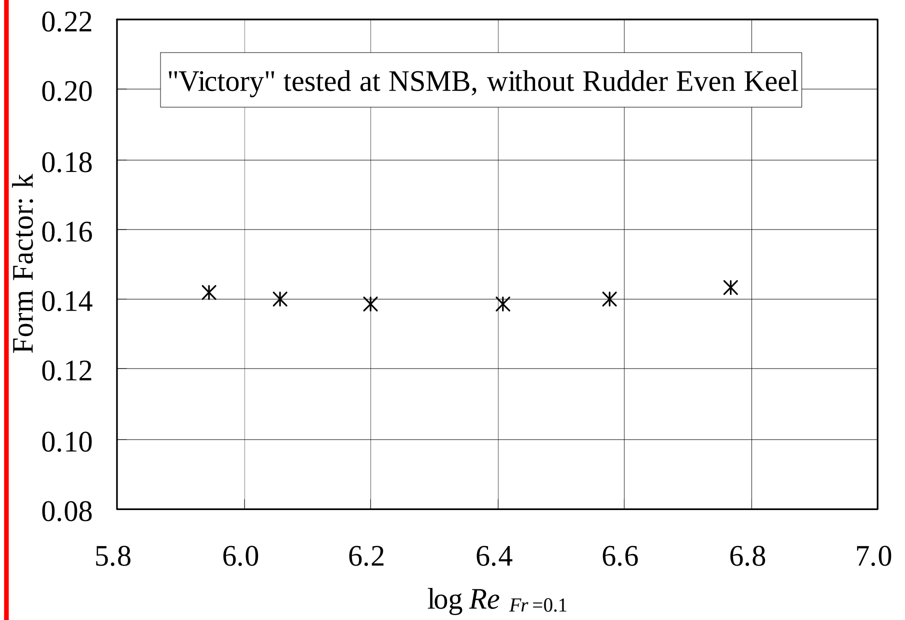
$$\text{Deviation Index}_i = \frac{\sum_{j=1}^{M} \frac{\sum_{k}^{N_j} (C_R\ \text{Dev.}_{i,j,k})^2}{N_j}}{M}$$

$$C_R\ \text{Dev.}_{i,j,k} = C_{R\ i,j,k} - C_{R\ \text{mean line}}(Fr_{j,k})$$

Resulting scale effect of form factor



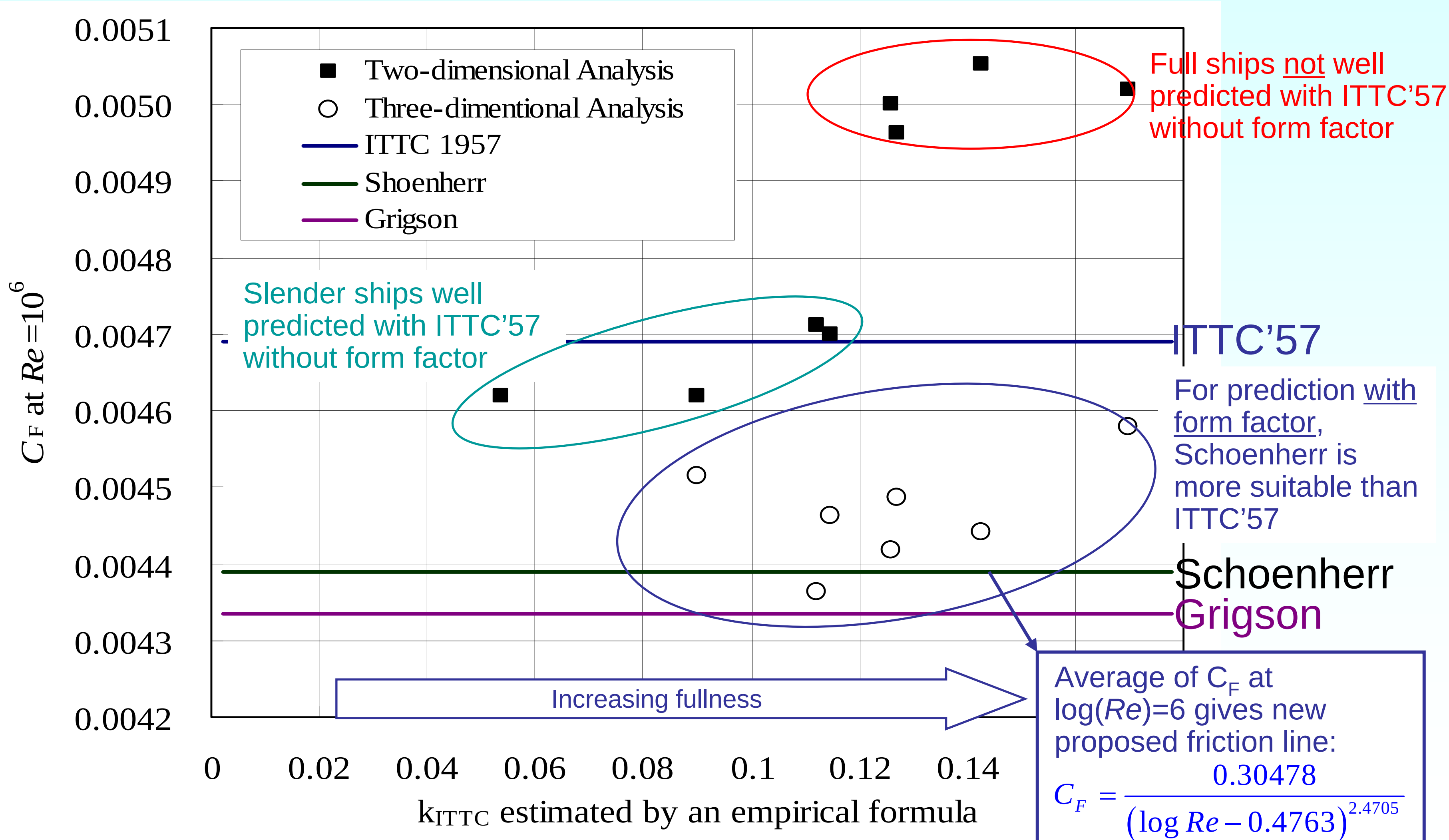
Form factor found using ITTC'57 friction line



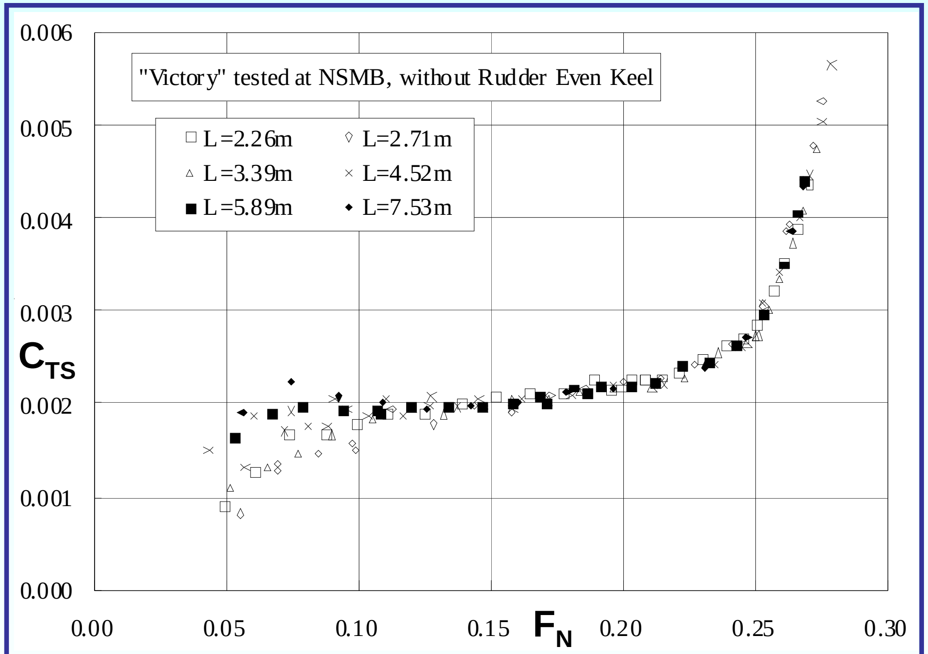
Form factor found using most suitable friction line

⇒ It is seen that in this case, the form factor scale effect can be effectively removed by change of friction line

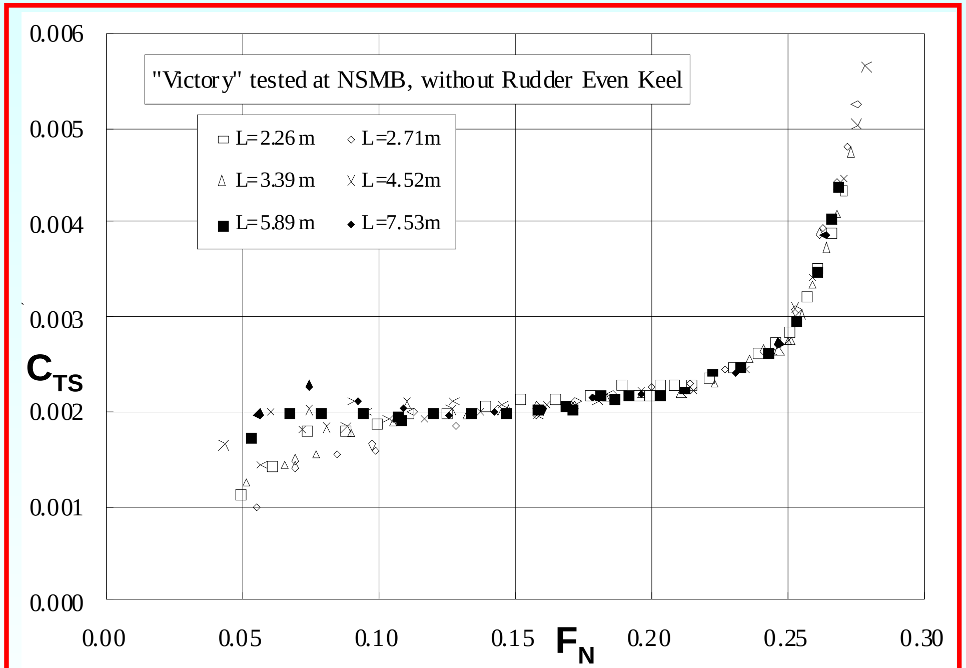
Most Suitable Lines for Geosim Series (2)



Effect of C_F on predicted C_{TS}



Predicted using ITTC'57 friction line



Predicted using new proposed friction line

$$C_F = 0.30478/(\log Re - 0.4763)^{2.4705}$$

⇒ The selection of friction line has negligible influence on level and scatter of predicted C_{TS}

- The main reason is that the level of C_{FS} is unchanged

Conclusions on choice of friction line

1. A friction line very similar to Shoenherr or Prandtl-Schlichting Lines is more appropriate than ITTC 1957 Line for 3-D extrapolation
   - ⇒ By the introduction of the newly proposed line, we can significantly reduce the form factor scale effect.
2. The scatter of the estimated total resistance coefficients of full scale ship remains almost the same
   - ⇒ Almost no improvement of the estimated full scale performance can be expected
3. We have to try more seriously to reduce the scatter of the measured results by model tests, before discussing the modification of ITTC 1957 Line.

Updates of the ITTC 1978 performance prediction procedure

- Removed the parts of the procedure describing the model tests
- Air resistance subtracted from C_R in model scale
  - Consistent with 7.5-04-01-01.2 Analysis of Speed/Power Trial Data
- Separate scaling of appendage resistance is introduced
  - Two different methods are given
  - ITTC could do more work on appendage scaling
- The Bowden-Davidson formula for ΔC_F has been replaced with a roughness correction that excludes correlation allowance, and an optional formula for C_A
  - This follows the recommendation of the Powering Performance Committee of the 19th ITTC
- A brief description of how to do predictions using torque identity, rather than thrust identity, has been added
  - Since one of correlation methods uses torque identity
- The formatting of the procedure has been updated to match the current standard
  - A flow chart describing the powering prediction procedure has been added
- Checked and corrected errors in the original procedure
  - The case of twin screw propulsion is more consistently represented

Non-Updates of the ITTC 1978 performance prediction procedure

- ”Propulsion test only” methodology is still not mentioned
  - Since it is rarely used in practice
  - Since the evidence on its superiority is too weak
- The form factor concept is unchanged
  - No formula for scale effect is introduced,
    - since the effect on the predictions is small
    - since it is in conflict with the basic principles of the resistance scaling methodology
- The ITTC’57 correlation line is still recommended as friction line
  - The benefits of changing friction line are too small to justify a change of a very well established formula
- The wake scaling is unchanged
  - What to do with wake scaling of twin-screw vessels has been debated
  - Some more guidance has been added to the procedure
- The alternative concepts for model-full scale correlation are kept basically unchanged
  - Due to the deficiencies of the ”database of 120 ships” it has not been possible to check different correlation concepts or to derive specific values of the correlation factors

Update of the Predicting powering margins procedure (Task 2)

- Purpose has been reformulated
- Definitions of the different types of margins have been adjusted
- A calm water powering margin has been included
  - A margin to provide safety against underprediction of power when C_A is determined strictly as an average value
- More references have been added to provide more guidance
- A method to actually calculate a sea margin using first principles has been added
  - The committee believes this to be the main deficiency of the previous version

Update of the Resistance of HSMV-procedure (Task 3)

- Added a section on how to perform tests of added resistance in waves
- Using *nominal* wetted surface for non-dimensionalisation of resistance
  - Previously, *running* wetted surface was used
  - Frictional resistance is still calculated using running wetted surface
- Expanded the discussion on use of form factors for HSMV
- Fixed several minor errors

Roughness allowance for HSMV

- Currently, there is no roughness allowance included in the procedure for HSMV
- For most HSMV, the flow will be fully rough in full scale, so a roughness allowance should really be applied
- The formula introduced in the updated ITTC'78 method is unsuitable for HSMV
- The committee recommends to search for a suitable roughness allowance formula

Accounting for drag reduction methods for HSMV (Task 3)

1. Conventional design optimization methods
   - Considered covered by the existing procedure
2. Reducing wetted surface area by introducing an air or vapour barrier between the hull and the water
   - Considered mainly covered by the parts of the existing procedure dealing with SES and ACV
3. Reducing friction by intrinsic friction reduction
   - Not covered
   - Can be accounted for by the current procedure if the change of friction coefficient is known
   - The literature search didn't reveal enough information to include anything on this issue in the procedure

Recommendations to the conference

- Adopt the updated procedure No. 7.5-02-03-01.4 Propulsion, Performance, 1978 ITTC Performance Prediction Method
- Adopt the updated procedure No. 7.5-02-03-01.5 Propulsion, Performance, Predicting Powering Margins
- Adopt the updated procedure No. 7.5-02-05-01 High Speed Marine Vehicles, Resistance Tests