INTERNATIONAL MARITIME ORGANIZATION

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MARINE ENVIRONMENT PROTECTION COMMITTEE
58th session
Agenda item 4

MEPC 58/4/28
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PREVENTION OF AIR POLLUTION FROM SHIPS

Technical information for the simulation of ship performance to obtain the coefficient "f_W" in the new ship design CO_2 index

Submitted by Japan

SUMMARY	
Executive summary:	This document provides technical information on the drag coefficient due to wind as well as the added resistance in regular waves, which are to be used in the draft "Guidelines for the Simulation of Ship Performance to Obtain the Coefficient f_W in the New Ship Design CO_2 Index"
Strategic direction:	7.3
High-level action:	7.3.1
Planned output:	7.3.1.1 and 7.3.1.3
Action to be taken:	Paragraph 3
Related documents:	MEPC 58/4, paragraph 2.23 and annex 5; MEPC 58/4/27; MEPC 57/4/3; MEPC 57/4/11; MEPC 57/4/12 and MEPC 57/INF.12

Introduction

1 This document provides comments on document MEPC 58/4 and is submitted in accordance with paragraph 4.10.5 of the Committees' Guidelines (MSC-MEPC.1/Circ.2).

2 Japan has submitted a document on draft guidelines describing the procedures for simulation of ship performance to obtain the coefficient "f_W" (MEPC 58/4/27). This document is a complement to the draft guidelines and provides technical information on the drag coefficient due to wind as well as the added resistance in regular waves due to ship motion and wave reflection.

Action requested of the Committee

3 The Committee is invited to consider the technical information set out in the annex to this document in the discussion of the draft "Guidelines for the Simulation of Ship Performance to Obtain the Coefficient "f_W" of the New Ship Design CO_2 Index".

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ANNEX

APPENDIX 1

DRAG COEFFICIENT DUE TO WINDS

Drag coefficient due to wind, C_{Dwind}, should be calculated by a formula with considerable accuracy, which has been confirmed by model tests in a wind tunnel. The following formula[1)] is known for the expression of C_{Dwind}, for example:

$$C_{Dwind} = -0.922 + 0.507 \frac{A_L}{L_{OA} B} + 1.162 \frac{C}{L_{OA}} \qquad \text{(A1.1)}$$

where:

B : ship breadth, A_L : projected lateral area above the summer load line,
L_{OA} : length overall,
C : distance from the midship section to the centre of projected lateral area; a positive value of C means that the centre of the projected lateral area is located ahead of the midship section.

Reference

1) T. Fujiwara, M. Ueno and Y. Ikeda: Cruising performance of a large passenger ship in heavy sea, Proceedings of the Sixteenth International Offshore and Polar Engineering Conference, Vol. III, pp.304-311, 2006.

APPENDIX 2

ADDED RESISTANCE IN REGULAR WAVES

Added resistance due to ship motion in regular waves, R_{wm}, is calculated by Maruo's theorem[1)] as follows:

$$R_{wm} = \begin{cases} 4\pi\rho\left(-\int_{-\infty}^{m_3} + \int_{m_4}^{\infty}\right)\left|H(m)\right|^2 \dfrac{(m+K_0\Omega_e)^2(m+K\cos\alpha)}{\sqrt{(m+K_0\Omega_e)^4 - m^2 K_0{}^2}}\,\mathrm{d}m & \left(\Omega_e \le \dfrac{1}{4}\right) \\ 4\pi\rho\left(-\int_{-\infty}^{m_3} + \int_{m_4}^{m_2} + \int_{m_1}^{\infty}\right)\left|H(m)\right|^2 \dfrac{(m+K_0\Omega_e)^2(m+K\cos\alpha)}{\sqrt{(m+K_0\Omega_e)^4 - m^2 K_0{}^2}}\,\mathrm{d}m & \left(\Omega_e > \dfrac{1}{4}\right) \end{cases} \qquad \text{(A2.1)}$$

$$\Omega_e = \frac{V}{g}\left(\omega + KV\cos\alpha\right) \qquad \text{(A2.2)}$$

$$K = \frac{\omega^2}{g} \qquad \text{(A2.3)}$$

$$K_0 = \frac{g}{V^2} \qquad \text{(A2.4)}$$

$$m_1 = \frac{K_0\left(1 - 2\Omega_e + \sqrt{1 - 4\Omega_e}\right)}{2} \tag{A2.5}$$

$$m_2 = \frac{K_0\left(1 - 2\Omega_e - \sqrt{1 - 4\Omega_e}\right)}{2} \tag{A2.6}$$

$$m_3 = -\frac{K_0\left(1 + 2\Omega_e + \sqrt{1 + 4\Omega_e}\right)}{2} \tag{A2.7}$$

$$m_4 = -\frac{K_0\left(1 + 2\Omega_e - \sqrt{1 + 4\Omega_e}\right)}{2} \tag{A2.8}$$

where:

- ρ : fluid density, g : gravitational acceleration, V : ship speed,
- ω : circular frequency of incident regular waves,
- α : angle between ship course and regular waves (angle 0(deg.) is defined as the heading wave direction),
- $H(m)$ is a function to be determined by the distribution of singularities which represents periodical disturbance by the ship.

Added resistance due to wave reflection in regular waves, R_{wr}, is the correction factor of the diffraction effect for the added resistance due to waves for the sake of accuracy. The correction should take into account the effect of the hull form above water line.

R_{wr} should be calculated by a formula with considerable accuracy. The following formula[2)] is known for the expression of R_{wr}, for example:

$$R_{wr} = \frac{1}{2}\rho g \zeta_a{}^2 B B_f \left(1 + C_U F_n\right) \frac{\pi^2 I_1{}^2 (K_e d)}{\pi^2 I_1{}^2 (K_e d) + K_1{}^2 (K_e d)} \tag{A2.9}$$

$$K_e = K\left(1 + \Omega \cos\alpha\right)^2 \tag{A2.10}$$

$$\Omega = \frac{\omega V}{g} \tag{A2.11}$$

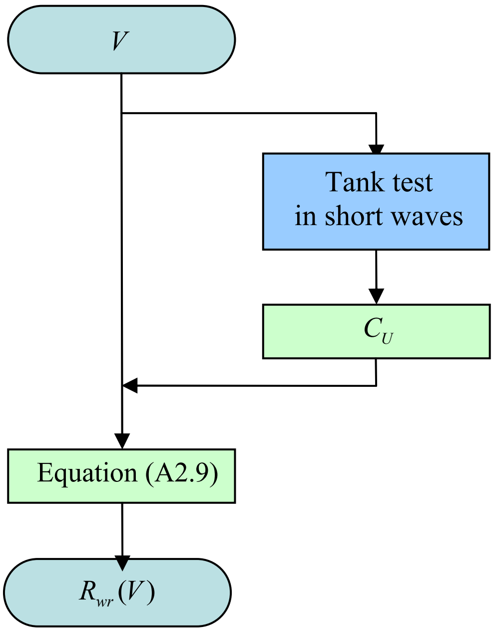
where:

- ζ_a : amplitude of regular waves, B : ship breadth,
- B_f : bluntness coefficient, which is derived from the shape of water plane and wave direction,
- C_U : coefficient of advance speed, which is determined by a tank test in regular waves or an equivalent formula with considerable accuracy,
- $F_n = V / \sqrt{L_{pp} g}$: Froude number (non-dimensional number in relation to ship speed),
- L_{pp} : ship length between perpendiculars,
- K : wave number of regular waves, d : ship draft,
- I_1 : modified Bessel function of the first kind of order 1,
- K_1 : modified Bessel function of the second kind of order 1,

- In case of conducting a tank test to obtain C_U, the following condition should be satisfied.

  A tank test to determine the coefficient of advance speed should be carried out in short waves since R_{wr} mainly works in short waves. The length of short waves should be $0.5 L_{pp}$ or less.

The basic procedures to obtain R_{wr} are shown in Figure A.



A tank test in short waves can be carried out with the same experimental setting of the test in a calm sea condition.

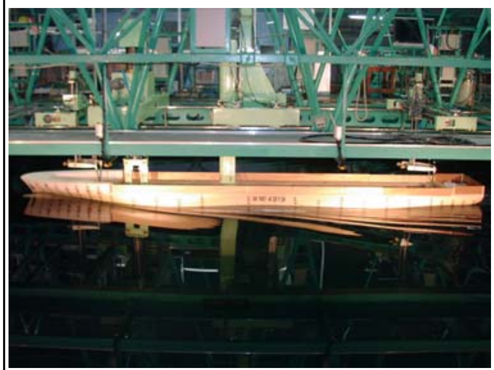


Figure A – Flow chart of calculation for R_{wr}
see http://www.nmri.go.jp/umi-10/Hybrid/index_e.html

References

1) H. Maruo: Resistance in Waves, Research on Seakeeping Qualities of Ships in Japan, The Society of Naval Architects of Japan, Vol.8, 1963, pp.67-102.

2) M. Tsujimoto, K. Shibata, M. Kuroda and K. Takagi: A Practical Correction Method for Added Resistance in Waves (submitting), Journal of the Japan Society of Naval Architects and Ocean Engineers, Vol.8, 2008.

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