ON THE LOSS OF SHIPS IN BAD WEATHER

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By

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From Vol. 6 No. 1

When a ship run into head winds and rough seas, it cannot keep its normal speed owing to the increases of ship resistance.

In this paper, an approximate method of estimating this loss of speed, in head winds and seas, is introduced. Assuming that a ship, which keeps its speed V_0 and resistance R_0 in fine sea, encounters rough weather and its speed decreases to V_1 and resistance increases to R_1' (Fig. 1), speed-decrease-percentage **A**, which is equal to $(V_0 - V_1/V_0)$, is derived from following equation.

$$\mathbf{A} = 1 - \frac{\nu}{\theta}, \tag{1}$$

where $\theta = \dfrac{R_1'}{R_0}$, $\nu = \alpha \cdot \beta \cdot \gamma \cdot \delta$,

$\alpha = \eta_{H_1}/\eta_{H_0}$: hull efficiency ratio.

$\beta = \eta_{P_1}/\eta_{P_0}$: propeller open efficiency ratio.

$\gamma = \eta_{R_1}/\eta_{R_0}$: relative rotative efficiency ratio.

$\delta = SHP_1/SHP_0$: shaft horse power ratio.

As resistance increases, following equations are used:

Owing to wind pressure: (see (1))

$$R_a = 0.0044 \frac{B^2}{2} (V_1 + V_f)^2, \tag{2}$$

Owing to ship's motion in head seas: (see (2))

$$R_w = \frac{B \cdot H_w}{2\pi} (V_1 + V_w)^2 (1 - \cos\varphi), \tag{3}$$

where V_f = wind speed, V_w = wave speed.

Equation (3) is that which was obtained by Mr. Stevens.

In the above equation, using the Kempf's wave height coefficient (μ) (see (3)), H_w is calculated by the equation.

$$H_w = \mu L_w \tag{4}$$

μ and H_w are shown in Fig. 2.

Assuming that the resistance of ships are proportional $V^2(R = KV^2)$, following equations are obtained.

$$\theta = (1-\mathbf{A})^2 + [C_1\{(1-\mathbf{A})+t\}^2 + C_2\{(1-\mathbf{A})+u\}^2], \tag{5}$$

where $C_1 = \dfrac{2.03\times10^{-4}\cdot B\cdot\mu\cdot L_w(1-\cos\varphi)}{K}$, $C_2 = \dfrac{0.98\times10^{-6}\cdot B^2}{K}$,

$$t = V_w/V_0, \qquad u = V_f/V_0.$$

In the next place, according to the experiments by Mr. Kent (see (4)), put $\alpha \doteqdot 1$, $\gamma \doteqdot 1$ and assume that β is due to increase of the ship mainly. Then we can put approximately:

$$\beta = 1 - K_0\,\Delta s - K_1(\Delta s)^2, \tag{6}$$

K_0, K_1 are constants which are obtained from the open test results, and Δs is slip increase of a propeller.

The relation between Δs and $\mathbf{A}$ varies with engines of ships. In this paper, as was assumed by Mr. Kent (see (4)), assume that SHP is constant in steam reciprocating engine and diesel engine, and torque is constant in turbine. Then following simple relation is obtained.

$$\Delta S \doteqdot C\mathbf{A} \tag{7}$$

This constant C is determined by the working condition of a propeller in still water and varies with engines.

Accordingly
$$\beta = 1 - K_2\mathbf{A} - K_3\mathbf{A}^2\,. \tag{8}$$

In turbine ships we can put $\delta = 1$, but in diesel ships SHP will drop in proportion to number of revolutions:

$$\delta = 1 - K_4\mathbf{A} \tag{9}$$

Therefore equations for ν are as follows:

For turbine ships
$$\nu = 1 - K_2\mathbf{A} - K_3\mathbf{A}^2\,, \tag{10}$$

For diesel ships
$$\nu = 1 - K_2'\mathbf{A} - K_3'\mathbf{A}^2\,, \tag{11}$$

where

$$K_2 = K_0\left(\frac{3}{\dfrac{q}{C_{Q0}} + \dfrac{3}{1-S_0}}\right), \quad K_3 = K_1\left(\frac{3}{\dfrac{q}{C_{Q0}} + \dfrac{3}{1-S_0}}\right)^2,$$

$$K'_2 = K_0\left(\frac{2}{\dfrac{q}{C_{Q0}} + \dfrac{2}{1-S_0}}\right), \quad K_3' = K_1\left(\frac{2}{\dfrac{q}{C_{Q0}} + \dfrac{2}{1-S_0}}\right)^2,$$

$$K_4=\frac{1}{2}\frac{q}{C_{Q_0}}\left(\frac{2}{\dfrac{q}{C_{Q_0}}+\dfrac{2}{1-S_0}}\right),$$

in which S_0 = slip ratio in fine weather condition.

C_{Q_0} = torque coefficient ($Q/\rho n^2 d^4$) at S_0

q = mean of the gradients of C_Q at S_0 and $S_0+0.2$

These values were calculated for the series obtained by L. Troost (see (5)) and are shown in Fig. 3, 4, 5. Using equations (5), (10) and (11), calculation formula for **A** are as follows:

for turbine ships:

$$(1-\mathbf{A})\{(1-\mathbf{A})^2+[C_1\{(1-\mathbf{A})+t\}^2+C_2\{(1-\mathbf{A})+u\}^2]\}$$
$$=(1-K_2\mathbf{A}-K_3\mathbf{A}^2) \qquad (12)$$

for diesel ships:

$$(1-\mathbf{A})\{(1-A)^2+[C_1\{(1-\mathbf{A})+t\}^2+C_2\{(1-\mathbf{A})+u\}^2]\}$$
$$=(1-K_2'\mathbf{A}-K_3'\mathbf{A})(1-K_4\mathbf{A}). \qquad (13)$$

Analysing the results of "San Francisco" by this method (see (3)), calculated **A** and measured $\mathbf{A}_0$ are shown in following Table and Fig. 6.

L_w	V_1	A	A_0
394 ft.	9.0 kt.	0.346	0.305
296	9.9	0.270	0.235
196	10.8	0.180	0.166
132	11.5	0.116	0.112
66	12.0	0.049	0.073

By this method, **A** values are over estimated a little at long wave length. This will be due to $\alpha=1$, $\gamma=1$ mainly.

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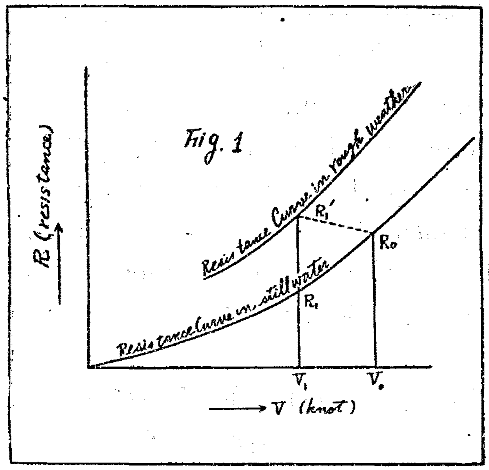
Fig. 1
R (resistance)
Resistance Curve in rough weather
Resistance Curve in still water
R_1'
R_0
R_1
V_1
V_0
V (knot)

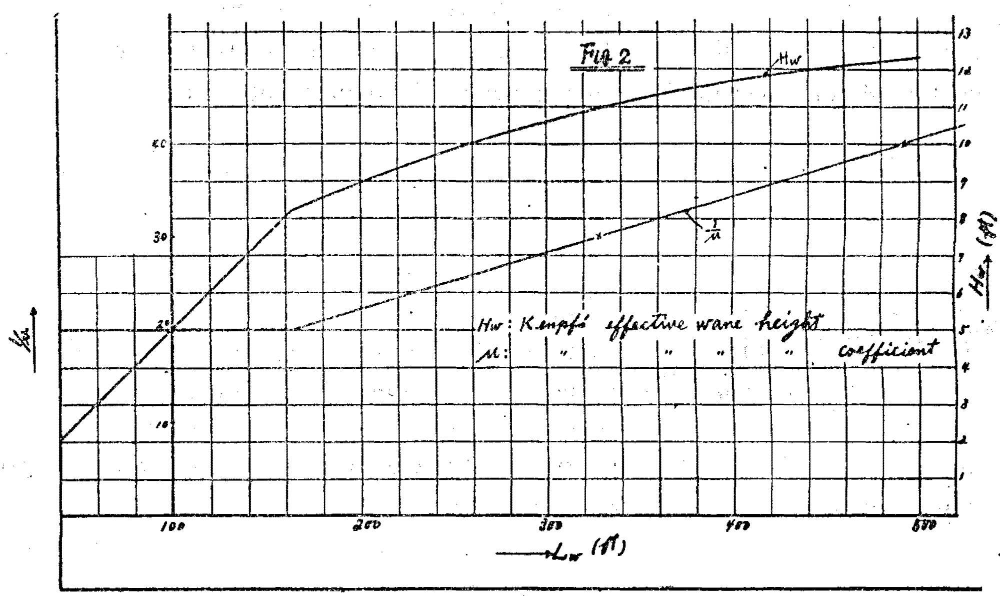
Fig 2
Hw
Hw: Kempf's effective wave height
μ: " " " " coefficient
100
200
300
400
500
Lw (ft)
Hw (ft)

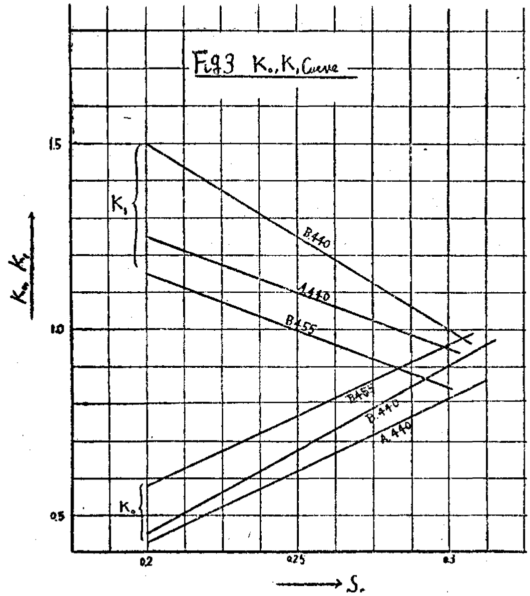

Fig.3 K_0, K_1 Curve

Fig.4 K_2, K_3 Curve

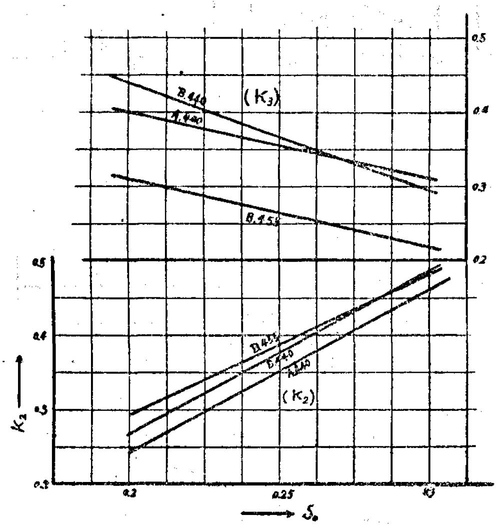

Fig 5 K_2', K_3', K_4' Curve