



Squat prediction in muddy navigation areas

G. Delefortrie^{a,*}, M. Vantorre^b, K. Eloot^{a,b}, J. Verwilligen^a, E. Lataire^b

^a Flanders Hydraulics Research, Berchemlei 115, 2140 Antwerp, Belgium

^b Ghent University, Maritime Technology Division, Technologiepark 904, 9052 Ghent, Belgium

ARTICLE INFO

Article history:

Received 5 May 2010

Accepted 22 August 2010

Editor-in-Chief: A.I. Incecik

Available online 15 September 2010

Keywords:

Mud

Sinkage

Trim

Mathematical model

ABSTRACT

Common squat prediction formulae to assess the navigation safety usually do not take into account the bottom condition. Nevertheless, the presence of a fluid mud layer is not an uncommon condition in confined areas where accurate squat predictions are necessary. From 2001 to 2004 an extensive experimental research program was carried out to measure the manoeuvring behaviour of deep drafted vessels in muddy areas. A part of the program focused on the undulations of the water–mud interface and their relationship to the ship's squat. Mostly the sinkage of the ship is damped due to the presence of the mud layer, but a larger trim can occur due to the water–mud interface undulations. This article presents a mathematical model to predict the squat in muddy navigation areas.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

Squat, defined as the sinkage and trim of vessels due to their own forward speed, is of particular importance in shallow water areas. Small under keel clearances cause large return currents which lead to important sinkages and higher risks of bottom touching as already mentioned by Constantine (1960).

In shallow navigation areas the presence of a soft fluid mud layer on the bottom is not exceptional, but its effect is mostly neglected in the formulation of squat. As a consequence pilots and scientists may disagree on the safety of navigation. Mostly pilots have to rely on the high frequency echo to determine the water depth. As the latter detects the top of the mud layer and not the solid (or nautical) bottom level, they may still be able to navigate safely through a muddy navigation area, even in case the ship is navigating at a zero (or even negative) under keel clearance according to the echo sounder. In cases where common squat formulae would predict grounding of a ship navigating in a shallow fairway at a rather high speed, the presence of a mud layer may prevent such grounding.

Indeed a limited or even negative under keel clearance referred to a mud layer does not necessarily lead to impracticable manoeuvres as mentioned by Delefortrie et al. (2007). When initially the ship has a small under keel clearance referred to the mud layer, she may hit the mud layer due to squat. This mud,

having a larger density than water, will affect the buoyancy of the ship and will probably smoothen the squat effect. However, to be sure about the mud effect additional research had to be carried out, because the literature offers very limited results on this topic.

2. State of the art

2.1. General research on squat

Scientific research on squat took off with Constantine (1960) who discussed the different squat behaviour for subcritical, critical and supercritical vessel speeds. In the subcritical domain ($F_{rh} < 1$) Tuck (1966) proved that for open water conditions of constant depth the sinkage and trim of the vessel to be linear with the parameter

$$\gamma(F_{rh}) = \frac{F_{rh}^2}{\sqrt{1 - F_{rh}^2}} \quad (1)$$

In which F_{rh} represents the depth related Froude number

$$F_{rh}^2 = \frac{V^2}{gh} \quad (2)$$

This theory was later extended to dredged channels by Beck et al. (1975). Naghdi and Rubin (1984) offer some reflections on Tuck's theory and introduce a new one. An analogous theory has been developed by Cong and Hsiung (1991).

Ankudinov and Daggett (1996) however are pessimistic about the complexity of numerical theories. For this reason, several

* Corresponding author. Tel.: +32 3 224 69 62; fax: +32 3 224 60 36.

E-mail addresses: Guillaume.Delefortrie@mow.vlaanderen.be (G. Delefortrie), Marc.Vantorre@UGent.be (M. Vantorre), Katrien.Ellood@mow.vlaanderen.be (K. Ellood), Jeroen.Verwilligen@mow.vlaanderen.be (J. Verwilligen), Evert.Lataire@UGent.be (E. Lataire).

Nomenclature

AEP	expanded area ratio of propeller (–)	S	solid bottom condition (–)
A_R	rudder area (m ²)	s_i	regression coefficient ($i=0,n$) (–)
a_i	regression coefficient, ($i=0,1$) (–)	T	ship draft (m)
B	ship beam (m)	TEU	(number of) twenty feet equivalent unit containers (–)
b	mud type, Table 2 (–)	T_P	thrust (N)
b_i	regression coefficient, ($i=0,1,2$) (–)	U	8000 TEU container ship model (–)
c	mud type, Table 2 (–)	ukc	under keel clearance (–)
C_B	block coefficient (–)	V	ship speed (m/s)
c_i	regression coefficient, ($i=0,1,2$) (–)	V_T	propeller induced speed, Eq. (22) (m/s)
C_S	dimensionless sinkage, Eq. (4) (–)	x	longitudinal coordinate, positive towards the stern (m)
C_T	dimensionless trim, Eq. (5) (–)	z_A	sinkage aft (m)
D	6000 TEU container ship model (–)	z_F	sinkage fore (m)
d	mud type, Table 2 (–)	α	increase parameter, Eq. (31) (–)
d_i	regression coefficient, ($i=0,\rho$) (–)	γ	parameter, Eq. (1) (–)
D_P	propeller diameter (–)	ζ	amplitude of rising (m)
E	tanker model (–)	ζ_{MAX}	maximal amplitude of rising (m)
e	mud type, Table 2 (–)	μ	dynamic viscosity (Pa s)
e_i	regression coefficient, ($i=0,1$) (–)	μ_{crit}	critical dynamic viscosity (Pa s)
f	mud type, Table 2 (–)	ρ	density (kg/m ³)
f_0	regression coefficient (–)	ρ^*	dimensionless density, Eq. (16) (–)
F_{rh}	depth related Froude number, Eq. (2) (–)	Π	keel penetration parameter, Eq. (21) (–)
g	mud type, Table 2 (–)	Π_h	keel penetration parameter, Eq. (14) (–)
g_i	regression coefficient, ($i=0,h$) (–)	Φ	fluidization parameter (–)
h	total depth (m) mud type, Table 2 (–)	Φ_{ij}	regression coefficient ($i=0,h$) ($j=0,\rho$) (–)
h^*	hydrodynamically equivalent depth (m)	Φ_{ij}^*	regression coefficient ($i=0,h$) ($j=0,\rho$) (–)
i_0	regression coefficient (–)	Φ_{ij}''	regression coefficient ($i=0,h$) ($j=0,\rho$) (–)
i_1	regression coefficient (–)	Φ_{00}''	regression coefficient (–)
j_i	regression coefficient, ($i=0,\rho$) (–)		
k_i	regression coefficient, ($i=0,\rho$) (–)		
L_{pp}	ship length (m)		
P	propeller pitch (m)		
p_0	regression coefficient (–)		
q_0	regression coefficient (–)		

Subscripts

n	propeller
1	related to water
2	related to mud

authors carried out experimental research as Dand (1972) and Gourlay (2000) – who offers a solution for squat prediction with random bottom conditions – to endorse their theories. Jiang and Henn (2003) present a numerical method valid from subcritical to supercritical speed. An overview of slender body methods is given in Gourlay (2008).

More practical methods based on experimental research are presented by Barrass (1979), however his results could not be validated by Seren et al. (1983). Barrass (2004) gives an overview of the work he performed on squat. More general overviews are given by Dumas (1982); Blaauw and Van der Knaap (1983), Millward (1990) and PIANC (1997) working group 30.

Interesting full scale measurements were carried out by Ankudinov et al. (2000), Stocks et al. (2004), Härting et al. (2009) and Härting and Reinking (2002) among others.

Most discussions focus on ships sailing in open water or in rectangular shaped canals without drift angle or propulsion. In some cases the drift angle was considered, as by Von Bovet (1985), Martin and Puls (1986), de Koning Gans and Boonstra (2007) and Elout et al. (2008).

2.2. Research on squat in muddy areas

The research on squat in muddy areas is a topic that has not been tackled thoroughly. Only three research institutes carried out experimental research focussing on the hydrodynamic forces.

The oldest results are presented by Sellmeijer and van Oortmerssen (1983) who also registered undulations in the water mud interface. The sinkage is less above mud in comparison with the solid bottom condition and decreases with increasing layer thickness. The mud density does not seem to have any effect.

Vantorre and Coen (1988) showed that three speed ranges can be detected for the behaviour of the water mud interface:

- At low speed a small sinkage near the fore body is detected, which disappears amidships and turns into an elevation abaft;
- At a certain speed value the sinkage at the entrance changes suddenly into an elevation. The section at which the jump occurs moves abaft with increasing speed;
- If the speed increases more, the rising of the interface occurs behind the stern. The amplitude of the elevation can exceed the mud layer thickness several times.

The latter occurs at a speed, which for inviscid fluids is given by the theoretical expression

$$V_{crit} = \sqrt{\frac{8}{27}gh_1 \left(1 - \frac{\rho_1}{\rho_2}\right)(1 - m_1)^3} \quad (3)$$

m_1 being the blockage of the ship in the water layer, meaning the ratio of the ship's immersed cross sectional area and the canal's cross section. Subscript 1 refers to the water layer, subscript 2 to the mud layer.

Download English Version:

<https://daneshyari.com/en/article/1726882>

Download Persian Version:

<https://daneshyari.com/article/1726882>

[Daneshyari.com](https://daneshyari.com)