

Forces, Moments and Motions Induced by the Vicinity of Banks on a Sailing Vessel

Evert LATAIRE

Supervisor: Prof. Marc VANTORRE

Abstract — The asymmetric flow around a ship induced by the vicinity of banks causes pressure differences between port and starboard sides. As a result, the whole ship tends to be attracted to, and her bow pushed away from the closest bank. A reliable estimation of bank effects is of importance for determining the limiting conditions in which a ship can safely navigate a waterway.

A mathematical model will be developed for bank effects based on a comprehensive model test program carried out in a Towing Tank. The emphasis is placed on hydrodynamic forces induced by sloped and semi-submerged banks, typical for the access channels to the Flemish and other international harbours. The results will be incorporated in the full mission bridge simulators at Flanders Hydraulics Research.

Keywords — Bank effect, confined water, towing tank, ship manoeuvring simulator, admittance policy

Website — www.BANKEFFECTS.UGent.be

I. INTRODUCTION

For years ships have become increasingly larger but the waterways they are sailing at have not been expanded at the same rate. Waterways become more and more confined, resulting in an increasing influence on the manoeuvrability of the vessels. One of the major influences of the environment on a sailing ship is called *bank effects*, a series of phenomena caused by the asymmetric pressure distribution around a ship induced by the vicinity of banks. As a result the ship tends to be attracted to the bank and her bow pushed away. Besides, the vessel's squat increases, causing an extra reduction of the net under keel clearance².

A reliable prediction of bank effects is of high importance for determining an admittance policy. Can a ship safely call a harbour or what should be done to be able to navigate safely the waterway under consideration?



Figure 1 Douro Queen on the Douro River along sloped banks.

Until now most research on bank effects focused on straight quay walls. The effect of a sloped bank or a sloped bank in combination with a submerged part has not been examined in depth. However, these banks are characteristic for many waterways in general, and for the access channels to the Flemish harbours (River Scheldt, Harbour of Zeebrugge, Canal Ghent – Terneuzen) in particular.

Flanders Hydraulics Research (Flemish Authorities) has commissioned the Maritime Technology Division of Ghent University to execute a comprehensive research program on bank effects with emphasis on sloped surface piercing and submerged banks.

II. EXPERIMENTAL PROGRAM

A. Experimental Setup

The experimental program, started in January 2006, consists of captive motion tests in the fully automated *Towing tank for manoeuvres in shallow water (co-operation Flanders Hydraulics Research – Ghent University)*. Tests are being performed with two ship models: a model of a LNG-carrier frequenting the harbour of Zeebrugge and an 8000 TEU¹ container carrier, typical for the traffic to both Antwerp and Zeebrugge. The container ship is being tested in two loading conditions (12.0m and 14.5m draft).

Seven different bank configurations are built in the Towing Tank (in pairs). Four surface piercing banks with four different slopes are installed subsequently:

- Straight quay wall (as in harbours)
- Slope 1/3 (as in a canal)
- Slope 1/5 (as in the harbour of Zeebrugge)
- Slope 1/8 (as on the River Scheldt)

Slopes 1/5 and 1/8 are combined with a submerged part varying in height and length. In this way, the influence of different bank configurations and bank parameters can be investigated.

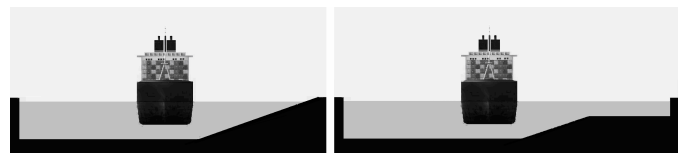


Figure 2 Cross section of ship in a waterway with sloped and sloped-submerged bank.

Taking into account Froude's scale law, the model ships are towed at speeds from 6 to 16 knots. Tests have been carried out at different propeller rates and drift angles.

¹ TEU = Twenty Feet Equivalent Unit

Several values for the water depth, expressed as the *under keel clearance* (UKC)² are selected: 35 and 70% for the LNG-carrier; 10, 35 and 100% for the container carrier.

Besides the ship's forward speed, the lateral distance to the bank is of high importance on the forces, moments and motions induced by the bank. Different lateral distances are tested varying from the centre line of the waterway to extremely close to the bank. Because the lateral distance is not unambiguous, a reliable expression for the lateral distance to the bank is indispensable.

More than 11 000 tests will have been carried out when the program is completed (November 2006). This will be the most extensive model test program ever executed world wide concerning bank effects.

B. Measured values

The ship model is free to heave z (squat) and pitch θ (trim), both motions are registered. All other degrees of freedom are restricted. The following forces and moments on the ship are measured: longitudinal force X , (lateral) sway force Y , roll moment K (about longitudinal axis) and yaw moment N (about vertical axis).

Forces and moments on propeller (thrust and torque) and rudder (lift and drag) are measured as well.

The free surface motion is registered by three wave gauges.

III. MATHEMATICAL MODEL

A. Limited Model

A model for each bank, ship, ship's draught and water depth will be formulated for the longitudinal force X , lateral force Y , yaw moment N and sinkage (fore z_f and aft z_a). This model will take into account only the forces (or moments or motions) which are related to the banks.

This means only the component F_{Bank} due to the presence of the bank will be modelled:

$$F_{\text{Total}} = F_{\text{OpenWater}} + F_{\text{Bank}} \quad (1)$$

F_{Total} being the total measured force. $F_{\text{OpenWater}}$, the force in open water (including restricted water depth). F_{Bank} , is modelled as a function of speed, ship-bank distance, propeller loading, etc.

B. Comprehensive Model

The final goal of this project is to create a model which takes into account properties of the environment (bank configuration, water depth, ...), design properties of the ship (ship's type, beam, draught, block coefficient, ...) and properties of the sailing vessel (ship speed, distance to the bank, propeller rate, drift angle, rudder angle, ...).

A model will be created for the forces on the hull (longitudinal and lateral), the moments on the hull (yaw moment and roll moment), and the motions of the hull (trim and sinkage). The influence on rudder and propeller efficiency will be investigated as well.

The waves created by the ship are of importance for assessing bank damage due to shipping traffic; an analysis of these data is however not in the scope of this research project.

IV. INTERNATIONAL COLLABORATION AND VALIDATION

International research institutes have been requested to collaborate to widen the scope of this project. Doing so, the model will be validated in many different ways. Numerical calculations will be carried out using Computational Fluid Dynamics (CFD) as well as potential flow theory. Results of these calculations will be compared with results of the comprehensive model for bank effects.

This comprehensive model will be incorporated in the full mission bridge simulators of *Flanders Hydraulics Research*. Pilots will carry out real time simulations and compare the simulated effects with their experience.



Figure 3 Full Mission Bridge Simulator at Flanders Hydraulics Research

At full scale the position (horizontal and vertical) of a ship as well as the rudder angle and propeller rate can be registered. These full scale tests will be compared with simulated tests on a full mission bridge simulator.

V. CONCLUSIONS

An extensive model test program is being carried out to be able to predict and model the forces, moments and motions on a ship induced by the vicinity of a bank. A limited model of the bank effects as well as a comprehensive model will result from these model tests.

The comprehensive model will be incorporated in the mathematical model of the full mission bridge simulator at *Flanders Hydraulics Research*. As a result, the accuracy and reliability of manoeuvring simulation as a tool for the admittance policy for the Flemish Authorities will be considerably enhanced.

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- [1] Vantorre M., Delefortrie G. & Elout K., *Experimental Investigation of Ship-bank Interaction Forces*, International Conference on Marine Simulation and Ship Maneuverability (MARSIM 2003), Kanazawa, August 2003

²UKC = the height of the water under the ship's keel expressed as a percentage of the draught