265. Simple but accurate calculation method for vessel speed in a minimum capacity lock

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Introduction

The increase of vessel size puts an upward pressure on the maximum allowed vessel dimensions in various inland waterways. Clearance between lock and vessel is decreasing to marginal values. This is especially the case with existing locks designed to provide sufficient locking capacity for large number of small vessels. However, with growing vessel sizes, these original "capacity" locks turn into "minimum" locks for the new modern vessels. As such, waterway authorities are increasingly challenged to allow vessels with dimensions that exceed the maximum allowed. Besides the risk of collision of the sill or the lock head, there is also the aspect of the time required to sail in and to sail out of the lock. This paper is a contribution to understanding the consequences of larger vessel size in the existing lock infrastructure focussing on the vessel speed during sailing in and sailing out of the lock and the subsequent increase of the lock-cycle time.

Background

For a specific canal in the eastern part of The Netherlands (Twentekanaal) the government decided to upgrade the canal to Class Va vessels. The canal was originally constructed for Class IV vessels with a draft of 2,6 m. In the existing locks (L= 133 m, W= 12,0 m, D: 3,45 m) the margins with a Class Va (D=2,8 m) vessel decrease to below the minimum values recommended in the Dutch Waterway Guidelines (WG,2011).

- Margin in width 2* 0,3 m =0,6 m where recommended: 2*0,55 m =1,1 m;
- Gross underkeel clearance 0,65 m, where recommended 0,70 m.

The questions that arise are:

- Is the UKC still positive and safe? Or does the vessel touch (or even damage) the lock sill?
- Is the vessel able sail in and out of the lock with acceptable speed?
- Is the increase of the locking cycle time acceptable?

Desk study

Where sailing in a canal can be characterised as sailing in confined water, sailing in a lock should be characterised as sailing in extremely confined water. The sailing speed in confined water can be calculated with the method described by Schijf (1949) and Jansen & Schijf (1953). Schijf's method has been applied for the calculation of the sailing speed and the squat of the vessel in the very confined water of the lock. The objective is to compare the critical sailing speed and squat for vessels from all CEMT-classes and at a number of drafts. The result of the calculations indicated that the existing navigation lock would be able to lock the larger ships safely, but that the locking cycle time would increase.

However, Schijf's method does not account for the important aspect of energy dissipation in the return flow and the increased water level in front of the bow in the dead end of the lock chamber. Therefore, it was decided to verify the results of the computations with prototype measurements.

Prototype measurements

Prototype measurements have been executed with a loaded CEMT Class Va container vessel. The vessel sailed up and down the canal twice and thus through the lock four times. During the sailing down and up, the following data was collected (frequency 1 Hz):

- Manoeuvring of the vessel (use of main engine, ruder and bow thruster);
- Position (x, y and z) of bow and stern of the vessel (RTK receiver); and
- Water pressure in the lock heads at (both sides of the gates).

A total of 4 sailing trips through the lock have been executed:

1. Sailing and locking down with a draft of 2.6 m
2. Sailing and locking up with a draft of 2.6 m
3. Sailing and locking down with a draft of 2.8 m
4. Sailing and locking up with a draft of 2.8 m

Characteristic values and verification of Schijf's method

From each measurement a number of characteristic values have been derived:

- Dimensions of the lock and the water level;
- Use of main engine (propeller) during lock entry and lock departure manoeuvre;
- sailing speed in the lock during sailing in and during sailing out;
- maximum squat of bow and stern in lock head;
- drop in water pressure inlock head during passing of vessel.
- lock entering time (from bow in lock head to stern in lock head);
- lock departure time (from bow out of lock head to stern out of lock head);

Verification calculations with Schijf's method

The verification calculations have been executed for the exactly the conditions and water depth that occurred during the measurements. The measured and calculated sailing speed and the time for sailing in and sailing out of the lock appeared to deviate significantly. The deviation appeared to be explained from the hydraulic processes that are not accounted for in Schijf's method:

- Dead end waterway (resulting in increased water level in the lock in front of the bow);
- Hydraulic resistance between vessel hull and lock chamber that results in a water level inclination along the vessel.

The above two effects have been added to Schijf's original method. This resulted in a very good agreement between the measured and calculated values.

Conclusions

A simple method has been developed to evaluate the sailing speed and time required for the entering and departing of the lock chamber. The basis of the calculation method is Schijf's well-known method that describes the hydraulics around a vessel sailing at constant speed in a uniform canal. The paper presents the calculation method, the measurements, the verification and the adaption of Schijf's method. In addition the paper will compare the calculation method with measurements of one vessel sailing through 5 locks in Belgium.