PIANC
The World Association for Waterborne Transport Infrastructure

InCom WG n° 155

Ship behaviour in locks and lock approaches

Terms of Reference

Background

The manoeuvring of ships in the approach of locks and the behaviour of the ships in the lock itself is a key factor for the hydraulic design of the locks. The design can significantly impact on the forces which act on the ship, as it approaches the lock, is being moored and moved upwards or downwards. The forces are the basis for the safety of the locking process, as they affect the ease to enter in the lock and the forces that are imposed on hawsers and bollards.

The previous InCom WG 29 "Innovation in navigation lock design" focused on the more general guidelines for lock design and it became clear, that the above topic could not be covered in sufficient depths. Thus, it is necessary to concentrate on the topic in a new dedicated working group.

Objective of the Working Group

The WG should investigate and report on;

i. An overview of the current knowledge to evaluate the forces which act on a ship while entering a lock and during the locking process;
ii. Methodologies to assess the acceptable levels of these forces;
iii. Guidelines in different countries to handle the design process in order to achieve the desired level of safety ;

The WG should use "lock" as a synonym for other constructions of comparable purpose (i.e. ship lifts).

Earlier reports to be reviewed

Report No. 106 "Innovation in navigation lock design" contains some basic information about the same topic. This information should be reviewed by the more specialized members of the new working group and then be enhanced and integrated.

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Matters to be investigated

The following issues which are relevant for a ship near to or entering into a lock should be evaluated:

The manoeuvrability of ships near locks in rivers is often hampered by longitudinal and cross-currents. These forces can be critical if the machinery of the ship is not able to compensate them or at least be discomforting for the pilot as a higher level of awareness is required.

For sea locks density currents can exert significant forces on ships when entering the locks. These forces are especially discomforting, as the visual impression is only showing the direction of the flow field on the surface while the direction in the deep water might be opposite and thus the resulting forces on the ship depend on the draught of the ship.

When the ship enters the chamber, it produces a wave in front of the ship. If the closing of the gate and the mooring process start early, these waves can generate significant mooring forces. The impact and methods to evaluate these forces should be gathered and possible remedies should be discussed.

The filling-and-emptying (FE) process generates a complex dynamic system consisting of the water in the chamber, the moving ship, the mooring lines and the (floating) bollards. It is very difficult to predict the behaviour of this system in advance in order to judge the quality of the FE-system and to fulfill the allowed loads on mooring lines and bollards. Thus, simplified approaches are commonly used.

Before a ship leaves the lock, the gates will be opened. In most cases a certain water level difference between the chamber and the approach areas can not be avoided.

For all the effects mentioned above it is necessary to judge their impact on the ship in advance during the design phase of the lock. The available methodologies for this should be gathered, compared and their range of applicability must be shown. Furthermore the available guidelines in different countries should be compared in order to give an overview of the allowable impacts.

All of the above effects are of different importance for different types of vessels. Thus the different impact on seagoing / inland waterway vessels, modern or old vessels, commercial vessels, white fleet and pleasure boats must be catered for.

Suggested final product of the Working Group

The working group shall first

- Present a *state of the art* report to assess the forces acting on ships (in lock), the ship motion and the mooring forces (physical modelling, numerical modelling and field measurement). The effects of density current must also be investigated.

- Gather case studies, examples, literature, statistics or other source material. Following data must be collected: data from users (subjective, experienced), measurements (objective, exact), numerical and physical modelling of levelling (prediction for prototype behaviours). The goal is to learn from existing practice and detect problems in existing designs.

- Discuss with experts for shipping (pilots, port and/or waterway authorities)

and then, the WG should investigate the following issues

a) <u>Synthesis of the forces acting on vessel in a lock chamber</u>

→ Description/definition of the different forces (hydrostatic, hydrodynamic, density effect, wind forces…) which are likely to be exerted on a vessel entering or moored in a lock chamber;

→ How and in what way these forces affect the ship dynamics and the mooring line forces (assessment of the component of every type of force in the total force);

b) <u>Setting of hawser force criteria</u>

→ Definition of the "hawser force" requirements according to the lock type (pleasure craft, commercial inland navigation, ocean going vessel);

→ Definition of a hawser force criteria so as not to exceed value for the forces exerting on the mooring lines;

→ Methodologies available to determine the force criteria – Literature references, available on-site measurements (of forces and or water slope), force-based and motion-based methodologies.

c) <u>Measurement & calculation methods of the forces acting on a vessel and/or in the mooring lines</u>

→ On site measurements – How to perform them (sensors that can be used, measurements methods…) – Results available on existing locks (Rhône River → Lock of Chateauneuf, pleasure craft locks on the Upper Rhône River) – Limit & efficiency of the on site measurements (measurement of the water slope, of the forces in the mooring lines);

→ Present (with applications) the modelling techniques and available tools. From rule of thumb, 1-D modelling, 2-D, 3-D, physical, modelling of water movements in lock and outer harbour. Numerical model calculation – Selection of the model (1D, 2D,

3D, …) depending on the design stage – Accuracy of each model – Influence of the boundary conditions - Calculation time & costs;

→ Physical model measurement – Selection of a measurement methodology (sensors to be used, measurements methods, accuracy…) – Sensitivity with respect to the scale of the model, to the ship model (hull shape, loading configuration…) – Measurements time & costs;

d) Recommendations to reduce the forces exerted in the mooring lines

→ During the conceptual stage of a lock design

Possible recommendations could be the general dimensions (ship versus infrastructure), shape and orientation of outer harbours, etc. The goal is to present overview of various techniques and tools that help to understand the hydrodynamic processes of a complete ship passage through a lock.

→ For a lock already in operation

In conclusion, the working group shall issue a Report in which the gathered material is to be condensed to a set of possible methods to tackle the aforementioned questions.

During the design of a lock, a key task is to assess the forces acting on the ship, his motion, etc. and to compare these values to the acceptable criteria.

So the WG challenge is to:

- Establish (and rank) the methods to assess these parameters: forces acting on the ship, ship motion, etc.
- Propose sets of allowable criteria (for various lock types and/or ship types). This means the requirements (specifications) to impose at the design stage concerning mooring forces, ship motion in lock chamber, etc.

Desirable disciplines of the members of the working group

The members of the WG should be experts or have experience in the following disciplines:

i. Navigation near or in locks (captains and lock keepers are welcome)
ii. Evaluation of forces on ships near or in locks
iii. Hydraulic design of locks
iv. Assessment of allowable loads on ships, mooring lines, bollards

Relevance for Countries in Transition

The subject of the working group can be considered as universal and will also be applicable, and can be helpful, for inland waterway projects in countries in transition. The report could be of value for countries in transition in supporting their application for a grant to a development bank or other fund holder.

Climate Change

During the preparation of the report, the possible impacts of Climate Change should be considered and any findings and/or recommendations should be made accordingly.