SPIN letter

Strategies to Promote Inland Navigation

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Foreword

Gert-Jan Muilerman from via donau

Inland navigation is different from other modes of transportation because of the natural characteristics of its main infrastructure, the river network. The dynamic nature of rivers (in terms of changing draught, varying waterway widths, etcetera) requires constant monitoring and operational flexibility from operators in the inland waterway sector. The recent historic low water period on the Rhine and Danube clearly showed the interdependency between inland navigation and its infrastructure: due to the limited draughts, the economic performance of inland navigation is directly affected. At other more strategic occasions the relation between vessel and waterway is also of critical importance; for instance in new waterway projects, questions whether the waterway should be adapted to the available vessels or the other way around are sometimes even dominating the discussion.

The SPIN consortium presents in a series of two SPINletter issues the backgrounds of the basic dependency between waterway and inland vessel. The first part deals with the physical particularities of inland navigation and is written by the European Development Centre for Inland and Coastal Navigation VBD from Duisburg. The second part - which will be published by via donau in the next SPINletter - discusses the economic implications of these physical particularities.

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Particularities of navigation on inland waterways

By Branislav ZIGIC, VBD:-

In comparison with the navigation in spacious and deep-sea stretches, the ship running on inland waterways meets certain specific restrictions. These restrictions characterised by shallow water or narrow waterway or - simultaneously and in most usual case - both, have a large impact on technical performances and consequently on economic effects of inland vessels. Hence the most direct, at the same time the cheapest and most probably the only feasible way to optimise the economy of inland navigation leads over the thorough and comprehensive investigations of ship-waterway interactions. The knowledge gained from such investigations is needed for instance for the determination of:

· Guidelines for the construction of navigable canals considering e.g. size, geometry, materials of bottom and side walls, effects of waves generated by moving vessels, jet streams and vortices caused by propulsion devices;
· Nautically permissible and practically feasible speeds of ships;
· Power requirements and propulsion characteristics;
· Manoeuvring particulars in restricted fairways;
· Behaviour of ships and pushed trains during passing by and overtaking in straight stretches and canal bends;
· Minimum space requirements for passing through, passing by and overtaking other floating objects in canal bends, etc.

Types of vessels on European waterways and their size

There are principally three different means of transportation on inland waterways: by self-propelled ship, by barges pushed by a self-propelled vessel (push boat or pushing cargo ship) and by barges towed by river tugs. The last method is nowadays almost completely abandoned on European waterways and might not be considered as typical any more.

Inland vessels are classified according to their size and purpose. The target group here are cargo vessels and these can be further distinguished by the kind of commodity, most generally into dry-cargo ships and tankers. As far as the main intention is to show processes and relations between ship and waterway the kind of commodity on board has no relevance for this particular topic. What is important is the size of a ship. For self-propelled cargo ships it varies from a small 38-40 m long "peniche" having a cargo capacity of only about 300 t at 2.5 m draught to a large 110 m long river ship with on average about 1900 t capacity at the same draught. In recent times even considerably larger vessels have become usual on the Rhine river having a length of up to 135 m, a beam of up to 17 m (with allowance and trends to be further increased!) and a capacity of about 3500 t at only 2.5 m draught.

Pushed trains usually consist of 2, 4 or 6 barges operated by a push boat of appropriate power. Standard European barges in common use in large number on the entire Rhine-Main-Danube corridor have a length of 76.5 m, a beam of 11.0 or 11.4 m and a carrying capacity of about 1650 t at 2.5 m draught. The large 6-barges train has a length of up to about 250 m (push boat and three barges in length, two side-by-side).

Cross sections of rivers and canals

Depth, width, cross sectional area and shape of the waterway are decisive factors for navigation and manoeuvring of ships and especially for their speed. On natural waterways - free-flowing and regulated rivers - only a part of the waterway cross section is used for the navigation - the so-called "fairway".

Fairway width and depth characterise the navigability of rivers. Thereby the actual water level has decisive influence on fairway depth and thus on navigability.

Propulsion and steering devices

The ship's motion through the water is enabled by propulsion and steering devices. The first mechanically, steam engine driven propulsion devices were side and stern paddle wheels that have been fully replaced by diesel-powered propeller in the last decades. The propulsion thrust generated by a rotating propeller brings the ship to move. Principally the propeller is a pump that accelerates a water jet in a certain direction. The thrust is generated opposite to this direction and is proportional to the quantity of water accelerated through the propeller within a certain time span.

Among numerous propeller types the conventional fixed pitch propeller (FPP) is the most common on river cargo ships.

The speed of the ship is determined by the size of thrust. Generally, the propeller efficiency grows with an increased propeller diameter. However, the propeller must also be well immersed within the water and arranged that way that no air will be sucked during the motion because otherwise the generated thrust would be considerably reduced.

Steering a ship means having control over her direction of motion. The most usual and simplest steering device is the rudder. The flow of water around the rudder blade in inclined position generates transversal force tending to move the stern opposite to the rudder inclination.

Navigation

Navigation means the motion of a ship through the water. With increasing speed grows the resistance of the ship to her motion through the water. Thereby the conditions within the navigation area have a decisive influence on the size of resistance and behaviour of the ship. Theoretically, four different situations might appear:

- Unrestricted waterway, i.e. a very wide and relatively deep waterway. Thereby "deep" means in some practical scaling the water depth which is at least about six times deeper than the draught of the respective vessel. Such ideal conditions do not exist in inland navigation;
- Narrow but deep waterway can eventually be found in certain gorges but on major European waterways such cases are very unusual.;
- Shallow and wide waterways can generally be identified on all major rivers within the European network. The attainable speed depends almost exclusively on the water depth.;
- Shallow and simultaneously narrow waterways are human-built canals. The maximal attainable ship's speed depends on the speed of propagation of waves, on the shape of the canal (trapezoidal, rectangular, arch-form) and the ratio between the cross sectional area of canal and the midship section.

In flowing rivers the ship is additionally affected by the stream flow rate. At low and normal water levels the stream flow rate of most navigable rivers in Europe is between 3 and 4 km/h. If assuming a standard running speed through the water of 13 km/h then the average ship's speed over ground would be 9-10 km/h upstream and 16-17 km/h downstream.

Manoeuvre

A ship operating in confined waterways, in relatively dense traffic, with sharp and narrow bends, numerous locks and bridges must match extraordinary high standards with regard to manoeuvring requirements such as course-keeping ability, turning, stopping, flanking, running astern etc. These abilities are important due to the very specific conditions of the navigation on inland waterways.

One of the numerous very demanding conditions for inland vessel is the safe operation when passing through the sharp

river bends. As a consequence of the common acting of various forces like resistance, centrifugal and steering forces induced by rudder blades, a torque appears that turns the vessel relative to the direction of its motion for so-called drift angle. In case of very long vessels like large pushed trains the width requirements through the curve might be considerably bigger than the total breadth of the vessel.

Additional very important manoeuvres for inland ships are "crash-stop", turning, flanking (moving sideward) and running astern. For example all ships operating on the river Rhine are requested to fulfil very tight and precisely defined requirements for stopping. These requirements set up the maximum distances after which the ship has to stop after previously running at a certain speed. Stopping in case of running downstream means not to stop moving through the water but relative to the ground. Accounting high stream flow rates at high water levels propellers must then bring the ship in running astern with a speed equal to the actual river flow rate. The importance of this ability in inland navigation is also evident from the fact that only river vessels are additionally and mandatory equipped with a stern anchor which might assist to a crash stop manoeuvre in case of emergency, to avoid collision or other accident.

Relevant and decisive technical aspects and relations

The above facts indicate the hydrodynamic complexity of inland navigation and very tight relations between the running ship and the restricted waterway. In some cases there are certain physical barriers which cannot be excelled. These barriers are expressed through relations among the size of the ship, cross section of the waterway, the speed of the ship and power requirements to enable that speed under given conditions. It is quite clear that the optimisation of the ship's operation in inland waterways - and that means that the target function is the economy of operation - can be done only for a concrete case and with a number of assumptions.

Specific power requirements per ton-deadweight of nowadays "standard large river ship" (GMS) is evidently the lowest and further increase in ship size leads again to higher power needs. But this can obviously be compensated by lower specific personnel cost of very large vessels. However, extremely large vessels come closer to the physical barriers for their operation on inland waterways, mostly as regards the draught restrictions. This

emphasises the need to apply a complex approach to the ship-waterway interaction in the future developments.

Following this approach considerable improvements in the ship's design were made in recent times. For instance, improvements of the stern tunnel geometry enable the installation of larger propellers and accordingly more power leading to higher speeds of the ship. Tests show that at a 5 m water depth an increase of speed of some 15-20%, dependent on the ship's type, could be achieved. Also the installation of propellers with optimised blade geometry shows a considerable gain in efficiency ranging from moderate 6 to even more than 20% in comparison to conventional propellers.

Finally, the optimisation of particular ship designs shows that in certain speed ranges the huge energy savings might be achieved by proper implementation of the best know-how.

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More detailed explanations of these challenging issues and relations appended with few sketches, figures and diagrams showing practical solutions and values can be found on SPIN-web www.spin-network.org > News & Events > Structure > Particularities of navigation on inland waterways by Branislav ZIGIC, VBD.

Contacts

For further information, please contact:-

First name	Name	Organisation	E-mail
Richard	IDIENS	FDC	richard.idiens@fdc.fr
Gert-Jan	MUILERMAN	via donau	muilerman@via-donau.org
Hilde	BOLLEN	PBV	hildebollen@binnenvaart.be
Cas	WILLEMS	AVV	c.p.m.willems@avv.rws.minvenw.nl
Branislav	ZIGIC	VBD	zigic@vbd.uni-duisburg.de

Abbreviation/acronyms list

AVV	Adviesdienst Verkeer en Vervoer (Transport Research Centre for the Ministry of Transport, Public Works and Water Management in the Netherlands)
DG-TREN	Directorate-General for Energy and Transport
EC	European Commission
EU	European Union
FDC	France Développement Conseil
FPP	Fixed pitch propeller
GMS	Großmotorgüterschiff (largeself-propelled ship)
PBV	Promotie Binnenvaart Vlaanderen VZW (Inland shipping promotion Flanders)
SPIN	Strategies to Promote Inland Navigation
SPIN-TN	SPIN Thematic Network
VBD	Europäisches Entwicklungszentrum für Binnen- und Küstenschiffahrt e.V. Duisburg (European development centre for inland and coastal navigation)
via donau	Donau Transport Entwicklungsgesellschaft mbH für Telematik und Donauschifffahrt–via donau (Development Agency of the Austrian Federal Ministry of Transport, Innovation and Technology)

Newsletter editor

FDC Rue du Cornet, 22 – B-1040 Brussels, Belgium
E-mail: ikoeppler@fdc.fr

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