SHALLOW DRAUGHT SHIPS FOR THE DANUBE

Dr. Dejan Radojcic, Professor
University of Belgrade, Faculty of Mechanical Engineering,
Dept. of Naval Architecture

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ENVIRONMENTALLY FRIENDLY INLAND WATERWAY SHIP DESIGN FOR THE DANUBE RIVER

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SHORT DESCRIPTION OF ASSIGNMENT:
DEVELOPING CONCEPT FOR SHIP DESIGN FOR THE DANUBE RIVER CONDITIONS
Presentation’s structure

- **INTRODUCTION** (4 slides)
- **WATERBORNE TRANSPORT** (1 slide)
- **TECHNICAL MEASURES THAT MAKE INLAND SHIPS CLEANER AND MORE EFFICIENT** (4 slides)
- **PROPOSED SOLUTIONS FOR THE DANUBE** (8 slides)
- **CONCLUSIONS** (2 slides)
Contemporary trends - Intermodal transport

• The land transport modes “dictate” prices.
  EU market share Rd/RI/IWT/Pp = 75/13/7/5; varies from one country to another

• IWT should adapt itself to other modes and hence standards that are broadly used in Europe (to pallet-wise containers - EILUs)

• The waterborne transport is only part of intermodal transport chain

• Transhipment costs are often substantial and are accounted to waterborne costs
General requirements

*Operational costs are dramatically reduced with increase of water depth, i.e. increase of vessel draught*

- During the low water levels, the ship should be able to operate with restricted economical effects
- The same ship should be able to operate in deeper water too, but will then be less efficient than the ship initially designed for deep-water operation only

Conclusions

- Transport costs, however calculated, are very much influenced by water depth
- Inland vessels should be designed (matched, adapted) according to the particular waterway
THE DANUBE WATERWAY

**Water depth**

Upper Danube – stretch Straubing-Vilshofen with $h_{W-LNRL} < 2$ m (1.7 m)
several sectors have $h_{W-LNRL} = 2.0 – 2.3$ m

Lower Danube – several sectors have $h_{W-LNRL} = 2.3 – 2.4$ m (1.5 m)

Elsewhere – $h_{W-LNRL} > 2.5$ m. Middle Danube - often above 5 m

**Bridge height or air clearance**

Critical bridges – Deggendorf $h_{A-HWL} = 4.73$ m and Passau $h_{A-HWL} = 6.36$ m

RMD canal bridges – ~ 6 m

Other bridges – upstream from Budapest ~6.7 m, downstream $h_{A-HWL} > 7.5$ m

**Size of locks**

Critical – Straubing at 12x190 m (as all locks of RDM canal)

Other on the Upper Danube are 2x24x190 m

The rest are 2x34x275 (310) m
All-around clearance between the vessel (or her cargo) and bridge/river-bottom/lock-side should be at least 0.3 m!

Maximal allowed vessel dimensions are:
For the whole Danube and DM Canal: $T < 1.7$ m (probably 2 m), $B \leq 11.45$ m
Downstream of Vilshofen: $T < 2.0$ m (probably 2.5 m), $B \leq 23.4$ m
The length of self-propelled vessels is practically unrestricted
Length of coupling train formation should be checked

In the shallow water, three characteristic regimes exist:
Sub-critical (according to ITTC, bellow $F_{nh} = 0.7$)
Critical, where $P_B$ increases dramatically
Super-critical, where $P_B$ may be smaller than in deep water

High speed vessels generate large wake (wash) which may cause serious bank erosion. So, the critical and near-critical speeds should be avoided due to environmental reasons as well.
**WATERBORNE TRANSPORT**

### PREVIOUS RESEARCH

**Barge trains** (for transport of large quantities of relatively cheap cargo)

- Partly loaded barges can be the simplest and cheapest answer to restricted draught problems (taking into account that power needed to push an additional barge (or few of them) rises slightly, while cargo volume can increase rapidly.
- The problem usually poses the draught of a pushboat which cannot be reduced. So, a shallow draught pushboat would be advantageous in these situations.

**Selfpropelled vessels** (for general, bulk and liquid cargo)

Selfpropelled vessels are faster and therefore more suitable for container transport (which has to compete with land transport modes, i.e. railway and truck).

**Statistics:** Rhine 84% & 34% and Danube 4% & 44% of European selfpropelled and pushed barges fleet, respectively.

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**Previous projects of particular interest** - INBISHIP, VEBIS and INBAT

The main reason why the innovative ship types are not applied in broader scale is economics (the state subsidies should be considered).
The main technical measures that enable fuel efficiency, hence cleaner and therefore more environmentally friendly shipping, are divided into four main groups:

**Improvement in Hull Resistance**
- Shallow water effects (choice of main parameters)
- Hull lines (Bow & Stern form)
- Weight reduction

**Improvements in Propulsion and Transmission Efficiency**
- Efficient propellers (propellers, water jets etc)
- New power transmissions (mechanic, hydraulic, electric)

**Improvement in Propulsion Plant**
- New generations of Diesel engines
- Other engine types

**Improvement of Ship Utilisation (Navigation)**
- Necessary crew and shore-personnel training
- River Information Services (RIS)
- Speed adjusting to specific waterway situation

**Fuel Efficient Ship for IW**

**Fuel Consumption**

\[ \text{Fuel Consumption} = f(P_D) = R_T \cdot \frac{\nu}{\eta_D \cdot \eta_S} \]
TECHNICAL MEASURES THAT MAKE INLANDSHIPS CLEANER AND MORE EFFICIENT

Conclusions

• Involve the hydrodynamic expertise an early design stage

• Reduce hull weight where possible (during ship production)

• New propulsor types should be considered

• New engine types should be considered for ship applications

• Command-bridge computerisation (RIS and other achievements)

• Crew training
TECHNICAL MEASURES THAT MAKE INLANDSHIPS CLEANER AND MORE EFFICIENT

AN INTERESTING TOPPIC - EMISSION LEGISLATIONS

- Time lag in implementation of EURO & CCNR emission regulations
- Ship have a lifetime of at least 20 years vs. 5 years for trucks
- Precondition for low emissions is a low sulphur fuel

Ship Diesel engines have CO₂ emissions lower than the truck engines, while NOₓ, PM and SOₓ emissions are higher.

CCNR norms are assumed to be relevant for IWT.
Ships are NOT so clean in terms of NOx and PM, unless Emission Reduction Technologies (ERT) are applied.

Standards according to CCNR III (corresponding to EURO V) may be met only by application of ERT.

Emission Reduction Technologies - ERT consist of several compatible and complementary measures:

- First step – Reduction of allowed sulphur for marine oil diesel
- Second step – Application of new diesel engine technologies and exhaust gas cleaning (older engines should be retrofitted with after-treatment devices)
PROPOSED SOLUTIONS FOR THE DANUBE

With the aim to demonstrate how a contemporary, safe, cost-effective, shallow draught vessel intended particularly for the Danube waterway should look like, some of the conclusions and technical achievements aimed at increasing efficiency of inland navigation are incorporated into design of two specific ship types:

- **Selfpropelled container vessel**
- **Barge train** (actually a pushboat) for bulk cargo

These two distinct ship type concepts are chosen because they are good representatives of typical ships used on the Danube.
PROPOSED SOLUTIONS FOR THE DANUBE

Danube container ship concept - Diesel-electric propulsion

Enlarged engine room
Danube container ship concept
“Z drive” rudder-propellers and a crane

Enlarged engine room
**PROPOSED SOLUTIONS FOR THE DANUBE**

**Main particulars of container ship concepts**

<table>
<thead>
<tr>
<th></th>
<th>Configuration</th>
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<tbody>
<tr>
<td></td>
<td>Basic</td>
<td>With a Crane</td>
<td></td>
</tr>
<tr>
<td><strong>Length</strong></td>
<td>104.0</td>
<td>102.5</td>
<td></td>
</tr>
<tr>
<td><strong>Beam</strong></td>
<td>11.65</td>
<td>11.65</td>
<td></td>
</tr>
<tr>
<td><strong>Height (Depth)</strong></td>
<td>3.1</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td><strong>Draught (max)</strong></td>
<td>2.5</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td><strong>Hold length</strong></td>
<td>80.0</td>
<td>78.5</td>
<td></td>
</tr>
<tr>
<td><strong>Hold width</strong></td>
<td>10.34</td>
<td>10.34</td>
<td></td>
</tr>
<tr>
<td><strong>Height above basis line</strong></td>
<td>8.3</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td><strong>Installed power</strong></td>
<td>4 x 400</td>
<td>2 x 700</td>
<td></td>
</tr>
<tr>
<td><strong>TEU (3 layers / 4 layers)</strong></td>
<td>156/208</td>
<td>134/172</td>
<td></td>
</tr>
<tr>
<td><strong>Payload capacity</strong></td>
<td>1950</td>
<td>1800</td>
<td></td>
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</table>
**PROPOSED SOLUTIONS FOR THE DANUBE**

**Some of the concept’s features**

Special attention was paid to low-draught performance. Proposed concept should be able to operate successfully and therefore be cost-effective at both low draught of up to 1.7–1.8 m (with two container layers) and full draught of up to 2.5 m (with 3 layers of full containers or even 4 layers of mixed full and empty containers)

The chosen hold length (80 m) and breadth (10.25 m) allow stowing of a variety of 2.50-2.55 m wide domestic containers

An on-board crane would allow transhipment at any port

Rudder propulsors enable exceptional manoeuvring characteristics

Position of the engine room at the stern and the crew premises at the bow offers additional crew comfort
PROPOSED SOLUTIONS FOR THE DANUBE

Barge train for transport of bulk cargo

- The main advantage of barge transport is that *cost-effective sailing with reduced draught, with partly loaded barges*, may be utilized.
- To substitute reduced carrying capacity, the number of barges in a convoy might be increased (power needed for pushing this convoy would not increase proportionally).

Tonnage capacity at reduced draught of a typical Danube barge (77x11x2.8 m) are given below:

<table>
<thead>
<tr>
<th>Draught [m]</th>
<th>~0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnage [t]</td>
<td>-</td>
<td>300-400</td>
<td>700-800</td>
<td>1100-1200</td>
<td>1500-1600</td>
</tr>
</tbody>
</table>

A *low draught pushboat* with a power of around 2000kW would be advantageous on the Danube.
PROPOSED SOLUTIONS FOR THE DANUBE

General Arrangement plan of a pushboat concept

Main particulars of pushboat concept

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td>30.0</td>
</tr>
<tr>
<td><strong>Beam</strong></td>
<td>11.0</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Draught</strong></td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Height above basis line</strong></td>
<td>6.0</td>
</tr>
<tr>
<td><strong>Installed power</strong></td>
<td>3 x 700</td>
</tr>
<tr>
<td><strong>Bow thruster</strong></td>
<td>250-300</td>
</tr>
<tr>
<td><strong>Crew</strong></td>
<td>8</td>
</tr>
</tbody>
</table>
The main advantages of the proposed pushboat concept

Its extremely low draught of only 1.4 m
(compared to draught of above 1.7 m of similar conventional pushboats)
This enables navigation with partly loaded barges on the whole Danube even at LNRL
Chosen length of 30 m and breadth of 11 m enables good packing possibilities of various push train formations

Enhanced manoeuvring (thanks to gondola-type bow thruster of 250 to 300 kW)

Application of the latest technological achievements that increase efficiency, safety, cleanliness and comfort

These benefits, however, are not a result of the proposed pushboat concept, but rather of a modern era. Namely, almost all Danube pushboats were built 30 or so years ago and therefore were equipped according to the standards belonging to the previous technological generation, so a newly built pushboat of any design or concept will be advantageous compared to the old (conventional) ones
CONCLUSIONS

• Contemporary (modern) shallow draught vessels, particularly suited for the Danube waterway are feasible (and desirable)

• They are inherently less efficient and less cost-effective (if water is deep enough) than the vessels with deeper draught

• When there is not enough water (when LNRL) low draught vessels will have a logistical advantage compared to deeper draught vessels as will be able to navigate all the year round

• Under which conditions IWT will work (i.e. what would be minimal/guaranteed water depth along the river and throughout the season, cost of fuel, taxes, eventual state subsidies etc.) is a political question which should be influenced, amongst other, by the technical and ecological requirements of IWT
COMMENT

Ships were navigating in the past although navigational conditions were worse (with a lot of shallows and free-flowing sectors), but the business environment was then different than it is today (with pipelines, railway and road infrastructure passing through the Danube corridor).

Under the present circumstances, there may be a limit (concerning low draught navigation) under which IWT will not be cost-effective anymore, as other modes, already much stronger and better positioned, will prevail.

Towing with the assistance of rail locomotives in Sipski kanal, Danube km 944+2200 m, right bank (current speed up to 18 km/h), from 1918 till the beginning of 1970.

THE END - Thank you for your attention