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Investigations of ship-induced waves on the Austrian Danube in the Donau-Auen National Park

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Abstract

The Donau-Auen National Park has initiated a research project to investigate the physical characteristics of ship-induced waves in the bank zone (littoral zone) of the free-flowing section of the Danube, east of Vienna. Using capacitance wave gauges the waves of about 40 passing ships were recorded with high temporal resolution. Supported by a statistical analysis, the characteristic parameters of the measured water-level variations (maximum rise of water level, deepest depression of water level, frequency and duration of waves, spectra) have been determined and related to the type and speed of ships. Obviously there is a huge influence of the form of the hull and the speed of the ships.

Keywords

Donau-Auen National Park, ship-induced waves

Figure 1: Map of the Donau-AuenNational Park (DONAU-AUEN NATIONAL PARK 2013)

Introduction

Through the area from the east of Vienna to the Slovakian border, the Austrian Danube flows, without a hydro-power plant, through the 93km² Donau-Auen National Park, as shown in Figure 1.

The Danube is part of the Pan-European Transport Corridor VII, which is the only route of the trans-European transport infrastructure comprising an inland waterway. This importance of the Danube waterway sometimes causes a lot of ship traffic which leads to increased stresses on the river shore areas. Such waves are known to have severe impacts on juvenile fish and other animals and plants living in the riverbank zone (GABEL 2012). They are a real challenge for the protected area of the Donau-Auen National Park.

Moreover, in recent years high-speed catamarans (the 'Twin City Liner') have intensified those problems in our study reach.

To study these waves and their dependence on different parameters, the Donau-Auen National Park administration approached the Consulting Engineer Gerhard Klasz and the Department of Hydraulic and Water Resources Engineering of the Vienna University of Technology to measure the ship-caused waves along the banks of the Danube, to evaluate and interpret them physically.

Aim of the research project

The aim of this research is at first to record the ship-induced waves depending on the discharge of the Danube River, ship type, direction (up- or down-stream), distance of the ship from the bank and the slope of the embankment. Based on these measurements it was desired to draw conclusions about the mechanical action and characteristics of the waves as a function of the most important parameters.

Experimental Investigations

Test Scheme

The monitoring program was divided into two series of measurements with different river discharges. The present paper represents the results of the first one. The second series is planned for the spring and summer of 2013. Each measurement series includes measurements on two days at two different embankment slopes.

The recorded data of each passing ship are the ship´s type and name, up- or down-stream travel, distance from the bank and the clock time. With the help of DoRIS, a GPS based data acquisition system of the *via donau* organization, the accurate route and the travel speed of each ship can be assigned.

In addition to the measurements of the water level, the maximum fluctuation range of the wave run-up on the bank was recorded and the velocity of the flow in the region of the water level sensors was continuously monitored.

Measuring Equipment

To be able to measure the height of the waves, the wave frequency, but also the angle and the speed of the wave fronts at which they strike the bank, three water level sensors were arranged in a triangle with a side length of about 1 m.

Because it was necessary to use the test equipment for both flat as well as steep banks, and the expected frequent transport of it through the National Park to the banks of the Danube, we had to design a lightweight structure with high flexibility. These conditions led to the choice of triangular aluminum lattice girders, consisting of four 2 m long individual elements which are assembled on site to form two main trusses. These two girders, mounted together with an intersection angle of 60 degrees, were arranged to rest on height-adjustable bearing blocks and carried the three measuring sensors. They are shown in Figure 2.

Figure 2: Overview of the experimental setup (© John Fenton)

The adjustment of the horizontal position of the trusses was carried out using a digital spirit level. Subsequently, the arrangement was secured by distance tubes and additional guys.

Measurement and recording techniques

Water level sensors

For an accurate measurement of the quickly and widely fluctuating water levels of the ship waves on the Danube we used the capacitive two-rod probes for continuous measurement in liquids with a rod length of 1500 mm. The continuous monitoring of the data was carried out by an online transmission of the analog 4-20 mA signals which were sampled at a frequency of 50 Hz.

In case of high waves when the lateral load capacity of the probes could be exceeded, additional guys to the truss system were mounted to stabilize the sensors.

In addition to the capacitance measurements of the water level, for all the measurements visual checks were carried out by means of a video-controlled vertically mounted scale, mounted so that it did not disturb the flow around the water level sensors.

Flow velocity measurement
Measurement of the local fluid velocity of the Danube was recorded for reference purposes during the complete test duration by means of a portable vane anemometer. To ensure that the anemometer was always oriented in the flow direction, it was arranged on a vertical axis with a vane.

Speed and paths of the ships
The determination of the ship's speed and exact position was carried out with the River Information Services DoRIS operated by the *via Donau*. DoRIS is based on the "Automatic Identification System" (AIS) and enables, by way of AIS transponders which are part of the mandatory equipment for vessels with more than 300 gross registered tonnes on the Danube since 2002, to identify the current position of the vessels using global positioning systems (GPS). It is a system in which ships continually transmit their ID, ship dimensions, maximum draught, position, course, speed, and other data to all other nearby ships and land-based authorities on a common VHF radio channel. Figure 3 shows an example of the evaluation of the navigation way of one ship.

Figure 3: Example of the navigated way of a ship (Vessel 9: "Twin City Liner" – see below) by DoRIS (© Boris Huber)

The lateral distance between the vessels and the observation bank were additionally measured by means of a Tevion laser distance measuring device with a precision of ±1 m.

Wave run-up on the bank
The measurement of the maximum fluctuation range of the wave run on the bank of the Danube, according to the occurring Sunk and wave phenomena, was performed using a visual check using a measuring tape fixed along the bank. With every ship transit the maximum deviations from the undisturbed water levels, both up and down, were recorded.

Remaining measurements
All other observations and measurements carried out, e.g. the direction (up- or down-stream), measurements of the distance between the ships and the bank, the maximum values of the water level fluctuations, etc. were noted manually with the ship´s name, the ship´s type and time of day.

Test Results

Figures 4 to 8 show typical wave records and wave spectra from representative vessel types. On the left of each figure is shown the wave record, with a constant vertical scale for all figures, so that the magnitudes can be compared between different vessels. On the right is shown the raw amplitude spectrum of the wave record, plus a line showing the smoothed spectrum.

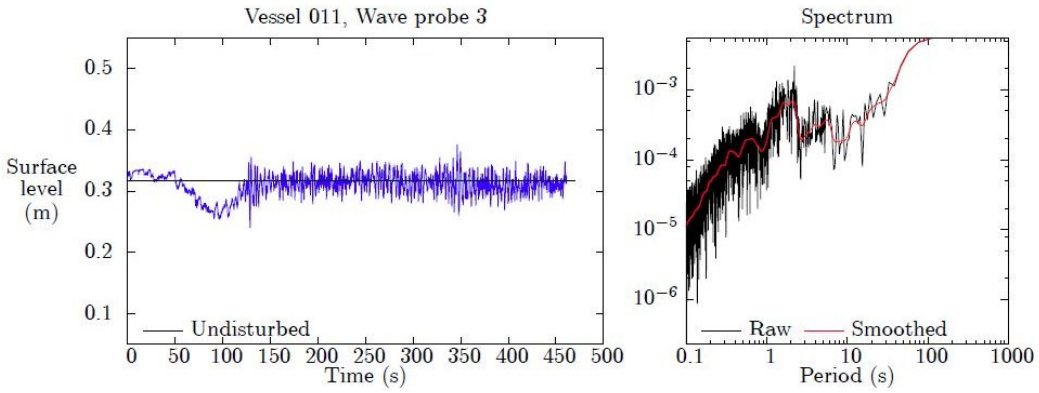

Figure 4: Vessel 11: "Max" Self-propelled barge, upstream, 67 m from bank, heavily laden, with a relatively strong bow wave (© John Fenton)

Figure 4 shows the record from a typical self-propelled river barge. In this case the vessel was heavily-laden, with a strong bow wave, travelling slowly upstream. It is surprising that, relative to others, this bulky vessel with a strong disturbance, only created a small drawdown and relatively small and short waves, although these continued for a long time. The persistence of disturbances to the river was surprising to the observers, partly due to strong reflections. An interesting video film of such a vessel on a canal in Belgium shows this clearly: http://www.flickr.com/photos/rothar/3604754330/.

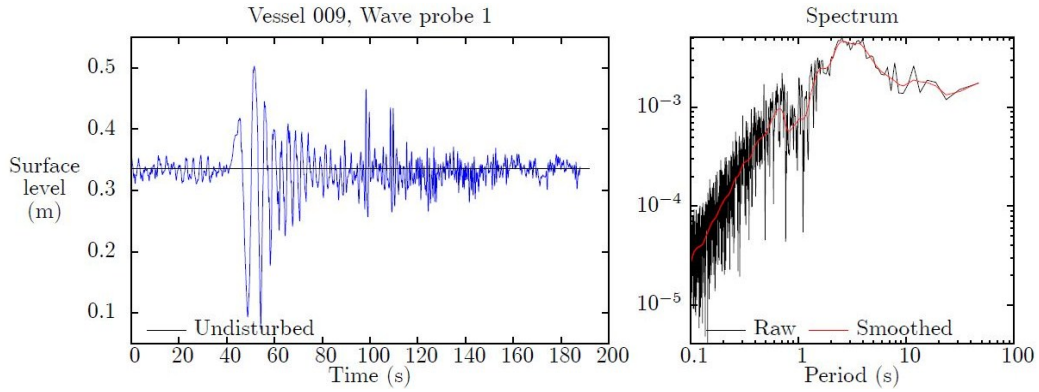

Figure 5: Vessel 9: "Twin City Liner" fast passenger catamaran, downstream, 130 m from bank (© John Fenton)

Figure 5 shows a very different situation, where the vessel was a fast passenger catamaran, clearly travelling at supercritical velocity. There was no drawdown, but the waves created were largest and longest of all the vessels we observed. In fact, this vessel made several passes during the day, as it has a regular service between Vienna and Bratislava. The record shown was the most dramatic of those passes. The highest waves were 0.4m, while the clear spectral peak was at about a period of 3 s. There were some reflections, but the disturbances to the river died down relatively quickly.

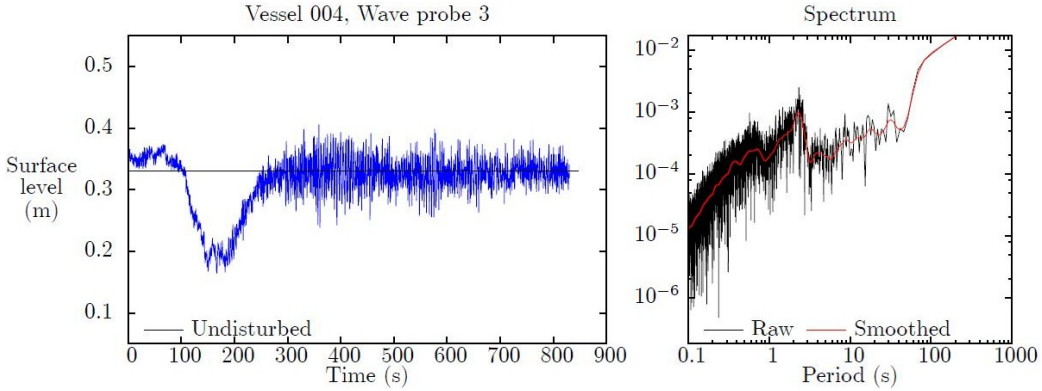

Figure 6: Vessel 4: "Ybbs" Push Tug with 2 barges laterally, a large obstruction, upstream, 86 m from bank, strong transverse secondary waves (© John Fenton)

The vessel, that created the record shown in Figure 6 was a very large combination of a push tug with two barges, all arranged side-by-side. It can be seen that with such a large blockage, there was a drawdown of some 0.2 m. The ship waves persisted for a very long time, with little diminution, and a marked spectral peak at about 2 s.

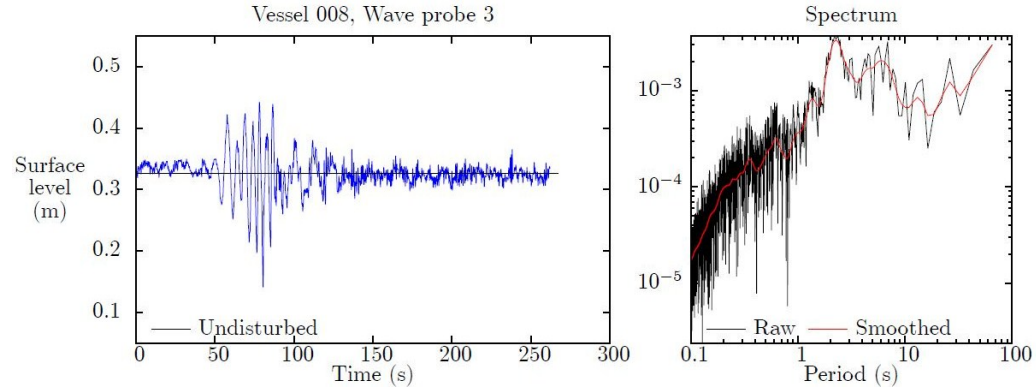

Figure 7: Vessel 8: "Wildungsmauer", Navigation Authority Motorboat, upstream, 62 m from bank (© John Fenton)

A large, but transitory effect was that caused by a single small but fast-moving motorboat, as shown in Figure 7. The effects were similar to, but slightly smaller than, the large passenger catamaran described above, and the disturbances decayed quickly.

Finally, another vessel very common to the Danube, is shown in Figure 8, which is a large passenger cruise boat, which, unlike commercial vessels, was well streamlined. It is notable, and surprising that the wave system generated was as large as it was. The drawdown was as large as the huge combination of three craft described in Figure 6, while the waves were not much smaller.

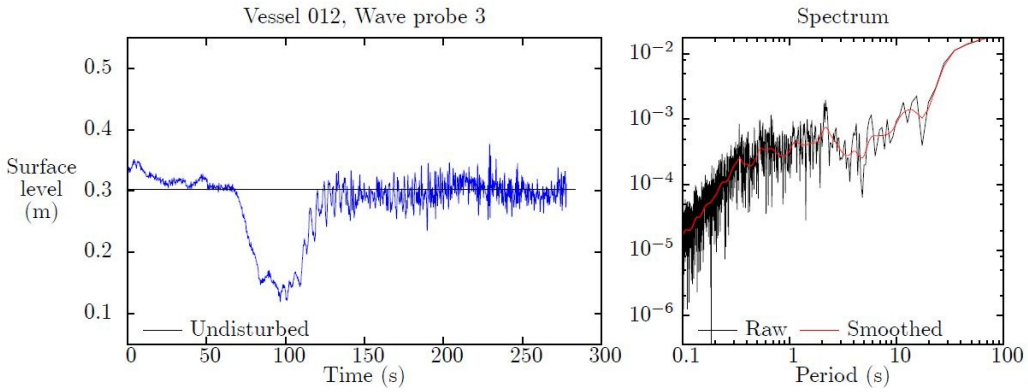

Figure 8: Vessel 12: "Scenic Emerald" Passenger cruise boat, upstream, 60m from bank (© John Fenton)

Conclusions

This study was not intended to examine the effects of various wave phenomena on the physical and biological environments, but rather to examine the disturbance characteristics of typical vessels on the river.

What was particularly notable to the investigators was the size of the drawdown created by vessels travelling at sub-critical speed. This, as suggested by simple theory, was proportional to the blockage cross-section of the vessel. Even if a vessel were streamlined, such as for the passenger cruise ships, the drawdown was large.

On the other hand, the waves created by streamlined sub-critical vessels were smaller than for bluff ones. For the super-critical fast catamaran and for the speedboat, the waves were highest and longest.

Another notable feature of the disturbances was the very long duration time of some wave systems. There must have been many reflections in the river, even though all measurements reported above were taken on a steep rocky bank, which would have absorbed short waves effectively.

References

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