FAST FERRY TRAFFIC AS A NEW FORCING FACTOR OF ENVIRONMENTAL PROCESSES IN NON-TIDAL SEA AREAS

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Summary The impact of wake wash from high-speed ferries on the coastal environment is analysed in terms of wave energy and power, and properties of the largest waves. Shown is that hydrodynamic loads caused by heavy high-speed traffic may play a decisive role in certain non-tidal areas with high wind wave activity. The main reason of concern is the long periods of wake waves. The leading waves typically have a height of about 1 m and a period of 10-15 s. They cause unusually high hydrodynamic loads in the deeper part of the nearshore. The fast ferry traffic is thus a qualitatively new forcing component of vital impact on the local ecosystem.

INTRODUCTION

The waves from fast ferries have become an environmental problem of growing concern during the last years. Fast ferries do not produce only higher waves than conventional ships, but also fundamentally different wave systems when sailing at supercritical speeds. The influence of ship-generated waves may be critical for certain processes in semi-enclosed estuaries or in areas usually not exposed to swell or severe local windseas [1]. It is generally believed that ship wakes are negligible and that their effect is sporadic in the high-energy coastal areas that are open seawards and where natural waves are frequently much higher than the wakes. This assumption is indeed true for coasts exposed to high tides or large wind waves.

The purpose of the current paper is to demonstrate that ship wakes may nevertheless be of particular importance in certain parts of coasts that are already subject to high hydrodynamic loads and intense beach erosion in natural conditions. The reason is a combination of specific features of the existing hydrodynamic loads (that are restricted, for example, to a particular direction or a certain frequency interval) with a special type of the coastal environment (that has reached a near-equilibrium stage of its evolution) and particularly high anthropogenic wave loads that are qualitatively different from the natural wave loads.

ENERGY AND POWER OF WIND WAVES AND SHIP WAKES IN TALLINN BAY, BALTIC SEA

The study is based on an extensive field study of both wind wave and ship wave properties in different parts of the coastal area of Tallinn Bay [2]. This bay is a semi-enclosed area in the central part of the Gulf of Finland. In recent years, the high-speed ship traffic has increased considerably and amounts up to 70 traverse per day during the high season.

The field results are compared with a long-term reconstruction of wind wave climate based on a high-resolution version of the wave model WAM. The properties of the wave field vary significantly in different areas of the bay. The highest waves occur in the central area of the bay where the 1-year return value of the significant wave height slightly exceeds 2 m and wave heights may reach 4 m during extreme NNW storms.

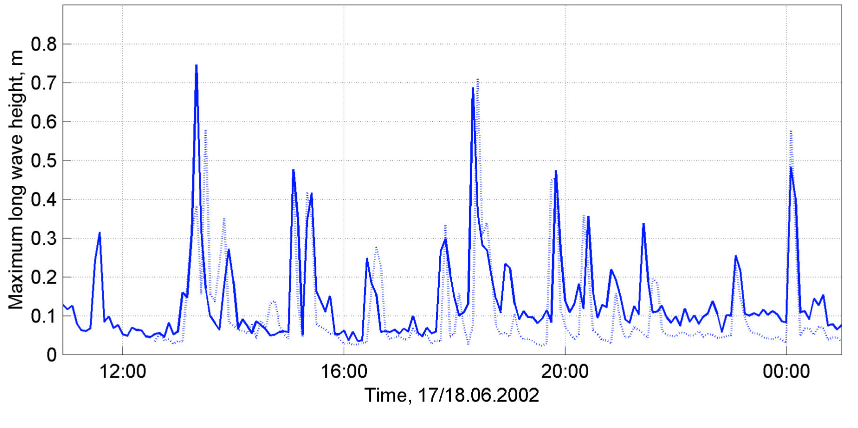

Fig. 1. The maximum height of the long-wave component (waves with periods exceeding 5 s and mostly representing wakes from high speed ships) near the western coast of the island of Aegna at the entrance of Tallinn Bay, at a distance of about 2 km from the ship lane on 17.06.2002 (solid line) and 18.06.2002 (dotted line). The significant height of the wind wave background is 40–60 cm on 17.06 and 30-40 cm on 18.06.

The heights of the wake waves of fast ferries are moderate in the coastal zone of Tallinn Bay and normally do not exceed 1 m (Fig. 1). In particular, they are much smaller than the highest wind waves reaching this area each year: the typical annual maximum significant wave height in the coastal zone is about 1.5 m, therefore, the highest single waves are about 3 m high. However, wind waves of this height occur seldom and the daily highest examples of ship waves mostly belong to the highest 1%–5% of wind waves. The fast ferry traffic is so heavy that the annual mean energy of ship-generated waves is 6-8% from the bulk wave energy and the ship wave power may be as high as 34% from the bulk wave power in the coastal zone of the bay [2].

ENERGY DISTRIBUTION IN WAKE WAVES FROM HIGH-SPEED FERRIES

The reason for such a large difference of the share of ship waves in the wave energy and power suggest that, at least, a part of wake energy is concentrated in wave components with periods greatly exceeding typical periods of wind waves. The daily average wave energy spectra (Fig. 2) indeed show a clear separation of the major portion of the energy of wakes from large high-speed vessels and the energy of wind waves in various natural wave conditions. The separation occurs at different frequencies depending on both the location of the site and the background wave field. The spectrum at Fig. 2a proves that the role of wakes from from conventional vessels and hydrofoils (that mostly exite waves with periods 3-5 s) is negligible in the total energy budget of the ship-generated waves.
A particularly important feature that follows from the spectra in Fig. 2 is that the major part of the energy of wake waves of high-speed vessels lies outside the frequency range of wind waves occurring in typical conditions. The well-defined peak corresponding to the longest waves in the energy spectra in Fig. 2 suggests that, in average, the energy of the leading waves (that are also the longest waves of the wake) considerably exceeds the energy carried by the the rest of the wake. Comparison of Fig.1 and Fig 2 reveals that the leading waves of a ship wake frequently have heights about 1 m and periods of 10-15 s. Waves with such properties do not exist in the natural conditions in the area in question.

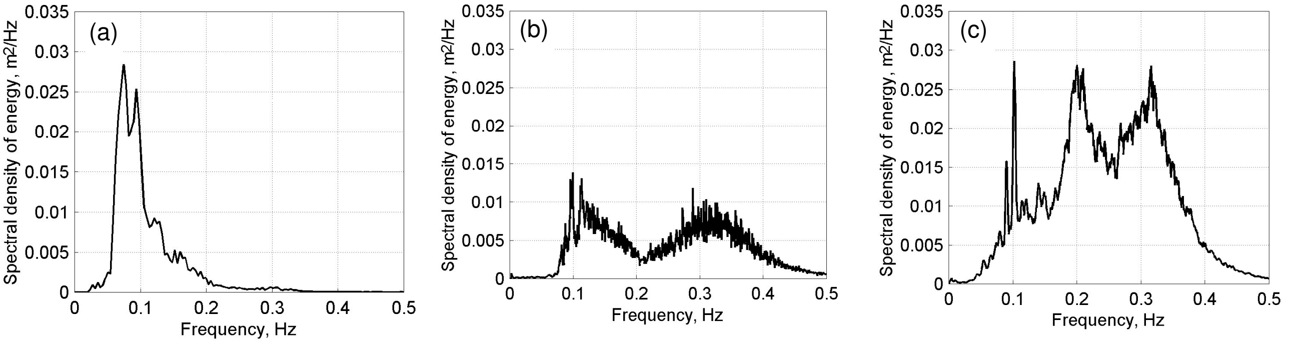

Figure 2. Daily mean joint energy spectra of wind waves and ship wakes in the coastal zone of Tallinn Bay at a distance of about 2 km from the ship lane (a) in perfectly calm conditions; (b) in the moderate wind conditions (the significant height of wind waves is about 40–60 cm, the temporal behaviour of the heights of long waves is given in Fig. 1, solid line); (c) in strong wind conditions (the significant height of wind waves is about 1 m and open sea swell with a period of about 5 s is also present). The measurement site for the panel (b) is located in the area where ships sail at moderate speeds.

ENVIRONMENTAL IMPLICATIONS

The difference of prevailing periods of the highest parts of the ship wash and the windseas is the most critical issue in the Tallinn Bay area. For a fixed wave height, the wave-induced near-bottom velocity depends essentially on the wave period and has the highest variation for the nearshore with the depth of 5-30 m when the wave period increases from 5 s to 8 s. Since the major part of the energy of the wakes from fast ferries is concentrated in the wave components with the periods exceeding 6-7 s [2], the impact of a typical ship wake on bottom sediments and aquatic wildlife at these depths is comparable with or even exceeds the impact of wind waves occurring in the most violent storms. Thus, the wake of fast ferries is a new forcing component of vital impact on the local ecosystem that may cause considerable intensification of beach processes as well as enhanced vertical mixing in the water body, and has a significant influence on the aquatic wildlife.
An abrupt intensification of long-wave activity may cause considerable changes in the existing balance of sediment distribution, because already relatively small levels of long-period wave energy in combination with wind waves can cause greater beach response than an equal amount of energy in the windsea only frequencies [3]. The gross influence of wakes from high-speed ships for a coast with a low hydrodynamic activity and a proper structure of bottom sediments may trigger a new phase of the coastal evolution through fast eroding the seaside part of the nearshore. This process creates a deficit of sediments at certain depths that will be balanced by a more intense transport of material from the vicinity of the shoreline. Another consequence is that after some time the intensity of wind wave breaking may decrease, and more wind wave energy may penetrate to the shoreline [4].

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