Use of metamaterials for surface wave control: examples on backscattering reduction and boat wake absorption

Samantha Kucher[1], Adrian Koźluk[12], Philippe Petitjeans[1], Agnès Maurel[3], Vincent Pagneux[4]

[1] Laboratoire de Physique et Mécanique des Milieux Hétérogènes, UMR CNRS 7636, ESPCI-Paris, Université PSL, Sorbonne Université, Université Paris Cité, 75005 Paris, France
[2] Institute of Aeronautics and Applied Mechanics, Warsaw University of Technology, 00-665 Warsaw, Poland
[3] Institut Langevin, UMR CNRS 7587, ESPCI-Paris, 75005 Paris, France
[4] Laboratoire d'Acoustique de l'Université du Mans, UMR CNRS 6613, 72085 Le Mans, France
samantha.kucher@espci.fr

Metamaterials are artificially architectured materials that affect the wave propagation in ways that are not usually found in nature. They initially emerged in the field of electromagnetism. However, they quickly spread to many other areas of physics since all waves share a fundamental nature. In the last years there has been an interest in the design of metamaterials for surface water waves. Such endeavour present both an advantage and a challenge. Surface waves are easily accessible as they are visible to the human eye. However, they are dispersive, which highly complexifies their dynamics. Here we pursue the challenge of controlling surface waves through metamaterials using a theoretical, numerical and experimental approach.

Two different, although closely related, wave control systems are studied: (i) the reduction of backscattering generated by a sharp bend in a channel thanks to an array of parallel plates, and (ii) the absorption of a boat wake by a microstructured wall consisting of resonant cavities. In both studies the periodic structure is carefully designed and described in terms of an effective medium using homogenization theory.

Firstly, we design a metamaterial consisting of a periodic array of parallel thin vertical plates, closely spaced. This array can be used to deflect waves at different angles depending on the thickness of the plates and the angle of incidence. We first study numerically the behavior of an infinite array of plates and then confine this array into a waveguide with two perpendicular turns. By placing the metamaterial in the central part we are able to reduce considerably the backscattering in the turns and thus obtain a high transmission [1].

Secondly, we consider the reflection coefficient in the complex frequency plane to design a microstructured wall capable of achieving perfect absorption [2]. Our wall consist of the repetition of resonant cavities and we use it to absorb the wake pattern of a boat. This system could be applied to coastal protection or on geometries with lateral confinement such as rivers.

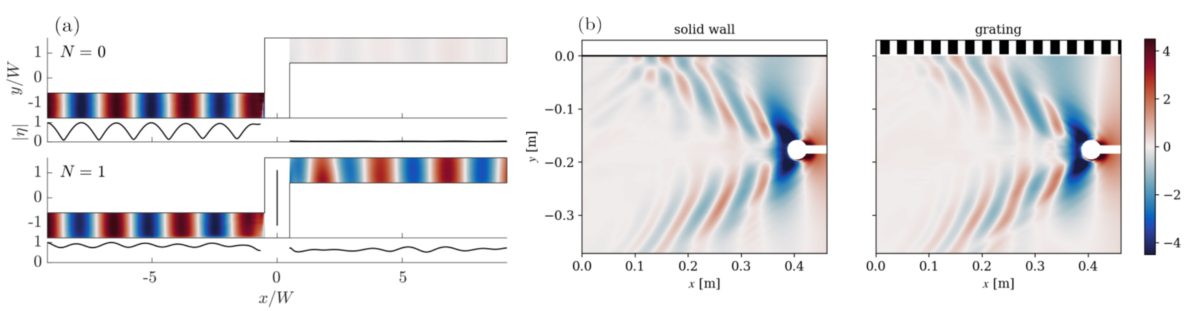

Figure 1. Measured free surface deformation fields: (a) Plane wave propagation in a channel with two perpendicular turns at a fixed frequency, in a configuration without the metamaterial and with one vertical plate. (b) Boat wake incidence on a solid wall and on a periodic grating made of resonant cavities.

References

1. S. Kucher, A. Koźluk, P. Petitjeans, A. Maurel, and V. Pagneux, Backscattering reduction in a sharply bent water wave channel, *Phys. Rev. B*, **108**, 214311 (2023).
2. V. Romero-García, G. Theocharis, O. Richoux, and V. Pagneux, Use of complex frequency plane to design broadband and sub-wavelength absorbers, *J. Acoust. Soc. Am.*, **139**, 3395–3403 (2016).