Experimental observation of elastic rogue waves

Murukesh Muralidhar[1,2], Antoine Naert[1], Sébastien Aumaître[2]

[1] Laboratoire de Physique, ENS de Lyon, UMR-CNRS 5672, 46 allée d'Italie, 69007 Lyon, France
[2] Service de Physique de l'Etat Condensé, DSM, CEA-Saclay, UMR 3680 CEA-CNRS, 91191 Gif-sur-Yvette, France

murukesh.muralidhar@cea.fr

Rogue waves are exceptionally large & extreme waves that take place in seas and oceans. A more classical definition is, waves with heights exceeding twice the significant height of a given sea state. [1]. These rare, destructive events demand an understanding of their underlying physical mechanism for their prediction, particularly considering their impact on seafaring and structures. This study aims to explore the existence and possibly characterize rogue waves in an analogous system—a thin, elastic stainless steel plate.

The elastic plate adheres to wave turbulence theory, assuming a 4-wave process. Despite analogies to surface waves, differences exist, notably the absence of an inverse cascade in these elastic waves. For waves longer than the plate's thickness, this dispersive media is considered two-dimensional, governed by a dispersion relation : $\omega = \lambda * k^2$, with λ as the efficient coefficient measuring the plate's response to external force [2]. A large electromagnetic shaker sustains the plate in a steady state of motion, out of equilibrium. Laser vibrometers are used to measure the displacement and velocity at different points. Questions arise regarding the system's ability to exhibit extreme states and the physical mechanisms involved. Can occurrences be quantified, and are the same mechanisms applicable to ocean waves ? Addressing the effect of forcing frequency and amplitude on rogue wave observation is a primary focus. Determining the proper wave description—geometrical or kinematic—is also crucial.

We show the first experimental observation of elastic rogue waves and characterize it. As expected, the spectral density of the displacement signal reveals a slope of -2 for the low frequency regime, lower than the excitation frequency, indicating the equipartition of energy at these frequencies [3]. Interestingly, the occurrence of rogue events is not strictly associated with the highest steepness of the waves, which may seem counter-intuitive. Another intriguing finding is that the asymptotic value of the percentage of occurrence of rogue waves appears independent of the forcing frequency, marking a significant inference. Future work would involve a more comprehensive description of such waves, particularly in terms of energy considerations.

Références

1. Michel, G., Bonnefoy, F., Ducrozet, G. & Falcon, E., Statistics of rogue waves in isotropic wave fields. *Journal Of Fluid Mechanics*, **943**, A26 (2022).
2. Nazarenko, S., Wave turbulence. (2011,1).
3. Miquel, B., Naert, A. & Aumaître, Low-frequency spectra of bending wave turbulence. *Physical Review E*, **103**, (2021,6).