Axisymmetric 'spike waves' far exceed limits previously thought to dictate maximum height of ocean waves

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Credit: University of Oxford

In a new study on ocean wave breaking, researchers have demonstrated that the breaking behavior of axisymmetric "spike waves" is quite different to the long-established theories on the breaking of traveling waves.

Traveling waves break when waves become so steep that the crest is no longer stable. This leads to a breakdown of wave motion and energy loss. As a result, the height of the wave is limited by the breaking process.

"Much of our understanding of wave breaking is routed in theories developed and experiments carried out in two dimensions when waves are moving in one direction," explained lead author Dr. Mark McAllister, Department of Engineering Science, University of Oxford. "However, wave breaking in the ocean is a three-dimensional process."

To establish the differences between wave breaking in two dimensions and three dimensions, researchers used the circular wave tank at FloWave Ocean Energy Research at the University of Edinburgh to reproduce an extreme three-dimensional axisymmetric wave, the spike wave.

Results from the wave tank demonstrated that axisymmetric wave breaking behavior was very different to the wave breaking associated with traveling waves.

As the waves formed, a large vertical jet of water erupted from the crest of the wave before going into freefall and colliding with the surface of the water below.

The experiments showed that, unlike traveling waves, the crest height of the spike wave was not restricted by the onset of breaking but by the stability of the jet.

Dr. McAllister said: "This study has revealed the fundamental mechanisms through which highly directionally spread and crossing waves can become much larger than other waves, accelerating upwards much faster than gravity for a short fraction of time."

The new research at three orders of magnitude larger than previous experiments reveals significant implications for maritime safety. As Professor Ton van den Bremer, Engineering Science, University of Oxford and Delft University of Technology explains, "The spike wave is an idealized example of a type of behavior that makes so-called crossing seas, where wave systems travel in different directions, so dangerous for shipping and offshore structures."

Understanding the dynamics of the spike wave could ultimately lead to advances in maritime safety based on improved data on wave height limitations and breaking behavior in extreme conditions.

The study undertaken in collaboration with researchers from the University of Edinburgh, the University of Manchester, Shanghai Jiao Tong University and Delft University of Technology is part of a large-scale investigation of crossing seas that can produce extreme three-dimensional waves.

"Wave breaking and jet formation on axisymmetric surface gravity waves," is published in the *Journal of Fluid Mechanics*.

More information: M.L. McAllister et al, Wave breaking and jet formation on axisymmetric surface gravity waves, *Journal of Fluid Mechanics* (2022). DOI: 10.1017/jfm.2021.1023

Provided by University of Oxford

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