

## **Floating Structure Responses in Shallow Water Rough Sea**

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### **ABSTRACT**

Study of floating structure responses in shallow water rough sea has involved many technical issues both numerically and experimentally. So far, not many results have been published on this subject. Floating structure responses in shallow water waves are different from the ones in deep water. The sea bottom effect is significant. In the current study, the water depth effect on response factor RAOs, wave spectrum and the response spectra are presented and discussed. A typical fine form vessel interacting with the typical hurricane generated waves has been simulated.

**KEY WORDS:** Shallow water wave; shallow water spectrum; fluid-structure interaction; forward speed; structural responses.

### **INTRODUCTION**

Shallow water storms are the major factors of consideration of the design criteria for the large floating structures such as very large crude oil carriers, ultra large container carriers, and increasingly more VLCC converted FPSOs. Because these types of vessels have very large draft, the shallow water wave effect will be significantly greater than that of smaller floating structures for certain depth of operation area. The shallow water storms usually lead to the floating structure's grounding, its collision with other floating structures, and the damaged mooring system. Because the shallow water wave and the deep water wave have different physical characteristics, the deep water theory cannot be directly applied to the shallow water case in general. Therefore, in current study, the theory of the consideration of water depth effect for the shallow water wave and the shallow water wave spectra have been introduced to better reflect the reality of floating structure responses in the shallow water rough (harsh) sea. In shallow water wave zone, the regular linear wave is generally defined as the airy wave; the regular nonlinear wave is defined as the high order stokes wave, the solitary wave, and the cnoidal wave. As a matter of fact, the realistic sea will have irregular (random) waves which can be considered as the superposition of all types of regular waves. Therefore, the wave spectrum has been adopted to describe the irregularity of random sea. However, due to the complexity of the irregular wave-floating-structure interactions, the floating structure responses in shallow water random sea are usually solved by combining

regular wave response amplitude operator (RAO) and shallow water wave spectrum to convert to the corresponding solutions. The shallow water Green functions have been employed to solve the boundary element problem for the Laplace equation to obtain the floating structure response RAOs. The TMA spectrum, which combines the JONSWAP spectrum and the shallow water effect transformation factor, has been presented to demonstrate the nonlinearity and irregularity of shallow water rough sea. The modification of TMA spectrum based on the effect of forward speed has been discussed. The spectrum shape parameter effects on the shallow water spectrum have also been discussed. A typical fine form vessel operating in shallow water zone suffering 100 year hurricane (tropic storm) at the sea has been simulated for the structure response studies.

The regular wave and the irregular wave in shallow water are different from the waves in deep water. The peaks are much sharper than the troughs, and the order of magnitude of the peaks is different from that of the troughs. The typical regular nonlinear waves in shallow water usually consist of the higher order stokes wave, the solitary wave, and the cnoidal wave. The typical regular linear in shallow water is presented as airy waves. Because nonlinear regular shallow water waves are not symmetric with respect to the calm water line, the wave height distribution no longer follows the Gaussian random process by not obeying normal probability law. In general, the irregular waves in shallow water will be considered as non-Gaussian distributions. Therefore, when irregular waves propagate from deep water to shallow water, the wave height spectra transfer from the Gaussian distribution to the Non-Gaussian distribution. However, irregular airy wave in shallow water (mild sea) still follow the Gaussian process because its wave profile remains symmetric about the calm water line. Therefore, the shallow water wave distributions depend not only on the water depth but also on the sea severity.

### **METHODOLOGY**

#### **Shallow Water Theory for Irregular Waves**

Shallow water wave spectrum distribution is different from wave spectrum distribution in deep water. The shallow water wave spectrum distribution is the narrow-banded Non-Gaussian distribution due to the