Simplified Analysis of Wave Impacts Hydroelastic Effects on Semisubmersible Structure in Steel

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HIGHLIGHTS

The local response of a steel panel on a semisubmersible model was examined in a severe wave-impact case. Modal decomposition and added-mass effects were examined comparing the measurements with a FEM-WAMIT numerical simplified analysis.

1 INTRODUCTION

Offshore structures are exposed to high and steep waves and their local interaction may lead to immediate damages. Therefore, it is important to identify the physics relevant for the structure's response in such scenarios. Here we focus on the local response induced by wave slamming, as continuation of the work documented in [1]; the study is relevant for structures in steel. A semisubmersible platform leg was modelled in a scale 1:40 and tested in long-crested irregular waves with 100-year return parameters in a towing tank at SINTEF Ocean, see fig.1. At first (A) the model was examined as fully rigid and wave-induced pressures were

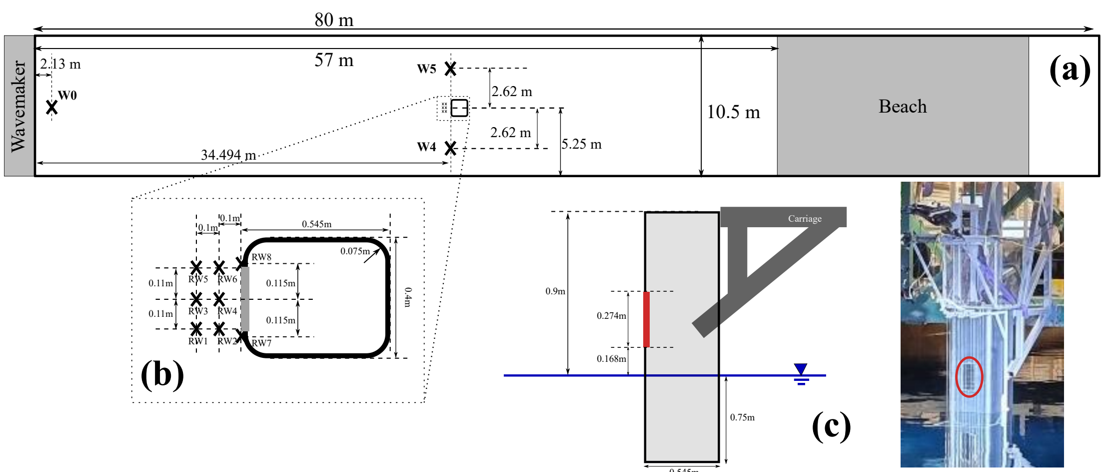

Figure 1: The setup for wave-slamming scenarios with the indicated structure: (a) Top view towards the tank setup. (b) Zoomed top view towards structure and relevant wave probes. (c) Model for the semisubmersible leg (the panel is indicated in red in the sketch and identified by the red ellipse in the physical model).

measured on a local structural component, hereafter called 'panel' and indicated in red in the figure. Then (B) the rigid panel was substituted with a panel mimicking a realistic steel component and strains were measured in the same wave conditions. Scenario A provided the excitation loads that triggered the local panel response in scenario B. The loads-response cross check identified two fluid-body interaction phases for the most severe impacts: 1) a forced-vibration phase and 2) a practically free-vibration phase. Phase 1 was associated with the largest response, differently from the hydroelastic cases of flat plates impacting the water at nearly zero angle (see e.g. [2]). In order to investigate this further and propose a simplified model, we here focus on phase 2 so to characterize the structural behavior and added-mass effects when the panel undergoes free vibrations. These aspects will be useful in a next-step analysis concerning phase 1. Experimental and FEM (finite element method) analysis of the dry elastic panel allowed to identify the shape of its dry modes and the corresponding natural frequencies (see [1]), and will be used here.

2 ANALYSIS OF THE MOST SEVERE SCENARIO

The most severe scenario in the wave-structure interaction recorded in the tests is associated with the largest integrated excitation force in scenario A and the largest strain response in scenario B. The wave probe measurements in front of the structure, together with the total force on the panel (obtained integrating the measured pressures, see e.g. fig.3.a-b) are shown in fig.2. The local incident waves appear almost 2D and quite asymmetric while approaching the structure. The same wave conditions were reproduced 11 times and the repetition error is quantified by the error bars. Phase 2 starts when the excitation force becomes negligible; in the analysis this is assumed to occur at the time of the vertical dashed line in the figure. Comparing the wave elevation at the structure (right plot) with the purple horizontal solid lines indicating the lowest and highest vertical coordinates of the panel, respectively, shows that we have water raised almost to the top edge of the panel within the free-vibration phase. The strain response caused by these waves was measured

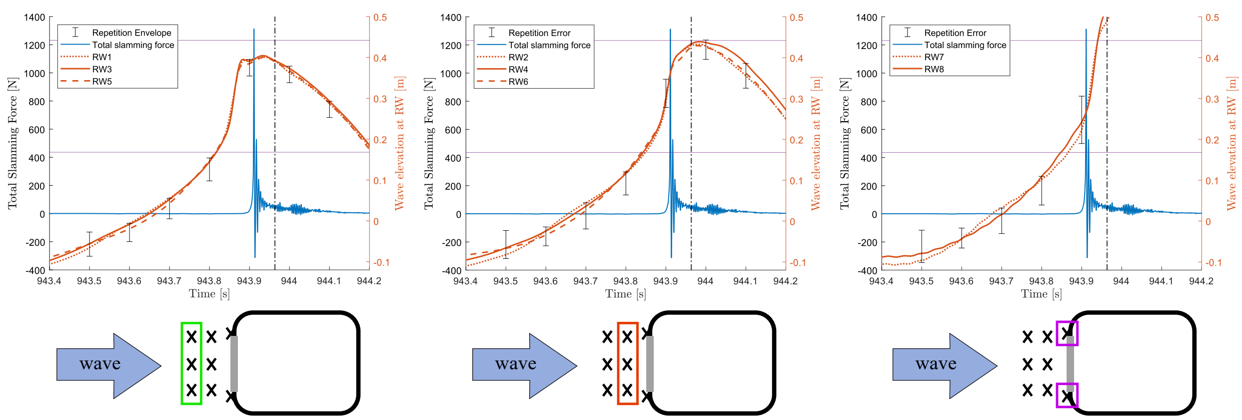

Figure 2: Local incident-wave profiles in front of the structure in the studied case.

in scenario B at the elastic-panel gauges indicated in fig.3.b and their frequency content in time was extracted through wavelet transform [3] and analysed during phase 2; this provides information on the natural frequencies of the panel in these wetting conditions. Figure 3.b-c provides the dry mode shapes from the FEM and the distribution of the experimental strain magnitude associated with each of the four most significant frequencies identified; their comparison indicates a consistency between dry and non-dry mode shapes (at 113, 197 and 243 Hz). The first mode dominates the response, as expected comparing the excitation pressures associated with the wave impact (in the left plot) with this mode shape, and has a frequency (113 Hz) much smaller than in dry conditions. However, also other modes contribute to the response. A simplified numerical analysis was then performed to quantify added-mass effects and hydrodynamic coupling of the structural modes. The panel was

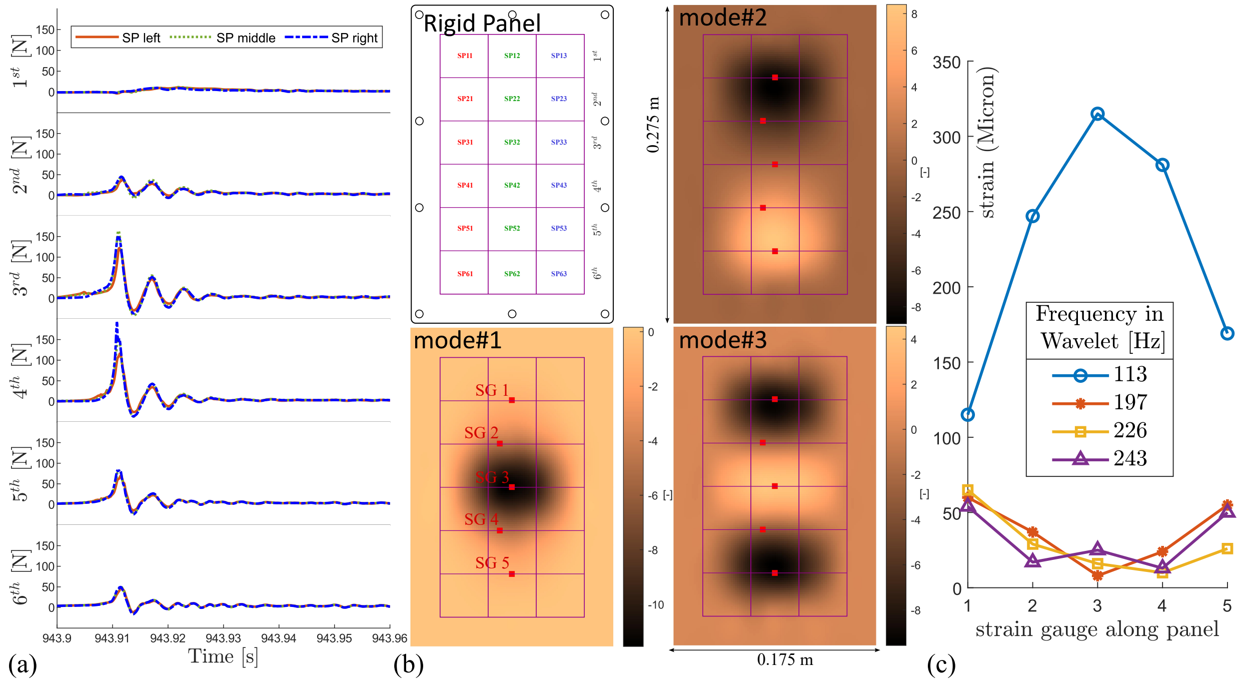

Figure 3: (a) Pressure measured from top (1^{st}) to bottom (6^{th}) and from left to right on the rigid panel; (b) rigid panel in scenario A, and first three dry FEM mode shapes for scenario B; (c) maximum strain magnitude associated with the first four frequencies dominating the response in phase 2.

modelled as a N-degree of freedom (N-DOF) system using the modal decomposition from FEM and following the procedure documented in e.g. [2]. As the panel is expected to be practically wet in phase 2, generalized added masses associated with the involved modes and with their hydrodynamic coupling must be estimated. This is done with WAMIT [4] at different panel wetness ratios (d/L, see fig.4.a), within a quasi-static approach. The resulting generalized added mass-to-mass ratios for the first three modes and for N=3 are provided in fig.4.b. Figure 5 examines the undamped wet-to-dry natural frequency ratios as a function of the wetness ratio, which as expected becomes unimportant for sufficiently large submergence of the panel; the corresponding frequency ratios from the experimental analysis are given by the horizontal lines. The comparison indicates that the experimental frequency ratios for the second and third modes seem to correspond to non-full wet conditions while for the first mode the experimental value corresponds to submerged panel conditions. The generalized added mass-to-mass ratio for this mode is $a_{11}/m_{11} \approx 18$ at $d/L = 1.50$; this is slightly smaller but consistent with the value 23 estimated directly from the experimental analysis [1].

3 CONCLUSIONS

The local structural response induced by a severe wave impact has been analysed in the free-vibration phase and using a simplified 3-DOF model. The importance of hydrodynamic

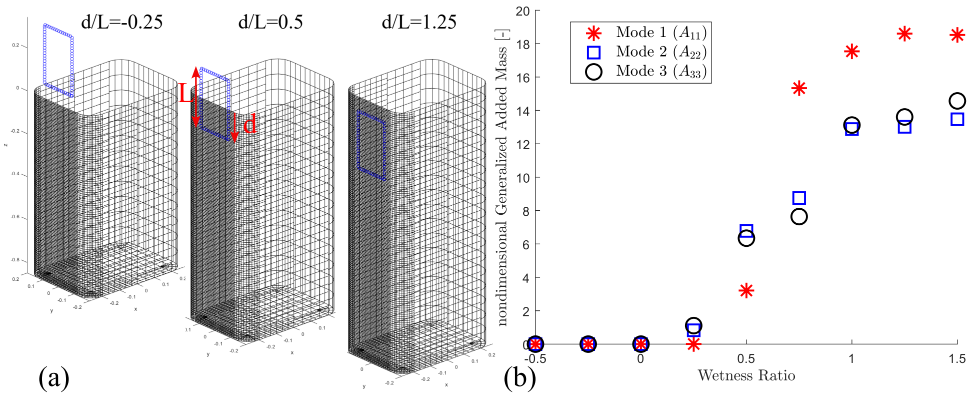

Figure 4: (a) Wetness ratio of the panel (indicated by the blue rectangle) is defined as d/L; (b) wetness-ratio effect on generalized added mass-to-mass ratios for the first 3 modes.

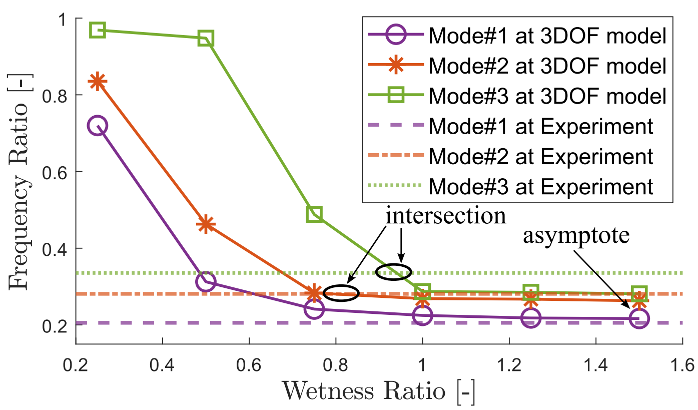

Figure 5: Wetness-ratio effect on natural frequencies of the panel.

coupling, as well as further steps in the analysis of the fluid-body interactions, will be discussed at the workshop.

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