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In-Service Dynamic Behavior of a Drilling Derrick on a Jacket Platform

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ABSTRACT

The results of experimental analyses performed to check the dynamic behavior of a drilling derrick after a seismic event are shown. The derrick analyzed is built on the Vega platform, located in the Sicily Channel. Identification of the main characteristics of the dynamic response of the structure was obtained. In addition, the maximum amplifications under sea action were evaluated. Several tests were carried out in the course of platform operations during drilling maneuvers. The maximum amplifications of the vertical loads were computed. The experimental results were compared with a numerical analysis. Lastly, comments are made on the utility of this comparison for derrick design.

INTRODUCTION

In-situ experimental analysis represents an important method for acquiring knowledge of the actual behavior of a structure. Moreover, a reliability analysis of a structural model and design assumptions can be performed, and indications for new designs can be derived from a comparison between numerical and experimental results.

The design of offshore platforms with a steel jacket structure is usually carried out with a careful modeling of the jacket; otherwise, the topside structures are added in a simplified way as appendixes. The derrick has a special importance among these appendixes. It is usually designed as an independent structure under live loads, and no dynamic coupling with the jacket structure is considered. The experimental evaluation of the derrick's dynamic characteristics makes it possible to verify the validity of the uncoupling hypothesis and to estimate the amplification of the derrick response under dynamic actions. Moreover, an important aspect of derrick design regards the stress peaks due to drilling operations: This aspect is considered by amplifying the static loads. A reliable estimate of the amplification coefficients can be made by analyzing actual in-service behavior.

The aim of this research is to analyze the in-service dynamic behavior of a drilling derrick and to compare the results with numerical studies. The derrick analyzed (Fig. 1) is installed on the Vega jacket platform, which is located in the Sicily Channel in the Marina of Ragusa, 25 km offshore at a water depth of 122.3 m.
The seismic design of the Vega derrick was derived from an equivalent static analysis; the accelerations in two horizontal and vertical directions at the base of the derrick were calculated from a dynamic analysis of the jacket structure, and then equivalent static forces were assumed to be constant on the whole height and were simultaneously applied. This approach considered the derrick as a rigid structure, disregarding the dynamic amplification. However a previous study pointed out that this approach cannot be reliable (Spadaccini and Vignoli, 1989).

First, the response spectrum analysis was utilized. The acceleration spectra at the base of the derrick (in the horizontal and vertical directions) were evaluated by considering the theory of a viscous-damped SDOF system subject to harmonic excitations. The values of the dynamic force were obtained from the peak accelerations of the four support joints of the wellhead module. The next step was the construction of the envelope spectrum relevant to each direction of the earthquake, with a damping factor equal to 0.05. The structural response was obtained by response spectrum seismic analysis considering these envelope spectra. The API reduction factors (API, 1984) were assumed to be equal to 1, 0.66 and 0.50, respectively, for the two horizontal (x,y) and the vertical (z) directions.

Furthermore, a time domain analysis was performed in the horizontal and vertical directions by simulating acceleration time histories from the calculated spectra. Four time-history analyses were performed in each direction of the derrick, and the maximum displacements were checked on certain joints of the drilling rig structure. In order to obtain the highest member forces in the structural model, accelerations were selected by considering the maximum displacement in one of the four support joints of the derrick substructure top. The choice of this joint was justified by the presence of heavy well-servicing masses at its level and by the changes in the structural scheme. In fact, above this joint, the derrick was essentially a lattice structure, while its substructure was an eccentrically braced frame. The response effects were combined linearly with the same API reduction factors.

The comparison between the design indications and the results of specific studies carried out after installation of the platform pointed out the limits of an equivalent static analysis which does not allow a correct evaluation of member stress in all the elements of the derrick caused by earthquake ground motions.

A seismic event occurred in southeastern Sicily on December 13, 1990, with its epicenter in Augusta Bay, 80 km from the Vega field. During the earthquake, large displacements of the top of the derrick tower were observed.

In order to check the structural behavior of the derrick, an

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