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A REDUCED INTEGRATION METHOD FOR THE COUPLED ANALYSIS OF OFFSHORE SYSTEMS

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ABSTRACT

This work presents the application of a reduced integration method to solve the coupled dynamic equations that describes the behaviour of offshore systems such as floating drilling and production platforms for oil exploitation.

Offshore oil exploitation activities have been recently advancing towards even deeper waters, reaching new frontiers so far not conceivable. Recently, the increasing number of mooring lines and risers that are connected to the platform motivated the development of numerical tools that consider the coupling between the hydrodynamic behavior of the hull and hydrodynamic/structural behavior of the lines [1]. The results of such coupled analyses, under environmental loadings such as wind, wave and marine current, are the platform motions and the forces acting on the lines. However, coupled analyses are heavily time-consuming, therefore new numerical strategies have been developed to to optimize the efficiency of the computational tool, such as the use of domain decomposition methods implemented in a parallel MPI environment [2].

The focus of this work is in another numerical strategy to reduce CPU costs, through the application of base reduction methods [3,4]. Such methods are recommended to solve mildly non-linear dynamic problems with a great number of d.o.f.'s submitted to conservative external loads. The offshore problems discussed here complies with this recommendation, since the dynamic analysis can be performed after a nonlinear static analysis submitted only to marine current, which can be considered invariant with time and is one of the main external loads acting on the lines that affect the motion of the hull. Also, the most important natural periods of the platform occurs in the horizontal plane and are relatively long (usually near 200 seconds) with respect to the time-step needed to integrate the dynamic equations of the lines (usually near 0.05 seconds). For these reasons the stiffness of the system, and therefore the reduction base matrix, may be recalculated few times, for instance only every 20 seconds. In this case a good accuracy is obtained in the determination of the platform motions, but not necessarily of the line forces, but the former results are more of interest in the context of the so-called "hybrid" design methodology described in [5] that focus in the platform motions.

Therefore, an implementation of the Ritz-Wilson reduction method [4] associated to a fully coupled scheme for the analysis of offshore platforms [6] was developed. This method is known to require fewer vectors to comprise the reduction matrix. Moreover, the reduced problem can be decoupled and the solution of each single reduced equation can be performed by an analytical formulation such as the Duhamel integration, as long as the variables of the problem (stiffness, added mass and damping) do not vary with frequency.

However, it has recently been observed in some offshore applications that the added mass and the hydrodynamic damping of the system may vary with frequency. In this case, the use of reduction base is still more relevant since it can be associated to the solution of the reduced decoupled equations using a step-by-step hybrid time/frequency-domain procedure as the Implicit Fourier Transform (ImFT) or the Implicit Frequency-domain Green's Approach (ImFGA) algorithms [7] that can consider frequency dependent properties.

These use of such techniques to solve fully coupled offshore systems are innovative, and have been applied for the fist time in the SITUA-Prosim program [1] developed in a partnership by LAMCSO and Petrobras, the Brazilian state oil company. Some large, actual examples were analyzed, demonstrating that the use of the reduction base method associated with an analytical solution has provided solutions ten times faster than the conventional direct integration method, while maintaining the desired accuracy in the representation of the motions of the hull.

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