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Dynamics of Two Flexible Hanging-off Circular Cylinders in Staggered Configurations

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ABSTRACT

The present paper is addressed to evaluate the hydrodynamic forces and motions experienced by two flexible circular cylinders in staggered arrays which are towed in still water. The cylinders were submerged partially into the still water from a towing carriage as hanging-off vertical cantilevers. Each cylinder has length-to-diameter ratio of 34.4 with low mass ratio (= 1.24). The Reynolds number varied from 27,000 up to 37,800. For examining wake interference effects on the forces and motion of the cylinders in the staggered configuration, a centre to centre longitudinal gap between the upstream and downstream cylinders was fixed by 4*D* with transverse gaps were varied by 1*D*, 1.5*D*, 2*D*, 2.5*D*, 3.5*D*, and 4.5*D*, respectively. Measurement of the hydrodynamics forces and motions in two, in-line and transverse directions to the flows were performed simultaneously. Frequency of the drag force was found approximately twice the corresponding lift force frequency at the related reduced velocity (*Ur*) for all cases and the forces frequencies ratio was independent from the *Ur* and L_T parameters in the range used. For the upstream cylinder, the $L_T = 2.5D$ became a critical value at which the forces coefficients started to jump into the higher values as the L_T increased ($L_T > 2.5D$). The influence of the wake interference on the inline and transverse amplitudes are gradually getting weaker as L_T increased. Beyond the stagger angle of 41.2^o ($L_T \geq 3.5D$), the downstream cylinder behaves approximately as the single cylinder one. In the staggered configurations, as the L_T increased, the trajectory patterns in the domain *Ur* are step by step approaching the characteristics of the single cylinder case; started at the gaps $L_T \geq 4.5D$.

KEY WORDS: hanging-off flexible cylinders; drag and lift coefficients; upstream and downstream cylinders; wake interference; motion trajectories.

INTRODUCTION

Future offshore structures such as OTEC or CO_2 sequestration platforms may has multiple cold water pipes (CWP) or CO_2 injection pipes in order to increase their productivity. If so, obviously it is need more clearly picture on physical mechanism of their pipes dynamics; because the pipes have distinct design with ordinary riser pipes of oil/gas offshore platforms which are typically terminated on sea bed. Better understanding on the dynamic behaviors of the flexible hanging-off circular cylinders arrays in water flow are required for design purposes of those types of structures.

General characteristics of flexible cylinders subjected to water crossflow are not well understood in various parameters because some factors, such as Reynolds number, flexibility level of the cylinders, interference effects due to the cylinders arrangement, and incoming flow condition affected the response. For instance, when two cylinders are free to oscillate between each other due to current flows, the wake interference among them gains much more complex and the downstream cylinder response becomes hysteretic. The wake of the upstream cylinder impinging on the downstream cylinder differs from the case of stationary cylinders. In turn, the response of the downstream cylinder differs from both that of a single and that of a cylinder in the wake of a fixed cylinder. Due to this complexity, some phenomena which were still not clearly understood need to be clarified, including their time-dependent fluid forces and motion characteristics.

Some works have been done on the dynamic response and fluid forces measurement of two circular cylinder arrays due to cross-flow. Brika and Laneville (1999) performed wake interference study on various configurations of two horizontally positioned cylinders including tandem and staggered arrangements. They found when the upstream cylinder is free to oscillate, the downstream cylinder response become hysteretic which is contras with that stationer upstream cylinder case. More recent studies by Assi et al. (2006, 2007) examined two vertically tandem cylinders with a fixed upstream and transverse-direction allowable oscillation only downstream cylinder. The former work (Assi et al., 2006) presented that the downstream cylinder peak amplitude was about 50% higher than experienced by a single cylinder and the galloping-like phenomenon was occurred in the gap range $3.0 < L_{UD} < 5.6$. Meanwhile, from Assi et al. (2007) was predicted that high amplitude oscillation experienced by downstream cylinder was due to excitation by the vortex component of the lift force at higher reduced velocity.

Pesce & Fujarra (2000) and Fujarra, et al. (2001) carried out towing test of a flexible cantilever cylinder in a water tank and found a jump phenomenon and influence of coupled streamwise-transverse motion on